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Sustainability Assessment of Urban Green Infrastructure: Development of an ESG+ Integrated Rating Framework

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ABSTRACT

Cities and their needs are growing rapidly. In this case, infrastructure systems must also keep up with this growth rate. At the same time, when the decreasing green areas along with the construction sector are considered, the importance of green infrastructure systems increases. Increasing urban areas and their transformation to green infrastructure projects as fundamental solutions for sustainable development, climate resilience and improved quality of life. Although existing sustainability assessment tools are often failing multi-dimensional effects and the full complexity, especially in urban areas, green infrastructure projects are crucial solutions for sustainable development, climate resilience, and developed urban quality of life. This thesis addresses this gap by proposing a comprehensive and integrated assessment framework especially designed for green infrastructure called “Green Infrastructure Sustainability Performance Assessment Model” (GISPAM). By analyzing well known international sustainability systems, GISPAM contains environmental, social, economic and governance (ESG+) dimensions with customized evaluation model. Application selected case studies shows that the GISPAM is more refined, comparative assessment of green infrastructure performance. These findings suggest that the framework can inform future practice and policy. Also, GISPAM provides practitioners with a strong tool for urban sustainability.

Keywords: Sustainability Assessment, Green Infrastructure, Multi-Criteria Decision Making, Urban Projects, Rating Framework, GISPAM

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Acronyms and Abbreviations

GISPAM	Green Infrastructure Sustainability Performance Assessment Model
ESG	Environmental, Social, Governance
ESG+	Environmental, Social, Economic, Governance
MCDA	Multi-Criteria Decision Analysis
ROC	Rank Order Centroid
MAVT	Multi Attribute Value Theory
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment
WELL	WELL Building Standard
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
EN	European Norm
IS Rating Scheme	Infrastructure Sustainability Rating Scheme
ISCA	Infrastructure Sustainability Council of Australia
USGBC	U.S. Green Building Council
EPA	Environmental Protection Agency
GHG	Green-house Gas
GDP	Gross Domestic Product
EU	European Union
UN	United Nations
OECD	Organization for Economic Co-operation and Development
NPV	Net Present Value
PM2.5/PM10	Particulate Matter (2.5/10 micron)
CSI	Case Study Investigation
ROI	Return of Investment
SDG	Sustainable Development Goals
db	Decibels (Noise Level)
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
SMARTER	Simple Multi-Attribute Rating Technique Exploiting Ranks

1 Introduction

1.1 Research motivation and significance

In recent decades, the concept of sustainability became a main concern in architectural and urban planning practices. As cities grow and the climate change impact's getting stronger day by day, it becomes crucial to integrate sustainable thinking into the design and development of public infrastructure. This thesis considers the assessment of sustainability of interventions in public spaces and green infrastructure within the broader context of urban projects, which encompass a wide range of typologies. Additionally, the multidimensional ESG+ framework is significant for its comprehensive analytical capabilities. While many tools exist for assessing sustainability, there remains a critical lack of focus on properly evaluating environmental impacts, particularly from an urban perspective and green infrastructure. Thesis is motivated by the need to develop a more inclusive and integrated model for assessing sustainability in green infrastructure.

‘’The construction industry is the world’s largest sector, employing around 7% of the global workforce and valued at approximately $13 trillion’’ (McKinsey, 2017). ‘’According to the United Nations, just the architecture and construction sector are responsible for 38% of global CO2 emissions. Moreover, construction sites are responsible for a significant amount of waste which is up to 30% of the total material weight delivered to a typical site ends up as waste’ (Osmani, 2021). These numbers shows that how urgent it is to address sustainability in the architecture and construction sector.

The global urgency of this issue is highlighted by major international policy frameworks. To exemplify, The UN New Urban Agenda (2016) calls for sustainable, inclusive and resilient urban infrastructure. Another example is UN Sustainable Development Goal 11 which particularly aims to ‘’make cities inclusive, safe, resilient and sustainable.’’ The European Green Deal and EU Biodiversity Strategy for 2030 mandate the creation and enhancement of green infrastructure in Europe. Also, The Paris Agreement focuses on the importance of nature based solutions and climate adaptation in urban areas. These frameworks underline the institutional legitimacy and urgency of advancing sustainability in urban projects (United Nations, 2016; United Nations, 2015; European Commission, 2019, 2020; UNFCCC, 2015).

Sustainable architecture means designing and building or urban in a way that reduces harm to the environment. Buildings use a lot of natural resources, produce waste, and cause greenhouse gas emissions. Consequently, in architecture and building design, there is an increasing emphasis on resource efficiency during the life-cycle of the structure to mitigate negative consequences. As cities expand, there is heightened demand for construction which translates into greater consumption of materials and energy. The issue is partially addressed with sustainable buildings that decrease energy expenditure and waste while enhancing occupant comfort.

1.2 Problem Statement: gaps in current sustainability assessment approaches

Although there are many existing sustainability assessment systems such as LEED (USA), BREEAM (UK), WELL (USA), DGNB (Germany), Envision (USA), IS Rating Scheme (Australia), Urban Audit (EU), and UNI/PdR 13:2019 (Italy), these models often focus on buildings rather than the larger urban scale. Most tools are designed for building projects and do not adequately address the long-term environmental, social, and governance aspects of public infrastructure. However, also some certificates has larger scale versions such as LEED for cities, BREEAM community, but these have also some missing points. Furthermore, they often prioritize environmental indicators while giving less weight to economic, social, and cultural dimensions.

Another important missing point is the lack of integration between life cycle thinking and systemic urban impacts. Many models fail to achieve the interconnected nature of cities and projects. These might affect mobility, energy networks, or social inclusion over time. In addition, the tools used in different countries vary greatly in terms of methodology, criteria, and rating logic, making global comparisons difficult.

Because of these limitations, current tools are not effective for policymakers, designers and planners to find correct solutions. It is obvious that there is a more balanced, adaptable and context sensitive assessment model that can evaluate the public infrastructure in a comprehensive way, considering not only environmental impacts but also long-term social value resilience.

This research especially focuses on these limitations in the urban green infrastructure projects. The existing assessment systems insufficient integration of ESG+ criteria and fail to capture the complex, long-term socio-environmental impacts inherent to public space and nature-based interventions

1.3 Research objectives and questions

The primary goal of this thesis is to develop a comprehensive and adaptable sustainability assessment model for urban scale- projects. This model aims to find the limitations of existing systems by integrating environmental, social, economic, and governance dimensions and by responding to the needs and impacts of urban development within complex city systems. In light of the growing importance of green infrastructure and public space initiatives for livability and urban resilience, this study focuses on creating a customized, ESG+ integrated sustainability evaluation model for urban-scale interventions of this type.

To achieve this goal:

- Identify the gaps and limitations in existing sustainability assessment tools.
- Define context specific sustainability criteria suitable for urban scale projects.
- Proposing a structured and multi-dimensional rating model
- Test and validation of the model with selected case studies

Based on these objectives, thesis aims to answer the following questions

- What are the disadvantages of existing sustainability assessment frameworks when it's applied to urban scale projects?
- What kind of indicators and criteria are most related for evaluating the sustainability of urban green infrastructure and urban public space projects?
- How can a rating model create to integrate multiple sustainability factors in a balanced way?
- How can the proposed model help decision makers make better decisions and evaluate projects in a more effective way?

1.4 Scope and limitations: focus on urban scale projects

This thesis focuses specifically on sustainability assessment in urban scale projects. These include mainly green infrastructure, public infrastructures, mixed use projects, public spaces and integrated mobility systems that shape urban life. The focus is on projects that affect the whole urban, not only single buildings.

Thesis focuses on evaluating the environmental, social, economic and governance dimensions of sustainability. It aims to build a model that supports decision making between disciplines and sectors. While the method does not focus on detailed level studies or energy modelling for individual buildings, the proposed model remains flexible and can also be applied to single building projects where relevant. The framework is developed mainly to address assessment gaps at the urban scale and green infrastructure projects.
Besides, the selected case studies represent diversity of urban context and project types, providing a good basis for model testing. While the model is designed as adaptable, between various regions, application should be integrated into local regulations, cultural norms and environmental conditions to make it successful. While the model presents theoretical adaptability for various urban-scale interventions, its development, reference values, and validation processes have been specifically customized for green infrastructure and public urban space projects. As a result, its applicability to other project types. For example, large-scale mobility systems or residential districts, need more adaptation or methodological refinements beyond the scope of this thesis.

1.5 Thesis structure overview

This thesis has 9 chapters that guide the reader. The first chapter introduces the background, motivation, objectives, scopes and overall structure of the study. Chapter 2 presents a review of existing literature related to sustainability assessment in architecture and urban planning, focusing on existing models' definition of them and finding their limitations. Chapter 3 creates the theoretical framework by explaining key concepts related to sustainability in urban scale and green infrastructure projects, including relationships and long-term impacts. Chapter 4 explains the research methodology. The research methodology contains three phase approaches which are Initiation, Intelligence and Application and details the data collection and analysis method. Chapter 5 focuses on the development of the proposed rating model GISPAM and describing criteria selection, weighting process and aggregation process. In Chapter 6, selected case studies are presented to demonstrate how the model can be applied to real world projects. In chapter 7, the discussion of results integrates an analysis of different scenarios to surface and elaborate on the main findings. The analysis is thorough yet concise, allowing for clarity in presenting comparisons across multiple cases. In Chapter 8 the thesis is concluded by repeating critical conclusions and providing recommendations for further scientific inquiry and practical implementation alongside scope for future work. Lastly, chapter 9 presents the list of references which were cited throughout the thesis.

2 Literature review

2.1 Sustainability assessment in architecture and urban planning

2.1.1 Historical development and current trends

Since the late 1990's, the idea of sustainability in architecture and urban planning has changed a lot. The Brundtland Report (1987), which established sustainable development as ''development that meets the needs of the present without compromising the ability of future generations to meet their own needs'' has been associated with its formal introduction. This original concept found a great focus on finding a balance between environmental protection, economic growth, and social equity.

After the Rio de Janeiro Earth Summit 1992, the built environment took attention in global as a crucial area for achieving sustainable goals. Sustainability guidelines, environmental performance tools and rating systems like LEED(USA), BREEAM(UK) emerged in the next decades. Initially, the primary focus of these tools was on environmental and energy efficiency indicators. However, in recent years, the focus has changed to more comprehensive integrated frameworks that address concerns of governance, social wellbeing and health.

Digital technologies such as GIS and BIM-integrated LCA performance-based regulations and focus on resilience, circularity and stakeholder engagement. In response to lack of resources, urban equity and climate change, these modifications represent a greater approach to sustainability in the built environment.

2.1.2 Multidimensional approaches: environmental, social, economic and governance

Modern sustainability assessment models accepting that are increasing to accept sustainability assessment is not a singular environmental issue but a multidimensional construct. These models include:

- Environmental: Focuses on waste reduction, biodiversity preservation, emissions reduction, energy consumption and resource efficiency. First founded systems such as LEED and BREEAM, placed a strong focus on this field.
- Social: Including quality of life, cultural preservation, safety community health, accessibility, and diversity. These aspects have been integral to advanced systems such as DGNB and WELL introduced recently.
- Economical: Addresses cost efficiency, life cycle costs, affordability, and economic resilience. These features have been overlooked until recently when systems like DGNB and IS Rating Scheme started considering economic indicators along with life-cycle cost assessment modules.
- Governance: Covers transparency as well as stakeholder engagement, policy integration, and institutional effectiveness. Envision and IS Rating Scheme are some of the first frameworks incorporating assessments focused on governance which highlights institutional responsibility through accountability for a given project’s outcomes.

2.1.3 Scale consideration: urban scale vs building scale

Multiple spatial scales are used in sustainability evaluation, and every one of them has own methodologies and goals.

- Building Scale: On this level certification systems evaluate individual buildings based on their design, construction, and operational performance. LEED, BREEAM, WELL and DGNB are main examples. These systems are suitable for assessing material choices, energy systems, water management and indoor air quality.
- Urban Scale: on urban scale it focuses on neighborhoods, districts or cities. They evaluate land use, mobility systems, public spaces, green infrastructures and social equity. There are some examples which are Urban Audit (EU), IS Rating Scheme (Australia) and Envision (USA) and LEED for cities. These methodologies require multi-stakeholder coordination and longer planning periods.

Importantly, assessment tools developed for buildings are not always adaptable for bigger scales. Urban scale sustainability systems are needed to incorporate policy, governance and long-term community engagement which are beyond the scope of building scale certifications. Therefore, selecting the proper frameworks based on a diverse scale is crucial for accurate and effective sustainability evaluation. This thesis focuses on the urban scale assessment of green infrastructure and public urban space projects. Traditional building-oriented certifications often fail to find systemic socio-environmental dynamics

2.2 Critical analysis of existing assessment models

- LEED for Cities and Communities (Leadership in Energy and Environmental Design) (USA)

It is developed by the US Green Building Council and is one of the most widely recognized for urban areas at the city or community scale. Unlikely the standard building level LEED system it is designed to greater sustainability outcomes. For example, energy, water, waste, transportation, land use quality of life, social equity, governance, innovation and resilience. There are different indicators that measure categories such as GHG emissions per capita, public health outcomes and stakeholder engagement process. However, LEED's building-centric structure provides limited insights into the systemic impacts of urban green infrastructure.

Structure: LEED for cities and communities operates on a credit-based system with categories such as natural systems and ecology, transportation and land use, water efficiency, energy and greenhouse gas emissions, materials and resources, quality of life, innovation, and regional priority. It has 3 different levels which are Silver, Gold and Platinum.

Criteria: Each category of qualifications and optional credits. Criteria address environmental performance, quality of life, equity and inclusivity, innovation and regional priorities, governance and community engagement.

Indicators: Examples include Greenhouse gas emission per capita, water consumption per capita, transportation mode share percentage of walking, cycling and public transit, access to open space and parks as a percentage, affordable housing units, stakeholder engagement process and public health outcomes such as life expectancy.

Limitations: LEED for Cities and Communities is one of the most comprehensive urban assessment systems. However, it can be difficult to acquire data to complete the system. And adaptability for specific context is limited. Especially for non-US works these challenges increasing.

- BREEAM Communities (Building Research Establishment Environmental Assessment Method) (UK)

  BREEAM communities is developed by the Building Research Establishment (BRE). world’s leading sustainability assessment method for large scales and cities and developed in the United Kingdom. This system focusing on masterplans and community scale interventions.

  Structure: BREEAM has a own scorec system which has 6 different categories. These certificate scores are ranked as Pass, Good, Very Good, Excellent and Outstanding.

  Criteria: Evaluate the project’s performance between management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology, pollution, innovation.

Indicators: Key indicators are stakeholder participation, sustainable economic strategies, energy and water management, biodiversity, accessibility, and health and wellbeing.

Limitations: Even though, BREEAM communities address many urban sustainability criteria, project teams require extensive documentation. It may require adaptation to governance context.

- WELL Building Standards (the USA)

  The WELL Building Standards, organized by the International WELL Building Institute, focus mainly on human health and wellbeing in the built environment. It is often used in combination with other green building certifications to address health centric performance.

  Structure: Divided into 10 categories which are air, water, nourishment, light, movement, thermal comfort, sound, materials, mind and community. Includes preconditions and optimizations.

  Criteria: Focused on health, including air and water quality, light levels, thermal comfort and mental wellbeing

  Indicators: Includes PM 2.5/PM10 concentrations, water contaminants, illuminance (lux) and thermal comfort parameters.

  Limitations: WELL, completes a great job of addressing health and wellbeing of its occupants however, it is limited when it comes to confronting ecological and economical sustainability. Its scope makes it difficult to apply to infrastructure or urban scale projects. Furthermore, its verification process requires a lot of resources, which may limit its use in budget-contained or publicly funded developments.

- DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen (GER)

  The German certification program DGNB is renowned for its life cycle-based and balanced approach to sustainability. It is well known for its performance-oriented evaluation and integrates sociocultural, economic, and environmental quality standards.

Structure: Categories include Environmental, Economic, Sociocultural and Functional, Technical, Process and Site Quality. Uses a life cycle assessment and performance benchmarking.

Criteria: Primary Energy demand (kWh/m²a), GWP (kg CO_2 eq./m²), waste rate (%), maintenance cost (euro/m²/year).

Limitations: Even though DGNB is one of the most comprehensive and life cycle-oriented systems, smaller scales or areas with less institutional capacity may find it difficult to meet its high technical and data requirements. Furthermore, stakeholder participation is frequently assessed as a technical element than as an inclusive design process, despite its social-cultural component.

- Envision Rating System (the USA)

For infrastructure projects created in the US, Envision is a rating sustainability ranking system. By combining more comprehensive governance and community requirements, it seeks to address long term performance and resilience.

Structure: there are five categories which are Quality of life, leadership, Resource Allocation, Natural World and Climate & Risk. Uses qualitative scoring which are improved, enhanced and superior.

Criteria: Includes stakeholder engagement, carbon footprint, ecosystem impact, and climate resilience.

Indicators: Community engagement plans, tCO_2e over lifecycle, reused materials (%), runoff reduction (%).

Limitations: While its implementation is mainly limited to North America, Envision specializes in combining governance, climate resilience, and long-term outcomes. In non-Western cultures, it missing global reach and standardization. Furthermore, some criteria are still qualitative, which makes scoring consistency and benchmarking more difficult.

- IS Rating Scheme (Australia)

The IS Rating Scheme, developed in Australia, focuses on evaluating sustainability performance in infrastructure projects. It offers a regional approach to governance, social responsibility, and environmental outcomes

Structure: Focuses on Governance, Economic, Environmental and social areas. Each area contains a credit score from 0 to 3.

Criteria: Addresses emissions, water usage, social inclusion, and heritage

Indicators: GHG per unit (kg CO_2-e) Indigenous engagement (%), construction water use (liter/day), biodiversity net gain (%).

Limitations: Although it offers a strong framework for infrastructure, the IS Rating Scheme has not been widely used outside of Australia. Compared to other systems, it gives a lower priority to sociocultural criteria and heritage preservation. Additionally, its evaluation framework is less established in terms of long-term performance monitoring.

- Urban Audit (EU)

Eurostat created the Urban Audit statistical data framework to evaluate the urban quality of living in European cities. Although it offers essential urban indicators for planning and policy, it is not a certification system.

Structure: Nine domains including Demography, Economy, Environment, Transport, Education, and Civic Engagement. No certification or data framework.

Criteria: Urban living quality, environment, transport, and education.

Indicators: PM_{10} levels (μg/m^3), unemployment rate (%), green space per capita (m^2), transport modal split (%).

Limitations: Urban Audit is a statistical data tool; it does not provide project-level certification or performance evaluation. Its metrics are general and frequently fall short of current development requirements. It does not quantify certain sustainability interventions and does not provide planners or architects with practical advice.

- UNI/Pdr 13:2019 (ITA)

UNI/PdR 13:2019 is an Italian guideline designed to evaluate the sustainability of construction and infrastructure projects in alignment with European sustainability goals.

Structure: Multicriteria framework aligned with EU directives. Covers environmental, resource, economic, and lifecycle dimensions.

Criteria: Includes LCA, resource efficiency, stakeholder inclusion, environmental cost.

Indicators: Embodied energy (MJ/kg), water footprint (m^3/year), noise levels (dB), renewables share (%)

Limitations: UNI/PdR 13:2019 provides a national-level sustainability approach and is in good alignment with European directives, although it is still relatively new and does not have worldwide recognition. Its approach might need more work for wider comparability and transparency, and its academic and empirical validation is currently lacking.

2.2.1 Comparative analysis and identified gaps

Current systems differ primarily in terms of applicability. The aims and scopes of the systems used today are also different. Despite their widespread adoption, LEED and BREEAM are sometimes known to be weaker than environmental in the social and governance fields. On the other hand, systems such as WELL give more importance to human health and well-being but do not effectively integrate environmental and economic factors. Although DGNB is known for its balanced, life-cycle-based approach, its technical complexity can limit the wider use. Region specific systems like the IS Rating Scheme (Australia) and Envision (USA) effectively include leadership and community engagement elements. However they have limited global reach. Although Urban Audit provides valuable sustainability data at the urban level, it is not aiming to evaluate or rank specific projects. In addition, UNI/PdR 13:2019 shows encouraging relation to EU sustainability goals, but it is still in development in terms of methodological reliability and international comparability.

There are certain deficiencies in these systems. Examples include inadequate post-use evaluation and inadequate adaptive governance mechanisms. These disadvantages indicate the need for a more efficient, scalable and context-sensitive sustainability method, especially for green infrastructure systems. Existing frameworks have the valuable potential for general sustainability assessment. However, they are generally insufficient the necessary integration of ESG+ dimensions when they applied to green infrastructure.

2.3 ESG integration

In recent years, ESG criteria have become a leading player in global sustainability issues. They play a significant role in finance, policy and infrastructure development. The integration of ESG principles into assessment processes is evolving and is known to be a critically important trend. This approach offers a greater understanding of sustainability by combining environmental performance with ethical responsibility, social equity and transparent governance practices. As built environments become increasingly complex and interdependent, ESG+ offers a multidimensional perspective from which architectural sustainability can be evaluated more holistically.

Environmental components have been included in architecture for a long time. For example, energy efficiency, carbon emissions, resource use and climate adaptation. These areas generally working same logic with traditional green building systems such as LEED, BREEAM and DGNB. However, ESG expands this framework to also focus issues such as long-term durability, impacts on biodiversity and alignment with scientific climate targets (UN PRI, 2021).

Social dimension addresses themes such as inclusivity, health and well-being, cultural identity and community participation. While systems such as WELL and Envision partially aim at these issues, the full integration of social indicators into assessment systems is still not fully completed. Problems such as user experience, access equity and long-term social value generation are overlooked in many certification systems. ‘’The inclusion of social indicators such as safety, demographic equality and accessibility can make architecture a tool for social cohesion and justice’ (Monfared et al., 2022).

Governance is one of the most ignored dimensions of ESG+ in architectural assessment. However, it directly affects the viability of sustainability through criteria such as stakeholder engagement, transparent decision-making, accountability and regulatory compliance. ‘’While systems such as Envision and the IS Rating Scheme partially integrate governance criteria with leadership, risk management and stakeholder processes, most building-scale systems leave this component out'' (Daniel & Pettitt, 2019). This multidimensional integration is crucial for the green infrastructure. They are interconnected socio environmental dynamics and governance. This condition shows us the demand of ESG based assessment frameworks.

2.4 Life cycle assessment (LCA) in sustainability evaluation

Life Cycle Assessment (LCA) is a method that evaluates the environmental impacts of a product or project at all stages from raw materials to production, construction, use and final disposal. In the context of architecture and urban planning,'' LCA plays a critical role in quantifying embodied carbon, material efficiency, energy consumption, and waste generation across a building's lifecycle.'' (Cabeza et al., 2014). LCA has four main phases which are Goal and Scope Definition, Inventory Analysis (LCI), Impact Assessment (LCIA) and Interpretation. To explain these phases, start with goal and scope definition means that sets the purpose, system boundaries and functional unit, secondly, inventory analysis. It is aiming to collect data on energy and material inputs and environmental emissions. Then, impact assessment which evaluates the potential impacts such as global warming potential or resource extinction, Finally, interpretation, where the results are analyzed to support decision making. Integrating LCA into sustainability certification systems improves the credibility and depth of environmental assessments. According to Pommeranz, ''the DGNB system relies heavily on LCA to evaluate environmental and economic performance metrics'' (Pommeranz et al., 2021) The LEED and BREEAM systems also contains LCA principles, particularly in the material and resource categories, but this integration is generally superficial, with many systems still treating LCA as an optional or complementary element.

In architectural projects, LCA supports sustainable design by checking alternative materials, construction methods and operational strategies. For example, LCA can give information about design decisions regarding facade systems or structural options based on their carbon footprint and resource intensity. It also plays an important role in renovation or adaptive reuse projects.
Integrating Life Cycle Assessment into sustainability certification systems is becoming more significant since it may improve the scientific reliability, comparability, and transparency of environmental assessments. There are

significant variations in the integration method and measurement in rating systems, which affects the overall effect of LCA in directing sustainable design.

DGNB is another certification system. It is widely known that its deep integration of LCA, making it a mandatory and weighted component of its core environmental performance assessment. It emphasizes life cycle thinking not only for environmental impacts but also for cost-effectiveness, promoting the parallel use of environmental and economic LCA models. This integrated approach encourages long-term sustainability rather than focusing solely on short-term operational efficiency. This partial risk has the potential of LCA as a decision support tool and may reduce the influence on overall strategy.

On the contrary, LEED and BREEAM incorporate LCA in more limited ways. LEED v4 introduces credits for whole-building LCA in the "Materials and Resources" category, but participation is optional, and impact categories are sometimes narrowly defined. Similarly, BREEAM includes LCA as a part of the Materials section. However, it relies on the Environmental Product Declarations (EPDs) rather than the full lifecycle modelling.

One of the newer certifications which are Envision (USA) and IS Rating Scheme (AUS), are using more systematic LCA applications, particularly in infrastructure projects. These systems not only require lifecycle evaluations but also encourage the use of LCA results for early-stage planning and stakeholder communication. The WELL certification, despite its primary focus on health, does not integrate LCA, indicating a thematic limitation that limits life cycle thinking to environmentally focused plans.

''Despite the growing interest in LCA, its widespread adoption still faces several challenges. These include the need for extensive data, expert knowledge, and specialized software tools, which can be prohibitive for small-scale projects or in developing regions' (Zhang et al., 2019). Additionally, uncertainties in system boundary definitions, life cycle inventory databases, and impact assessment methodologies can hinder comparability of results between different projects and contexts.

However, LCA is still a crucial method for environmental accountability and lifecycle thinking. As sustainability frameworks change, deeper LCA integration is crucial to improving long-term decision-making and enable clear, performance-based assessments. This integration became even more crucial for urban infrastructure projects. Long term environmental impacts, resource flows and the systematic contributions of nature-based solutions need better life cycle evaluation approaches.

2.5 Current applications and potential

Urban projects and infrastructure projects generally require long-term resilience, transparency, and stakeholder participation. That is why ESG+ integration is more important in these areas. Rating systems such as Envision (ISI, 2018) and IS Rating Scheme (ISCA, 2022), they include social equity and governance, represent this new trend. However, systems like LEED and BREEAM, which emphasize building-scale evaluation, still generally rely on environmental indicators, therefore, their ESG scope is limited. ESG integration can connect design with sustainable finance, legal requirements, and social values, especially through tools like green bonds, ESG-aligned investments, and public-private partnerships (UNEP FI, 2021). Green infrastructure projects are important urban scale projects because they directly address social well-being, ecological resilience and systematic urban sustainability. These features focus the requirement for an ESG+ comprehensive evaluation customized for especially for these projects.

2.6 Challenges and opportunities

One of the main challenges to ESG+ integration in green infrastructure projects is the missing points of stable project-scale frameworks and relevant indicators. "The translation of corporate ESG strategies into applicable design-level metrics is often hindered by institutional inertia, methodological inconsistencies, and limited data availability’ (UNEP FI, 2021). Despite these obstacles, a special opportunity is presented by the rising demand from governments, investors, and civil society. "ESG-aligned design not only improves access to sustainable finance and enhances public trust but also supports the development of ethically responsible and resilient urban environments" (PRI, 2021). This is especially relevant for green infrastructure projects. They need to addressing environmental resilience, social equity and governance challenges and also requires ESG assessment models.

ESG Coverage by Certification Systems			
Certification Name	Environmental E	Social S	Governance G
LEED	Yes	No (limited)	No
BREEAM	Yes	No (some)	No
WELL	Yes (limited)	Yes	No
DGNB	Yes	Yes	No
Envision	Yes	Yes	Yes
IS Rating	Yes	Yes (partial)	Yes
Urban Audit	Yes	Yes	No
UNI/PdR 13:2019	Yes	Yes	Yes

Table 1 *ESG coverage by certification systems*

Although the general ESG coverage of current certification systems is highlighted in this comparative overview. Many of these frameworks has limitation when they used for green infrastructure projects.

3 Theoretical framework

3.1 Sustainability dimensions for green infrastructure

Sustainability in public infrastructure projects requires more than a standard approach. Especially, green infrastructure projects represent an important focus of this thesis. Their crucial role in improving ecological resilience, social inclusion, and long-term sustainability. It demands a multidimensional assessment framework. The four pillars of sustainability which are Environmental, Social, Economic, and Governance (ESG+) form the foundation for evaluating long-term value creation and risk management. In this context, this thesis explains the GISPAM model, a customized framework titled “Green Infrastructure Sustainability Performance Assessment Model” (GISPAM), specifically developed for the evaluation of green infrastructure projects. The model is created around ESG+ dimensions and supported with a weighted scoring methodology to measure and compare sustainability performance in public infrastructure. Each dimension has a selected set of criteria, allows a comprehensive and balanced assessment. This multidimensional integration allows the framework to assess not only direct environmental impacts but also broader social, economic, and governance, which are particularly critical in green infrastructure development.

The GISPAM model is built on key theoretical methods such as Multi-Criteria Decision Making (MCDM). By combining different approaches, the model aims at the increasing complexity of urban systems, where green infrastructure decisions must reflect a wide array of interconnected sustainability indicators. MCDM supports the evaluation of multiple, and sometimes conflicting, criteria, while systems thinking provides insight into the interdependencies across sectors and governance layers.

Certification Name	Structure	Covered Sustainability Dimension
LEED	Credit Based	Environment and Social
BREEAM	Weighted Scoring	Environment, Social & Economic
WELL	Preconditions and optimizations	Social
DGNB	Performance based	Environment, Social & Economic
Envision	Qualitative Scoring	Environment, Social, Economic & Governance
IS Rating	Modular Weighted scoring	Environment, Social, Economic & Governance
Urban Audit	Indicator Based	Environment, Social & Economic
UNI/Pdr 13:2019	Multicriteria Evaluation	Environment, Social, Economic & Governance

Table 2 *Coverage of existing certification ESG+*

3.2 Significance of green infrastructure for urban sustainability

Green infrastructure has an important role in shaping urban metabolism, affecting land use, energy and water systems, transportation, and social equity. It is a vital tool for achieving sustainability goals at the urban scale because of its long lifecycle and systemic influence. Thus, infrastructure is considered as both a product and a driver of urban development in the theoretical basis of the GISPAM model. Assessing its sustainability requires tools capable of capturing not only component-level performance, but also system-wide effects and externalities.

Most current assessment systems do not fully reflect how complex and connected today's cities and green infrastructure really are. Many of these systems were designed mainly for buildings, so they often ignore things like how well policies work together, how inclusive a project is for different social groups, or how efficient the local governance is. Thats why there is a gap when it comes to evaluating sustainability at a larger, city-wide level. The GISPAM model was created to fill this gap. It offers a flexible way to measure different aspects of sustainability which are environmental, social, economic, and governance customized green infrastructure projects and the urban scale.

Certification Name	Limitations
LEED cities	Point-chasing limited, post occupancy, weak governance
BREEAM	Complex Region-specific, low on social aspects
WELL	Narrow Space, high costs, not suitable for urban scale
DGNB	Technical Barriers, data heavy procedural participation
Envision	North America focus, subjective scoring
IS Rating	Limited adoption, weak cultural/long term performance tracking
Urban Audit	No project level scoring, lacking data
UNI/PdR 13:2019	New, low adaption, limited validation

Table 3 *limitations of current certifications*

3.3 Systemic impacts and interdependencies

Infrastructures have interconnections with each other. All of them depend on others to work effectively transport systems require some form of energy input; water networks are dependent on electricity; social services rely on

proper governance alongside accessibility. These connections create both risks and opportunities. A problem in one system can affect others, while good coordination can lead to shared benefits between sectors.
In green infrastructure projects, these relationships are more important. Nature based solutions, for instance, support water management, reduce energy demand, and improve social well-being.

That’s why the GISPAM framework was designed to show these systemic links. It organizes sustainability criteria to capture how environmental, social, economic, and governance dimensions interact in complex ways. The model uses weighted criteria and a consistent scoring method to evaluate these connections properly.

3.4 Long term resilience considerations

Resilience is a critical component of sustainable infrastructure. Also, it can be defined as the capacity of a system to absorb shocks, adapt to changing conditions and maintain function in time. Climate change, resource scarcity and fluctuation in social demand assessment models that look beyond short-term efficiency. The GISPAM model incorporates resilience as a cross-cutting principle within its evaluation dimensions. Environmental resilience is assessed via resource loops and emissions performance, social resilience through equity and inclusion, economic resilience through life cycle cost analysis and governance resilience through policy alignment and adaptive capacity. The model’s reliance on both quantitative and qualitative data and expert validation further enhances its strength over time. This approach related for green infrastructure projects when long term resilience depends on managing environmental interactions and evolving urban systems.

3.5 Scalability and replicability factors

A useful sustainability assessment model should work in different project types, places, and scales. Scalability means the model can be used for both small local green spaces and large regional green infrastructure systems. Replicability helps the model be used in many projects and even shape policy. The GISPAM framework is created to be flexible and modular. Its dimensions and criteria can be adapted to match local needs while still keeping a clear structure. Also, expert validation is included in the scoring process, which makes the results more reliable and accurate. Thanks to this flexibility, the model is not only strong in theory, but also practical for real world green infrastructure planning and decision-making.

4Research methodology

4.1 Research design

This research adopts a combined methods design to evaluate the sustainability performance of green infrastructure projects through the application of ''The Green Infrastructure Sustainability Performance Assessment Model'' (GISPAM) which was developed specifically to address assessment needs at urban scale. The methodology is created to combine theoretical and practical evaluation. It has both qualitative and quantitative criteria to support a multidimensional sustainability assessment model.

The GISPAM model emerged as a solution to the need for more holistic and integrated evaluation frameworks. Some existing certification systems, while useful, tend to focus on single-scale or sector-specific outcomes. A number of these certification systems overlook critical environmental, social, economic, governance (ESG+) related factors that are essential for infrastructure planning. This model seeks to fill that void by applying a structured rationale which relies on weighted criteria and indicators based on literature reviews as well as consultations with experts.. Finally, the model with selected projects.

The research design includes three key phases:

1) Initiation: The first phase focuses on selecting the model's dimensions and identifying a set of measurable criteria under each ESG+ dimension. This process is supported by existing certification systems, and selected literature reviews. An extensive study was completed to understand existing certificates such as: LEED, BREEAM, WELL, DGNB, Envision, IS Rating Scheme, Urban Audit and UNI/PdR 13:2019.

2) Intelligence: In this phase, the model explains a weighting system to differentiate the relative importance of each criterion. These weights are determined using expert input through questionnaires. In parallel, data for each indicator is collected or prepared for normalization and analysis.

3) Application: Finally, the model is tested through its application to selected green infrastructure projects. A scoring process is conducted, using normalized values. This is followed by a validation process through expert feedback to ensure reliability and context related.

During the study, the model's flexibility allows it to be applied at urban scales. The criteria and structure are adaptable enough to be changes if the provided project specific data is available. The research design therefore ensures both depth in assessment and relevance to different planning and policy contexts. By applying this structured yet adaptable framework, the study contributes to the development of more inclusive and practical tools for sustainability assessment in green infrastructure.

4.2 Phase I: Initiation

4.2.1 Problem framing

Sustainability assessment in architectural and infrastructure projects has traditionally focused on single dimensional evaluation methods, such as only energy use or carbon footprint, predominantly favoring environmental metrics while often neglecting the social, economic, and governance dimensions. Many existing assessment systems are optimized for the building scale, using checklist or credit-based approaches that are missing points of addressing the complex, integrated demands of urban-scale public infrastructure. Key sustainability dimensions ESG+ is also the base for the proposed method. Especially, focuses on addressing the sustainability challenges of green infrastructure projects.

This research begins by identifying the main problem: the absence of a comprehensive, flexible, and multidimensional tool that can effectively assess the sustainability of green infrastructure projects. "Infrastructure developments involve long-term, systemic impacts that require evaluation mechanisms capable of addressing interdependencies, stakeholder diversity, and policy dynamics which conventional rating systems often lack" (Mas-López et al. 2023). Each dimension also has sub criteria based on literature review and expert validation.

4.2.2 Research Gap Identification

Despite offering systematic frameworks for evaluating the environmental and health-related aspects of buildings, well-known certification systems like LEED, BREEAM, WELL, DGNB, Envision, IS Rating Scheme, Urban Audit, and UNI/PdR 13:2019 show significant limitations when applied to urban infrastructure. These systems often lack integration between building and urban scales and tend to underrepresent governance factors, lifecycle resilience, and community engagement.

Additionally, there is an absence of information about the interactions between various sustainability features in real-world scenarios. This gap highlights the urgent need for a flexible methodology that combines systemic assessment tools suited to infrastructure situations with ESG perspectives, as the lack of a uniform set of sustainability criteria continues to hinder the integration of sustainability principles into infrastructure planning and development (AIS, 2023).

4.2.3 Scope definition

The scope of this thesis is focused on the development and application of GISPAM method. The purpose of this model fills the gap by providing correct and accurate results for green infrastructure projects. Although the main goal is green infrastructure the model is designed to be adaptable with policy and planning needs to relate to sustainable urban development. In this way, it aimed to provide opportunities for future studies.

4.2.4 Criteria and indicator selection

The selection of sustainability criteria was selected by a comprehensive review of academic literature and established certification systems. The literature review contains journal articles, international guidelines and reports from recognized green infrastructures systems such as LEED for cities and community, BREEAM communities, Envision, WELL, DGNB, IS Rating Scheme, Urban Audit, Uni/PdR 13:2019. Each ESG+ dimension has specific criteria and indicators.

Inclusion and exclusion criteria for certificates and assessments criteria were determined to ensure relevance to green infrastructure. Some certificates are excluded due to focused primarily on building scale performance. Only systems that addressed multiple dimensions and had approved applications to infrastructure were included.

After gathering a comprehensive list of candidate criteria detailed reduction process were applied. Then criteria examined according to their relevance to green infrastructure directly. Duplicated and overlapping indicators enforced and some criteria were removed due to not measurable or not supported by data.

Final criteria were selected based on a combination of frequency and significance in literature, documented use in well known certificates and co decision and high ratings from expert's feedback. This multi steps approach shows that the selected criteria area strong, practically applicable and well aligned with the challenges of assessing green infrastructure projects.
The finalized indicators serve as base for scoring within the GISPAM model and will be refined as case study analysis progress.

4.3 Phase II: Intelligence

The Intelligence phase focuses on two main activities: establishing the weighting system for the selected criteria and organizing the data collection process for each indicator. This phase creates a bridge between theoretical model design and its operational application. Especially, customized to assess the sustainability of green infrastructure.

4.3.1 Weighting process

To find the relative importance of each criteria for the GISPAM framework, a structured weighting process is applied. This process combines two main sources: a literature review and expert validation.

Then, values and priorities found in existing certification systems such as BREEAM, Envision, DGNB, WELL, IS Rating Scheme, UNI PdR 13:2019, Urban Audit and academic studies are examined to understand common emphasis areas between sustainability frameworks. These outfits serve as a preliminary guide for weight calibration.

To enhance this theoretical framework, a ranking procedure based on experts was completed. A questionnaire was developed listing the identified environmental, social, economic and governance and criteria, and experts were asked to rank them based on importance in sustainability assessment. The collected rankings were then processed using the Rank Order Centroid (ROC) method, which converts ordinal rankings into numerical weights while preserving the relative importance given by the experts.

This approach guarantees that the weighting system contains both stakeholder insights and experimental findings. Additionally, the use of diverse expert profiles allows the model to be more reliable in sustainability context. The detailed distribution of weights derived through the ROC method and their integration within the model structure are explained in detail in Chapter 5. These weights reflect the sustainability priorities of green infrastructure.

4.3.2 Data collection and organization

For every indicator, the proper data and source are identified. Sources include official planning documents, infrastructure performance reports, environmental impact assessments, and socio-economic statistics. Data collection is aligned with the structure of the ESG+ framework, ensuring accuracy and balance.

Indicators rely on qualitative judgments such as stakeholder participation or institutional transparency are organized for evaluation through scoring qualitative content analysis. Quantitative indicators such as energy use, emissions or cost are combined in a format for normalization. For the qualitative criteria direct methods were used.

4.3.3 Preparation for normalization

Since the indicators have different units and data types, normalization is obligatory to ensure comparability. This stage includes not only a full normalization process but also preparing datasets for proper usage. This means that if there is any extreme result, this result can affect normalization in a bad way. In that case firstly, that extreme result should be checked, if it is correct, it can be assigned as a special situation and evaluated in a different perspective. Or some cases have some missing data. There are some steps that these missing data can fill. First, missing data is found and completed, or if it is filled in with average values taken from similar projects. Lastly, If the data cannot be found or the average value cannot be written instead, the data is marked as missing or that criteria is not evaluated. These steps are critical to ensure data quality for normalization.

4.4 Phase III: Application

4.4.1 GISPAM development

The GISPAM model is applied to a few selected green infrastructure projects in the last phase. Measurable standards and indicators that are consistent with sustainability goals are included in the framework, which is organized around the ESG+ aspects. A balanced and multidimensional evaluation is ensured by guiding each indication to certain sub-criteria and evaluating it in accordance with the established approach.

The structure of the model makes it applicable to projects at the urban scale. The scoring system may be used in a variety of institutional and geographic contexts since it is made to adapt to context specific project goals and handle different data availability.

4.4.2 Rating logic construction

The application process starts with data normalization, which is crucial for comparing indicators across different units and scales. The normalized and weighed indicator values were aggregated according to structure. This rating logic ensures consistency, transparency, and adaptability, allowing the model to function as both a diagnostic and comparative tool with a specific focus on green infrastructure projects.

4.4.3 Testing and validation methods

The evaluation method integrates expert validation directly into weighting and ranking of the sustainability criteria by applying the Rank Order Centroid (ROC) to the scores provided by experts. This approach shows that experts' opinions play a critical role in determining the relative significance of each criterion. Rather than using expert validation only as a separate verification step, their scores are integrated directly into the framework.

Real case studies were used for testing the GISPAM. For each project, sustainability performance was calculated, and the result rankings were checked for logical consistency.

This approach shows the methodological scalability of GISPAM. It has the potential to generate logical insights for sustainability focused decision making in green infrastructure projects.

5 Rating model construction

This chapter shows the technical structure of the GISPAM (Green Infrastructure Sustainability Performance Assessment Model) rating model. The model integrates ESG+ based sustainability criteria into a structured scoring framework. It allows infrastructure projects to be evaluated between environmental, social, economic and governance dimensions using standardized processes. The model is designed to be adaptable and scalable, ensuring applicability for urban scale projects. However, the model was developed according to green infrastructures. All the normalization values are set according to green infrastructures systems. All normalization values are set according to these projects.

5.1 Criteria selection

The selection of sustainability criteria was guided not only by Established ESG frameworks, but also by the green infrastructure projects. Green infrastructure is radically different from conventional infrastructure because it provides multifunctional ecosystem services, supports urban biodiversity and provides natural climate resilience. Unlike traditional risk and management oriented ESG approaches, green infrastructure projects improve ecological connectivity, allowing nature-based solutions. This integrated value proposition justifies the need for criteria that go beyond conventional sustainability assessment models, ensuring that the framework reflects the true value and complexity of green infrastructure. The selection of criteria for the GISPAM model followed a systematic, multi-step process to ensure methodological transparency and relevance to green infrastructure projects. In the beginning, a comprehensive pool of 33 which presented in ''Table 4'' candidate criteria were selected by extracting indicators the latest versions of major international certification systems which area LEED v4.1 for Cities and Communities, BREEAM Communities, DGNB Urban Districts, WELL Community Standard v2, Envision v3, IS Rating Scheme, Urban Audit, UNI/PdR 13:2019.

There are required indicators for inclusion criteria for the beginning pool. Should be relevant to urban green infrastructure or public urban space project, applicable at the urban scale, measurable and supported by accessible data or standardized methodologies, referenced in certificates systems or major sources.

On the other hand, exclusion criteria also require some indicators. These are: indicators relevant only to single buildings, indicators with no measurement protocols or available data, duplicates or overlapping with other indicators, criteria not directly applicable to the green infrastructure context.

At the beginning, 33 criteria were systematically reviewed and decreased through monitoring for relevance, feasibility, and sustainability. Indicators, directly related to green infrastructure projects, not measurable at the urban scale, or overlapping with other criteria were eliminated. After this reduction process, the number of criteria was decreased to 12 presented in ''Table 6,7,8,9 , each representing a distinct aspect of ESG+ dimensions.

As a result, the model incorporates 12 criteria, categorized under the four main ESG+ dimensions: Environmental, Social, Economic, and Governance, which are identified through expert input collected via a structured questionnaire. Based on this questionnaire, the criteria were listed according to the order of importance determined by the experts. In the next paragraph, experts comments are examined and explained in detail.

No	Criteria Name	Source
1	Energy Efficiency	LEED v4.1 Cities, BREEAM Communities, DGNB Urban, Envision
2	Carbon Footprint / GHG Emissions	LEED v4.1 Cities, Envision, IS Rating, BREEAM Communities
3	Water Management	BREEAM Communities, WELL Community, Urban Audit, LEED v4.1 Cities
4	Resource Efficiency (Materials)	DGNB Urban, IS Rating, UNI/PdR 13:2019, BREEAM Communities
5	Land Use & Biodiversity	LEED v4.1 Cities, BREEAM Communities, DGNB Urban, Envision
6	Pollution Reduction (Air/Soil/Water)	BREEAM Communities, Envision, IS Rating, WELL Community
7	Climate Resilience / Adaptation	LEED v4.1 Cities, Envision, IS Rating
8	Urban Heat Island Mitigation	LEED v4.1 Cities, DGNB Urban, Urban Audit
9	Habitat Connectivity	DGNB Urban, LEED v4.1 Cities, BREEAM Communities
10	Accessibility / Inclusivity	BREEAM Communities, WELL Community, Urban Audit, LEED v4.1 Cities

11	Health and Well-being	WELL Community, BREEAM Communities, DGNB Urban, LEED v4.1 Cities
12	Social Equity	LEED v4.1 Cities, Urban Audit, BREEAM Communities, IS Rating
13	Community Engagement & Participation	BREEAM Communities, DGNB Urban, LEED v4.1 Cities, Urban Audit
14	Safety & Security	WELL Community, BREEAM Communities, IS Rating, Urban Audit
15	Cultural Preservation & Identity	Urban Audit, BREEAM Communities, UNI/PdR 13:2019
16	Educational Value / Awareness	WELL Community, Urban Audit
17	Stakeholder Involvement	LEED v4.1 Cities, BREEAM Communities, IS Rating
18	Transparency & Accountability	Envision, IS Rating, UNI/PdR 13:2019
19	Monitoring & Evaluation	IS Rating, Envision, Urban Audit
20	Policy Integration & Regulatory Support	UNI/PdR 13:2019, Envision, DGNB Urban

21	Institutional Capacity & Governance Efficiency	BREEAM Communities, Envision, UNI/PdR 13:2019
22	Multi-Level Governance	IS Rating, Urban Audit, UNI/PdR 13:2019
23	Life Cycle Cost	Envision, IS Rating, DGNB Urban
24	Cost Effectiveness	LEED v4.1 Cities, IS Rating, BREEAM Communities
25	Resource Efficiency (Economic)	IS Rating, DGNB Urban, UNI/PdR 13:2019
26	Local Economic Impact	Urban Audit, IS Rating, BREEAM Communities
27	Economic Resilience	LEED v4.1 Cities, Envision, Urban Audit
28	Financial Accessibility	BREEAM Communities, Urban Audit, IS Rating
29	Sustainable Mobility & Transport	LEED v4.1 Cities, BREEAM Communities, Envision
30	Innovation	LEED v4.1 Cities, BREEAM Communities, DGNB Urban
31	Public Space Quality	Urban Audit, BREEAM Communities, WELL Community
32	Green Space Ratio / Provision	LEED v4.1 Cities, Urban Audit, BREEAM Communities
33	Waste Management	LEED v4.1 Cities, BREEAM Communities, Envision

Table 4 *Pool of criteria*

Dimension	Criteria	Source	Definition	Measurement Unit
Environmental	Energy and Carbon Emissions	LEEDv4.1 Cities , DGNB Urban, BREEAM Community, IS Rating Scheme, Envision	The project's contribution to reducing carbon emissions and greenhouse gases through renewable energy integration, energy-efficient systems, and low-carbon materials.	$kgCO_2e$/year, Energy Use Intensity (kWh/m²/year)
	Water Efficiency and Water Management	BREEAM Community, LEED v4.1 Cities, Urban Audit	The implementation of systems and strategies to reduce water use, manage flows, and ensure clean and safe water across infrastructure operations.	m³/year, % of water reused, Water Quality Index
	Climate Adaptation and Resilience	LEED v4.1 Cities & Communities, Envision, IS Rating Scheme, DGNB Urban	The project's capacity to resist and adapt to climate-related risks such as flooding, extreme heat, or drought through resilient infrastructure planning and design.	% of flood-protected area, Resilience Index, Yes/No checklist

Table 5 *Environmental Criteria Table*

Dimension	Criteria	Source	Definition	Measurement Unit
Social	Social Equity and Access	LEED v4.1 Cities & Communities, Urban Audit, BREEAM Communities	Equal access to infrastructure services such as mobility, water, and digital systems regardless of income, age, gender, or physical ability.	% of inclusive design coverage, accessibility index
	Health and Well being	WELL Community, LEED v4.1 Cities & Communities, DGNB Urban	How the infrastructure promotes public health through clean environments, safe public transport, access to water, and psychological comfort.	Health Index, % of people with access to safe infrastructure
	Community cohesion and social Infrastructure	BREEAM Communities, DGNB Urban, Envision, Urban Audit	The project's contribution to strengthening social networks, inclusion, trust, and access to essential public services such as healthcare, education, and public space.	Community engagement score, % population served, Yes/No checklist

Table 6 *Social Criteria Table*

Dimension	Criteria	Source	Definition	Measurement Unit
Economic	Life Cycle cost Efficiency	Envision, DGNB Urban, IS Rating Scheme, UNI/PdR 13:2019	How the infrastructure design, construction, and operation minimize total costs over its full life cycle, including capital, operation, and maintenance expenses.	€/m² over 30 years, Net Present Value (NPV)
	Cost effectiveness and operational savings	IS Rating Scheme, BREEAM Communities, DGNB Urban	Delivery of infrastructure projects that balance capital investment with future savings in energy, water, maintenance, or operational efficiency.	% operational savings, Return on Investment (ROI)
	Economic performance	IS Rating Scheme, Urban Audit, BREEAM Communities	Evaluation of how well an infrastructure project contributes to economic growth, employment, and investment at local or regional levels.	% employment growth, local GDP impact, investment volume

***Table** 7 Economical Criteria Table*

Dimension	Criteria	Source	Definition	Measurement Unit
Governance	Stakeholder Engagement and Public Involvement	LEED v4.1 Cities & Communities, Envision, DGNB Urban, BREEAM Communities	How the project ensures early and continuous participation of relevant stakeholders, including communities, through consultation, feedback, and co-design processes.	Level of stakeholder involvement, number of consultation rounds, Yes/No checklist
	Governance and Management Systems	IS Rating Scheme, DGNB Urban, UNI/PdR 13:2019, Envision	The existence and quality of structured governance frameworks and project management systems that planning, decision-making, and implementation of infrastructure.	Existence of certified governance system, checklist score
	Transparency & Reporting	Envision, IS Rating Scheme, UNI/PdR 13:2019, LEED v4.1 Cities	The transparency and clarity with which project objectives, performance metrics, and progress are documented, communicated, and made publicly accessible.	% of documentation publicly available, frequency of reporting

***Table 8** Governance Criteria Table*

Interviews were carried out with professionals not only in an academic way but also in actively working architects. These professionals are working in architecture, urban planning, sustainability assessment and infrastructure design areas. Experts were asked to evaluate the relative importance of each sustainability dimension which is ESG+, as well as the criteria within each dimension. Each expert ranked from the most important one to least important criteria using Likert scale. To enhance the consistency and reduce subjectivity multiple experts from each field of expertise were interviewed. To mention these experts: Professor Caterina Caprioli from Politecnico di Torino, Phd Guilio Cavana from Politecnico di Torino, MsC architect Sandro Serapioni who is founder of Serapioni Progetti, Marta Serapioni who is a creative director and director of technical services of Serapioni Progetti from Italy, Yasser Shalaan who is MSc. Architect from Egypt, Chloe Tan who is MSc architect from Malesia. As a result of the experts being from different countries and different professions, enhanced the adaptation process for the method. This was used as a method to increase the validity of research. In the next paragraphs expert comments and score explained in detail.

Prof. Caterina Caprioli is a professor at Politecnico di Torino, in Italy, with expertise in urban sustainability, infrastructure planning and resilient design. Professor's academic work focuses on integrating environmental, social and governance aspects into large urban scale projects.

Infrastructure projects, as Prof. Caprioli noted, are crucial for social cohesion and economic contribution. She also discussed the social inclusiveness along with the economic development and environmental resilience interdependencies of green infrastructure. In the interview, Prof. Caprioli pointed to community cohesion as an important issue of social infrastructure for urban projects. Professor also highlighted economic performance as highly relevant. Energy and carbon emissions were rated as very important, and professor added some recommendations to strengthen renewable energy indicators. Health and wellbeing underlined as significant, especially in the context of public space design. Water management and climate resilience were both crucial, however, there are existing difficulties in ensuring consistent measurement of these aspects in practice.

Dimension	Score
Environmental	5
Social	4
Economic	3
Governance	4

Table 9 *Prof. Caterina Caprioli dimension scores*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	7
	Water Efficiency and Water Management	6
	Climate Adaptation and Resilience	5
Social	Social Equity and Access	4
	Health and Well being	6
	Community cohesion and social Infrastructure	7
Economic	Life Cycle cost Efficiency	4
	Cost effectiveness and operational savings	5
	Economic performance	7
Governance	Stakeholder Engagement and Public Involvement	6
	Governance and Management Systems	4
	Transparency & Reporting	4

Table 10 *Prof Caprioli criteria Scores*

Dr. Guilio Cavana is a researcher at Politecnico di Torino in Italy. His specializes in sustainable infrastructure, energy efficiency and urban resilience. His work focuses on integrating technical sustainability assessment tools with assessment tools systemic approaches to enhance the environmental and operational performance of large scale projects.

Dr. Cavana focused one of the critical role of environmental criteria. Dr Cavana especially highlighting the significance of reducing energy and carbon emissions in infrastructure projects. He rated Energy and carbon emissions, social equity, and health and wellbeing with the highest importance which is 7 out of 7 and indicating their fundamental role for sustainable development. He provided technical notes on measurement units which is the proper usage of $kgCO_2e/m^2$ indicators. Dr. Cavanda also focused the need for proper normalization process to ensure comparability between different projects.
For governance, he provided moderate scores and suggesting its indirect but supportive influence on projects. His results aligns with an academic practice perspective, contributing detailed quantitative suggestions and reinforcing the need for better environmental metrics.

Dimension	Score
Environmental	5
Social	4
Economic	4
Governance	3

Table 11 *Phd Cavana dimension scores*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	7
	Water Efficiency and Water Management	5
	Climate Adaptation and Resilience	6
Social	Social Equity and Access	7
	Health and Well being	7
	Community cohesion and social Infrastructure	5
Economic	Life Cycle cost Efficiency	5
	Cost effectiveness and operational savings	5
	Economic performance	6
Governance	Stakeholder Engagement and Public Involvement	6
	Governance and Management Systems	5
	Transparency & Reporting	4

***Table 12** PhD Cavana criteria Scores*

Sandro Serapioni is the founder of Serapioni Progetti in Torino, Italy. With the over 40 years of experience in architecture. He has worked extensively across the Europe, Africa and The Middle East, leading diverse projects such as hospitality, residential, transportation infrastructure and green infrastructure projects. His expertise shows us valuable practical point of view into the real world applicability of sustainability criteria.

During the interview, Serapioni emphasized in a balanced approach. For example, economic viability and social inclusion, rating Social Equity and Access, Life Cycle Cost, and Health and Well-being as highly important. Environmental indicators such as Energy and Carbon Emissions and Water Management were seen as relevant but secondary to user-centered and cost-efficient design. His feedback reflects a practitioner's focus on realistic, implementable sustainability strategies.

Dimension	Score
Environmental	4
Social	4
Economic	5
Governance	3

***Table 13** Sandro Serapioni dimension scores*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	5
	Water Efficiency and Water Management	5
	Climate Adaptation and Resilience	4
Social	Social Equity and Access	6
	Health and Well being	6
	Community cohesion and social Infrastructure	5
Economic	Life Cycle cost Efficiency	6
	Cost effectiveness and operational savings	6
	Economic performance	4
Governance	Stakeholder Engagement and Public Involvement	5
	Governance and Management Systems	4
	Transparency & Reporting	4

Table 14 *Sandro Serapioni criteria scores*

Marta Serapioni is the director of technical services and creative director at Serapioni with over 10 years of experience. Her expertise focuses on the economic dimension of architecture and urban projects. Also, with the practical experience in design implementations across Europe, Africa, and The Middle East.

During the interview, Marta Serapioni prioritized both economic and social sustainability aspects. She rated Energy and Carbon Emissions, Life Cycle Cost Efficiency, Health and Well-being, and Cost Effectiveness as highly important which is 7 out of 7, underlining the relevance of efficient resource use and project affordability. She also gave high scores on Stakeholder Engagement, Water Efficiency, Governance Systems, and Climate Resilience, reflecting a comprehensive understanding of the need for inclusiveness and operational power. She also scored Economic Performance and Transparency & Reporting received moderate importance and her feedback focused on balancing measurable economic impact with the feasibility of real world projects.

Dimension	Score
Environmental	5
Social	4
Economic	4
Governance	4

Table 15 *Marta Serapioni dimension scores*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	7
	Water Efficiency and Water Management	6
	Climate Adaptation and Resilience	6
Social	Social Equity and Access	5
	Health and Well being	7
	Community cohesion and social Infrastructure	6
Economic	Life Cycle cost Efficiency	7
	Cost effectiveness and operational savings	7
	Economic performance	4
Governance	Stakeholder Engagement and Public Involvement	6
	Governance and Management Systems	6
	Transparency & Reporting	5

Table 16 *Marta Serapioni criteria scores*

Yasser Shalaan is MSc architect from Egypt and graduated from Politecnico di Milano. Beginning of his career he managed his own architecture office in Egypt. Then he relocated themselves to Italy to pursuit his career. His professional experience includes significant works on large scale projects an urban space. Combining knowledge with practical implementation across different cultural and urban contexts.

His evaluation emphasized a balance between environmental performance and social inclusion. He rated Energy and Carbon Emissions and Life Cycle Cost Efficiency as highly important, which is 6 out of 7. Representing a strong focus on both climate conscious design and economic feasibility. Social Equity and Access, Health and Well-being, and Stakeholder Engagement were also rated over moderate which is 5 points, explaining to importance of inclusive, user-centered green infrastructure and urban spaces. According to his expertise, governance criteria such as Transparency and Reporting received lower importance, and his overall feedback shows the perspective of a practitioner prioritizing measurable environmental benefits, accessibility, and operational efficiency in green infrastructure projects.

Dimension	Score
Environmental	4
Social	3
Economic	4
Governance	3

Table 17 *Yasser Shalaan dimension scores*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	6
	Water Efficiency and Water Management	4
	Climate Adaptation and Resilience	5
Social	Social Equity and Access	5
	Health and Well being	5
	Community cohesion and social Infrastructure	4
Economic	Life Cycle cost Efficiency	6
	Cost effectiveness and operational savings	5
	Economic performance	3
Governance	Stakeholder Engagement and Public Involvement	5
	Governance and Management Systems	3
	Transparency & Reporting	2

Table 18 *Yasser Shalaan ESG+ Scores*

Chloe Tan is MSc architect from Malaysia and graduated from Politecnico di Torino. She continues her career by working on architectural and urban design projects both in Malaysia and Italy. Her background brings an important perspective from Asia to sustainable urban development. And she is combining design experience with variety of regional experiences. Her experience on different continents has helped the model gain international validity by providing a different perspective on green infrastructure.

Tan rated Energy and Carbon Emissions, Climate Adaptation and Resilience, and Cost Effectiveness as highly important which is 6 out of 7. Tan give more importance environmental efficiency and operational savings in urban projects as 6 points. Social dimensions such as Equity and Access, Community Cohesion and Stakeholder Engagement were moderately scored as 5 and 4. Governance indicators received average scores, while Transparency and Reporting was considered less critical in practice which is 4. Tan's feedback brings an important Asian viewpoint, emphasizing measurable sustainability outcomes combined with real-world design feasibility.

Dimension	Score
Environmental	5
Social	4
Economic	4
Governance	3

Table 19 *Chloe Tan dimension scores*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	6
	Water Efficiency and Water Management	5
	Climate Adaptation and Resilience	6
Social	Social Equity and Access	5
	Health and Well being	4
	Community cohesion and social Infrastructure	4
Economic	Life Cycle cost Efficiency	5
	Cost effectiveness and operational savings	6
	Economic performance	5
Governance	Stakeholder Engagement and Public Involvement	5
	Governance and Management Systems	5
	Transparency & Reporting	4

Table 20 *Chloe Tan ESG+ Scores*

Experts evaluations were collected using a 7 point Likert scale for criteria and a 5 point Likert scale for dimensions. These raw scores were aggregated and ranked. The criteria and dimensions who has higher point achieved higher ROC weight. Then, These Roc weights were prepared for the case studies for GISPAM.

Dimension	Dimensions Score
Environmental (E)	28
Social (S)	23
Economic (Ec)	24
Governance (G)	20

Table 21 *Aggregated Scores of Dimensions*

Dimension	Criteria	Score
Environmental	Energy and Carbon Emissions	38
	Water Efficiency and Water Management	31
	Climate Adaptation and Resilience	32
Social	Social Equity and Access	32
	Health and Well being	35
	Community cohesion and social Infrastructure	31
Economic	Life Cycle cost Efficiency	33
	Cost effectiveness and operational savings	34
	Economic performance	29
Governance	Stakeholder Engagement and Public Involvement	33
	Governance and Management Systems	27
	Transparency & Reporting	23

Table 22 *Aggregated Score of Criteria*

In the chapter 5.2.2 and 5.2.3 explained in detail how the expert validation scores used in ROC weight method used for GISPAM.

5.1.1 Environmental impact indicators

The environmental dimension of the model aiming for reducing ecological harm and increasing the responsible use of natural resources. Three main environmental indicators selected for inclusion in the expert validation phase due to their high relevance in the context of architectural and urban scale green infrastructure. These are, energy and carbon emissions, water efficiency and water management and climate and adaptation and resilience. The first criteria is energy and carbon emissions which evaluates a project's contribution to reducing greenhouse gas emissions through renewable energy integration, energy efficient systems, and low carbon material use. This criteria is strongly related in nearly all sustainability frameworks such as LEED, DGNB, BREEAM, IS Rating Scheme and Envision. It is measured in units such as kilograms of CO_2 equivalent per year or energy use intensity (kWh/m^2/year), capturing both operational and embodied carbon impacts.
The second environmental indicator is water efficiency and water management. This criteria show how infrastructure systems implement strategies to minimize water consumption, manage flow and reuse, and maintain safe water standards. Recognized in LEED, DGNB, and WELL systems, it is commonly measured in cubic meters per year, percentage of water reused, and where applicable, water quality indices. This indicator plays a critical role in ensuring environmental protection and aligns with circular resource principles in sustainable infrastructure design.

The third key indicator is climate adaptation and resilience. This indicator, which is recognized by the IS Rating Scheme, DGNB communities, Envision, and LEED for cities, measures how successfully a project will resist and adapt to climate-related risks. For example, flooding, extreme heat, or drought, through strong infrastructure planning and design. Measurement units may include the percentage of flood-protected areas, a resilience index score, or the number of adaptation strategies implemented based on a checklist. Given the increasing frequency and severity of climate impacts, this criterion reflects a project's long-term sustainability and ability to serve future generations. These indicators will be subject to expert evaluation using a Likert scale to determine their relative importance in green infrastructure sustainability assessments. The outcome will support the ROC weighting and MAVT aggregation process in subsequent model phases.

Dimension	Criteria	Source	Definition	Measurement Unit	Total Score from Experts
Environmental	Energy and Carbon Emissions	LEED, DGNB, BREEAM, IS Rating Scheme, Envision	The project's contribution to reducing carbon emissions and greenhouse gases through renewable energy integration, energy-efficient systems, and low-carbon materials.	$kgCO_2e$/year, Energy Use Intensity (kWh/m²/year)	**38**
	Water Efficiency and Water Management	LEED,DGNB, WELL, WQI	The implementation of systems and strategies to reduce water use, manage flows, and ensure clean and safe water across infrastructure operations.	m³/year, % of water reused, Water Quality Index	**31**
	Climate Adaptation and Resilience	LEED, DGNB, Envision, IS Rating Scheme	The project's capacity to resist and adapt to climate-related risks such as flooding, extreme heat, or drought through resilient infrastructure planning and design.	% of flood-protected area, Resilience Index, Yes/No checklist	**32**

Table 23 *Environmental dimensions expert validation scores*

5.1.2 Social impact indicators

Social sustainability within green infrastructures focuses on inclusion and accessibility, health, reinforcement of social cohesion and strengthening bonds among members of society. For this model, the criteria selection has been defined by well-known frameworks like LEED, WELL, DGNB, Envision or Urban Audit which acknowledge that social developments are integral for equity in enduring green infrastructure development.

The first criteria of this dimension are social equity and access. This criterion evaluates whether infrastructure projects ensure equal access to essential services regardless of socioeconomic status, age, gender, or physical ability. Highlighted particularly in the LEED framework, this indicator is commonly measured through metrics such as the percentage of inclusive design coverage and the accessibility index. It captures the measures to which infrastructure promotes equity and universal usability.

The second criteria is health and wellbeing. Guided from WELL and Urban Audit standards, this criterion evaluates how infrastructure supports the physical and mental health of users by providing clean environments, safe mobility options, and access to essential services. Measurement may contain parameters of health outcomes, or the proportion of the population with access to safe, clean, and health-promoting public infrastructure.
The third social indicator is community cohesion and social infrastructure. This guides the project's role in encouraging social networks, public

participation, and access to public spaces such as healthcare, education, and recreation facilities. Envision, DGNB and LEED are all frameworks that consider this a fundamental indicator as part of holistic inclusive urban design. It can usually be captured through engagement scores (sometimes also referred as participation), population served percentage or structured checklist counts reflecting participatory processes or shared space inclusion.

All these indicators combined together demonstrates how much infrastructure projects serve communities while empowering them. This allows for sustainability assessment using expert weighting with a Likert scale evaluation on those criteria included through more participatory defined model enters per from experts stemmed provided their collective expertise shared voice was heard.

Dimension	Criteria	Source	Definition	Measurement Unit	Total Score from Experts
Social	Social Equity and Access	LEED	Equal access to infrastructure services such as mobility, water, and digital systems regardless of income, age, gender, or physical ability.	% of inclusive design coverage, accessibility index	**32**
	Health and Well being	WELL, Urban Audit	How the infrastructure promotes public health through clean environments, safe public transport, access to water, and psychological comfort.	Health Index, % of people with access to safe infrastructure	**35**
	Community cohesion and social Infrastructure	Envision, DGNB, LEED	The project's contribution to strengthening social networks, inclusion, trust, and access to essential public services such as healthcare, education, and public space.	Community engagement score, % population served, Yes/No checklist	**31**

Table 24 *Social dimensions expert validation scores*

5.1.3 Economic impact indicators

Economic sustainability in public infrastructure emphasizes achieving long-term financial efficiency, value creation, and resilience against future uncertainties. The selection of economic criteria for this model is taken from existing frameworks such as DGNB, LEED, BREEAM, IS Rating Scheme, and UNI/PdR 13:2019, which focuses the requirement for infrastructure projects to deliver both immediate cost-efficiency and sustained economic benefit in time.

Life cycle cost efficiency is the first selected indicator. This criterion considers how design, construction and operation of an infrastructure minimizes total expenditure over the project's life, spanning from capital investment to maintenance and operational costs. Life cycle cost efficiency as noted in DGNB and UNI/PdR 13:2019 is predominantly evaluated through financial lenses. It highlights the economy of planning and budgeting practices.

The second indicator is cost effectiveness and operational savings. This concerns how well resource saving in energy, water, or maintenance is obtained relative to initial investment on infrastructure solutions. This metric serves as an incentive for efficient project design under frameworks such as LEED and BREEAM.It is usually measured by the percentage of operational savings and return on investment (ROI), offering insights into economic optimization strategies

The third economic indicator is economic performance in terms of local and regional development impact. This criterion assesses the infrastructure initiatives in regard to their role in fostering employment opportunities as well as stimulating investment and economic development, which has been stressed by the IS Rating Scheme. It is measured using indicators such as the percent increase in employment, economic production quantifiable at a regional level, and the aggregate direct and indirect investment facilitated as a consequence of the project.

These economic indicators collectively support the assessment of infrastructure projects not only as built environments but also as supports of the financial and social stability. They will be evaluated through expert input to determine their relative importance within the model using a structured Likert scale approach.

Dimension	Criteria	Source	Definition	Measurement Unit	Total Score from Experts
Economic	Life Cycle cost Efficiency	DGNB, UNI/PdR 13:2019	How the infrastructure design, construction, and operation minimize total costs over its full life cycle, including capital, operation, and maintenance expenses.	€/m² over 30 years, Net Present Value (NPV)	**33**
	Cost effectiveness and operational savings	LEED, BREEAM	Delivery of infrastructure projects that balance capital investment with future savings in energy, water, maintenance, or operational efficiency.	% operational savings, Return on Investment (ROI)	**34**
	Economic performance	IS Rating Scheme	Evaluation of how well an infrastructure project contributes to economic growth, employment, and investment at local or regional levels.	% employment growth, local GDP impact, investment volume	**29**

Table 25 *Economical dimension expert validation table*

5.1.4 Governance impact indicators

Governance plays a foundational role in sustainable infrastructure by providing transparency, accountability, participatory decision-making, and institutional effectiveness. The governance related indicators in this model are taken from by the criteria used in systems such as LEED, DGNB, Envision, IS Rating Scheme, and UNI/PdR 13:2019. These frameworks focus the critical significance of planning processes and institutional structures in achieving sustainability outcomes.

The first selected criteria is stakeholder engagement and public involvement. This shows the extent to which relevant stakeholders, including local communities, are provided participation opportunities in planning, designing and implementing infrastructure projects.. As explained in LEED, DGNB, and Envision, meaningful engagement is a core aspect of governance quality. It can be assessed by stakeholder participation levels, number of consultation rounds held, and inclusiveness assessments based on checklists.

The criteria cover governance and management systems. This measures gaps in the existence and functionality of organized management processes that guide construction or infrastructure projects, including their supervision and control. “As taken from” DGNB, IS Rating Scheme, and UNI/PdR 13:2019 this indicator assesses if institutions operate within set standards, maintain institutional continuity, and respond to changing circumstances as needed. It is usually evaluated through the presence of certified systems as well as other identifiable outcomes provided by system and outcomes-based managerial structures.

The third criteria is transparency with reporting which was highlighted in LEED, Envision, and DGNB. This criterion deals with the public availability of information about projects which includes clear statements of objectives, progress indicators, milestones achieved marks alongside other contemporary benchmarks discarded during project execution evaluation matrices within defined timelines. Evidence for transparency could also be sourced from documented evidence showing the proportion of relevant documentation available to the public alongside regular intervals set for progress update delivery.

By including these governance indicators, the model ensures that the quality of institutional arrangements and the accountability mechanisms within infrastructure projects are given due significance. These aspects will be evaluated through expert validation using a Likert scale to determine their significance in sustainability performance.

Dimension	Criteria	Source	Definition	Measurement Unit	Total Score from Experts
Governance	Stakeholder Engagement and Public Involvement	Envision, LEED, DGNB	How the project ensures early and continuous participation of relevant stakeholders, including communities, through consultation, feedback, and co-design processes.	Level of stakeholder involvement, number of consultation rounds, Yes/No checklist	**33**
	Governance and Management Systems	DGNB, IS Rating Scheme, UN/PdR 13:2019	The existence and quality of structured governance frameworks and project management systems that planning, decision-making, and implementation of infrastructure.	Existence of certified governance system, checklist score	**27**
	Transparency & Reporting	LEED, Envision, DGNB	The transparency and clarity with which project objectives, performance metrics, and progress are documented, communicated, and made publicly accessible.	% of documentation publicly available, frequency of reporting	**23**

Table 26 *Governance dimension expert validation table*

5.2 Normalization process

This process plays an important role for the rating model. Since sustainability is a multi-dimensional concept, assigning appropriate weights for necessary to show both theoretical priorities and practical relevance. Then, in order to use these values there will be normalization method used.
With this process, a structured weighting process was applied in multiple ways: the Min-Max normalization technique was used to standardize indicator values, the Rank Order Centroid (ROC) method was used for both dimension-level and criterion-level weighting based on expert validations, and finally, the Multi-Attribute Value Theory (MAVT) framework was used to aggregate scores into a unified sustainability rating

5.2.1 Normalization process steps

Before the weighting procedure, a min-max normalization method was used to convert raw indicator values into a standardized which between 0 and 1 scale. This ensured comparability between indicators with different units or scales. For criteria where lower values indicate better performance such as carbon footprint or energy use, inverse normalization was used

Standard normalization

$$X_{normalized} = \frac{(X - X_{min})}{(X_{max} - X_{min})}$$

Figure 1 *Standard normalization formula*

Reverse normalization:

$$X_{normalized} = \frac{(X_{max} - X)}{(X_{max} - X_{min})}$$

Figure 2 *Reverse normalization formula*

5.2.1.1 *Energy and carbon emissions normalization*

Energy and carbon emissions criteria aims to evaluate the contribution of a project to energy efficiency and the reduction of greenhouse gas emissions (GHG). on these criteria, the amount of carbon emissions emitted annually per square meter (kgCO2e/m². year) is used.

To evaluate these criteria, the min max normalization was used. Based on the international standards and sustainability ratings systems, operational and embodied carbon emissions in green infrastructure projects typically range between 5 $kgCO_2e/m^2$/year (for high-performance projects) and 70 $kgCO_2e/m^2$/year (for conventional infrastructure) (ISO 14067:2018; LEED v4.1 for Cities and Communities, 2019; DGNB Urban Districts, 2021; US EPA, 2022).. This method allows all values to be scaled between 0 and 1, allows a standardized scoring system between projects.

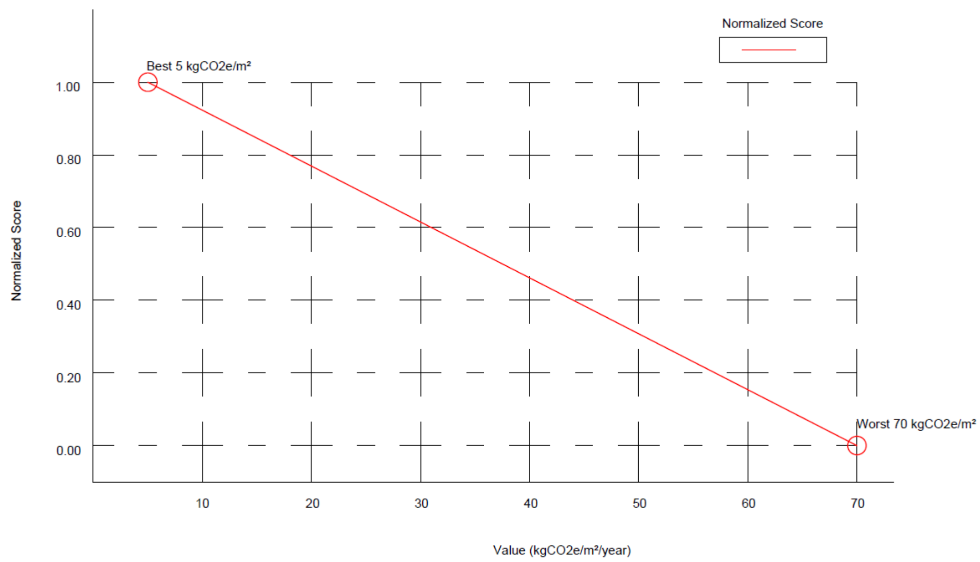

Table 27 *energy and carbon emissions normalization*

5.2.1.2 *Water efficiency and management normalization*

Water efficiency and management criteria evaluates a project's ability to reduce water consumption, reuse water, and manage flows efficiently. In this thesis, indicator selected to represent this effect is the percentage of water reused.

Based on established benchmarks and international guidelines, this rate typically ranges between 10% and 90% in green infrastructure projects (EPA, 2014; WELL Standard; ISO 46001; UNI/PdR 13:2019). Therefore, the min and max values are defined as 10% and 90%.This method allows all values to be scaled between 0 and 1, allowing a standardized scoring system between projects.

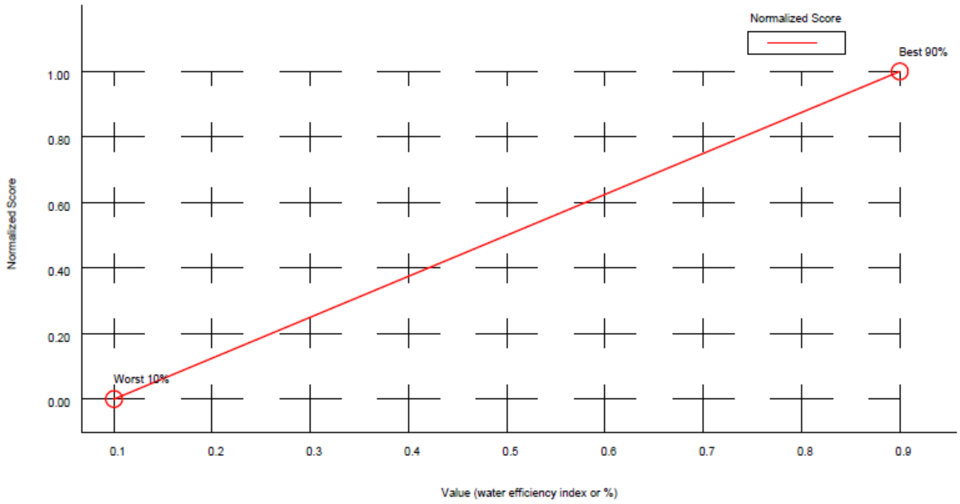

Table 28 *water efficiency and management normalization*

5.2.1.3 Climate adaptation and resilience normalization

Climate adaptation and resilience criteria aims to assess a project’s capacity to adapt to climate change and withstand extreme weather events. In this thesis, the selected indicator is the number of implemented climate adaptation strategies.

According to established certification systems and standards this number typically ranges between 0 and 8 (Institute for Sustainable Infrastructure, 2020, Infrastructure Sustainability Council, 2018, ISO 14090:2019). Therefore, minimum and maximum values are set as 0 and 8. This method allows all values to be scaled between 0 and 1, allowing a standardized scoring system between projects.

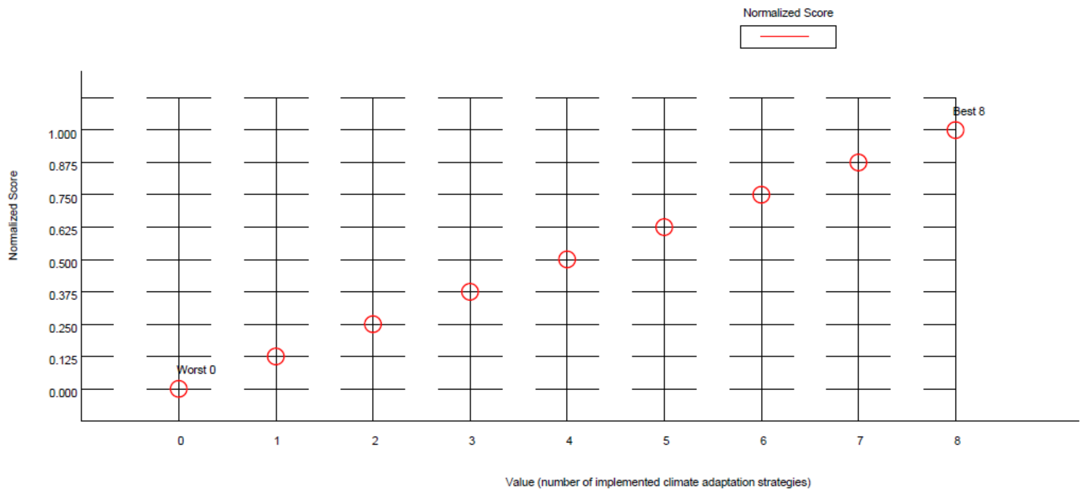

Table 29 *number of implemented climate adaptation strategies*

5.2.1.4 Social equity and access normalization

Social equity and access criteria aiming green infrastructure projects provide equal access to all people which especially focuses on disabilities. The selected indicator is the percentage of inclusive design coverage.

According to major certification systems and international standards which includes LEED, WELL, and ISO 21542, this value typically ranges between 30% and 100% (LEED v4.1; WELL, ISO 21542). Therefore, min and max values are defined as 30% and 100%.This method allows all values to be scaled between 0 and 1, allowing a standardized scoring system between projects.

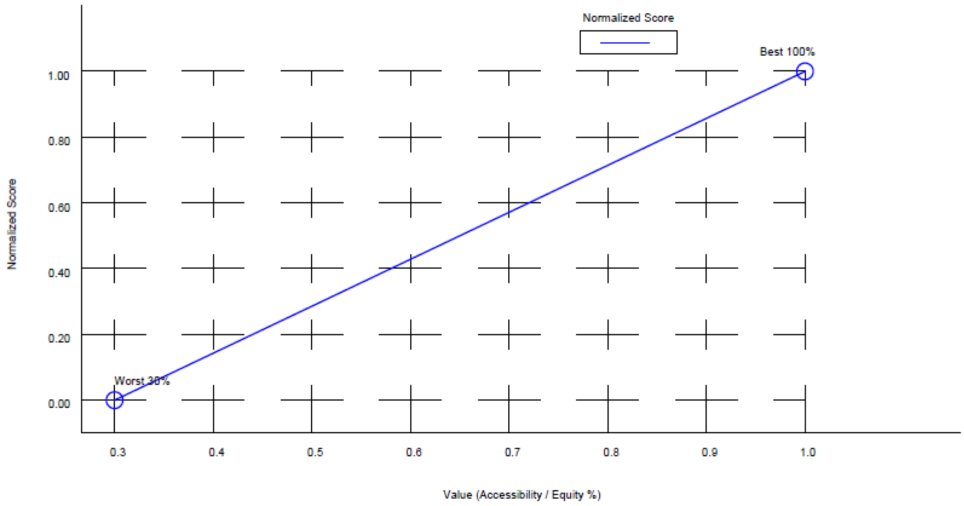

Table 30 *Social equity and accessibility*

5.2.1.5 Health and wellbeing normalization

Health and wellbeing criteria evaluates the impact of green infrastructures projects on the mental and physical health of people. The indicator used is the percentage of the population with access to health promoting green infrastructures.

According to benchmarks from the World Health Organization, Urban Audit, and BREEAM Communities, this value typically ranges between 40% and 100% (WHO, Urban Audit, BREEAM Communities). Therefore, the minimum and maximum values are set at 40% and 100%.This method allows all values to be scaled between 0 and 1, allowing a standardized scoring system between projects.

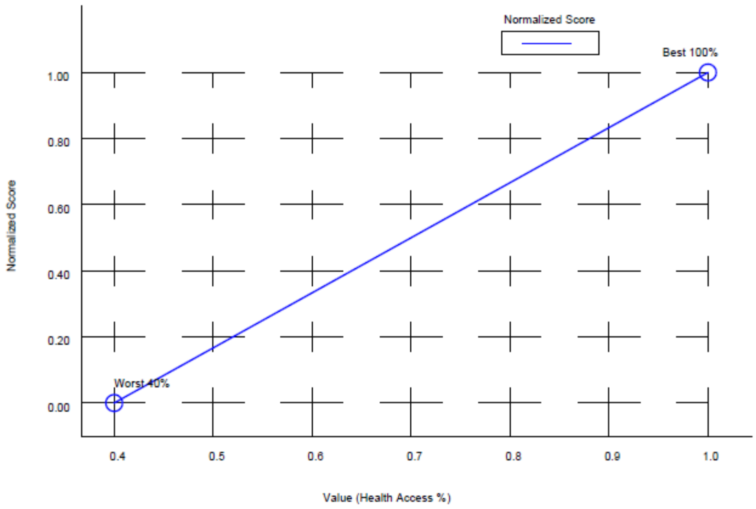

Table 31 *Health access*

5.2.1.6 Community cohesion and social infrastructure normalization

Community cohesion and social infrastructure criteria evaluates the capacity of the green infrastructure projects to enhance community bonds, improve social interaction and provide inclusive public social infrastructure. In this thesis the indicator is based on a mixed structure that combines aspects such as community engagement score, the percentage of the population served by the project’s infrastructure, and a qualitative yes/no checklist related to participatory processes or availability of public spaces. However in order to use quantitative assessment, the indicator used for normalization is the percentage of population served.

According to Urban Audit, DGNB Urban Districts, and Envision rating systems, this value typically ranges between 30% and 100% in green infrastructure projects (Eurostat, 2020; DGNB, 2021; Institute for Sustainable Infrastructure, 2018). Therefore, min and max values are set at %30 and %100.This method allows all values to be scaled between 0 and 1, allowing a standardized scoring system between projects.

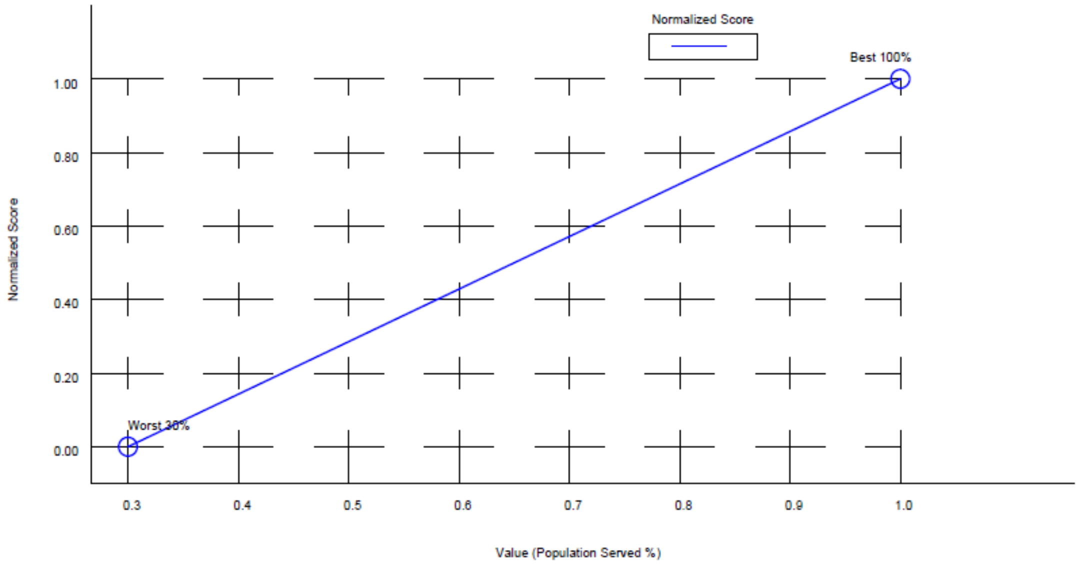

Table 32 *Community cohesion and social infrastructure normalization*

5.2.1.7 Life cycle cost efficiency normalization

Life Cycle Cost Efficiency criteria evaluate the cost-effectiveness of a green infrastructure project throughout its entire lifespan. The selected indicator is the total life cycle cost per square meter (€/m², Net Present Value, NPV), which includes construction, operation, maintenance, and end-of-life costs. This indicator is generally used in sustainability assessment frameworks such as DGNB (2018), EN 16627 (CEN/TC 350, 2015), and the IS Rating Scheme (ISCA, 2018).

According to these frameworks, typical values for this indicator range between €300/m² and €1500/m² in green infrastructure projects (ISCA, 2018; DGNB, 2018; CEN/TC 350, 2015). According to this, the minimum and maximum thresholds were set at 300 and 1500. Lower values represent better performance, a reverse min–max normalization method was applied.

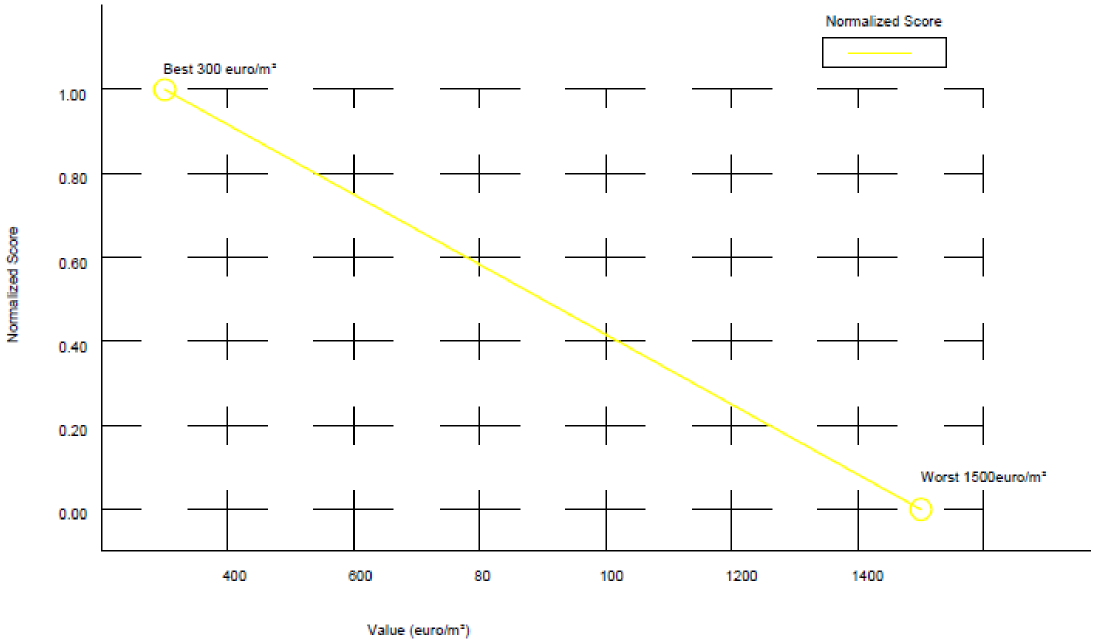

Table 33 *life cycle cost efficiency normalization*

5.2.1.8 Cost effectiveness and operational savings normalization

The Cost Effectiveness and Operational Savings criterion evaluates how green infrastructure projects balance initial investment costs with long-term operating and maintenance savings. The indicator used is the percentage of operational savings or return on investments. This indicator is generally used in sustainability frameworks (BRE, 2014; USGBC, 2019; ISI, 2020).

According to these frameworks, typical savings for green infrastructure projects range between 5% and 40% (BRE, 2014; USGBC, 2019; ISI, 2020). Accordingly, the minimum and maximum values were set at 5 and 40, and the min–max normalization formula was applied.

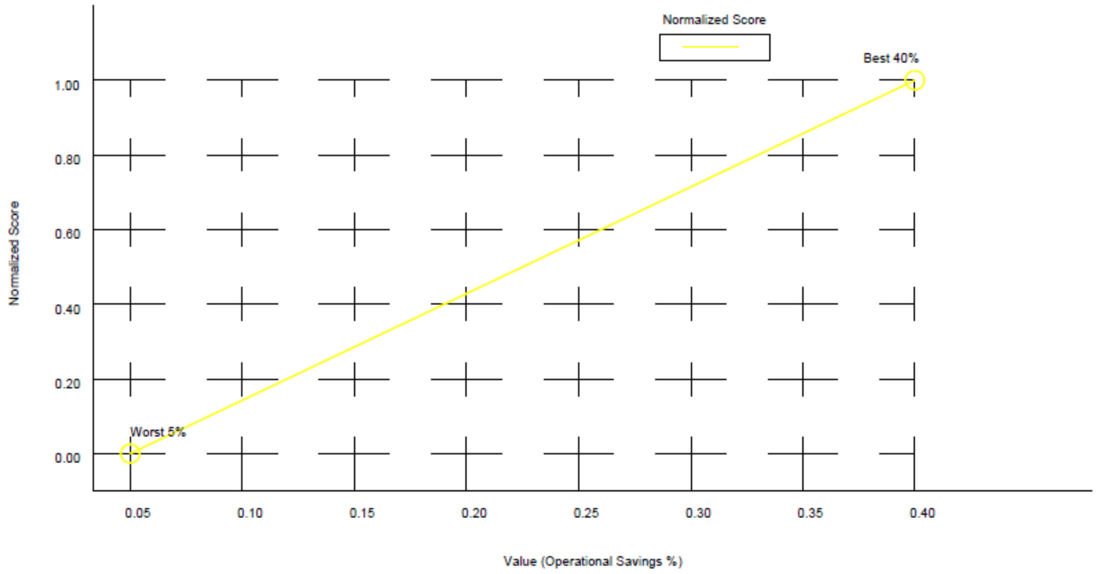

Table 34 *Cost effectiveness and operational values*

5.2.1.9 Economic performance normalization

Economic performance criteria evaluates the contribution of green infrastructure projects to local economy. It includes indicators such as percentage of employment generated and local GDP contribution. These indicators are known in sustainability assessment systems such as Envision (ISI, 2020), Urban Audit (European Commission, 2018), and UNI/PdR 13:2019.

According to these frameworks, local economic impacts typically range between 0.5% and 3.0% (European Commission, 2018; ISI, 2020; UNI, 2019). Therefore, the minimum and maximum values were defined as 0.5 and 3.0, and the min–max normalization formula was applied.

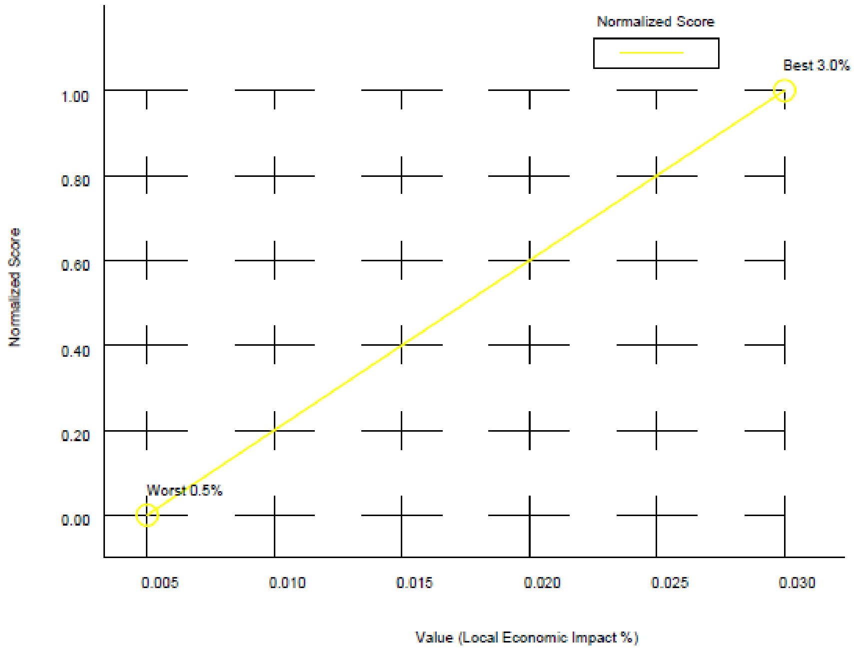

Table 35 *Economic performance normalization*

5.2.1.10 Stakeholder engagement and public involvement normalization

The Stakeholder engagement and public involvement criteria measures how the green infrastructure projects contain relevant stakeholders through participatory processes. Indicators include the number of consultation rounds, level of co-design, and the use of participation checklists. To exemplify, community members, civil organizations, and local governments. This criterion is embedded in established sustainability frameworks such as LEED (USGBC, 2019), Envision (ISI, 2020), and DGNB (2018), where public engagement is seen as a fundamental component of project legitimacy.

According to these frameworks, typical engagement levels range from 0 to 5 consultation or participation steps (USGBC, 2019; ISI, 2020; DGNB, 2018). Based on this, the normalization range was set between 0 and 5, using the min–max formula.

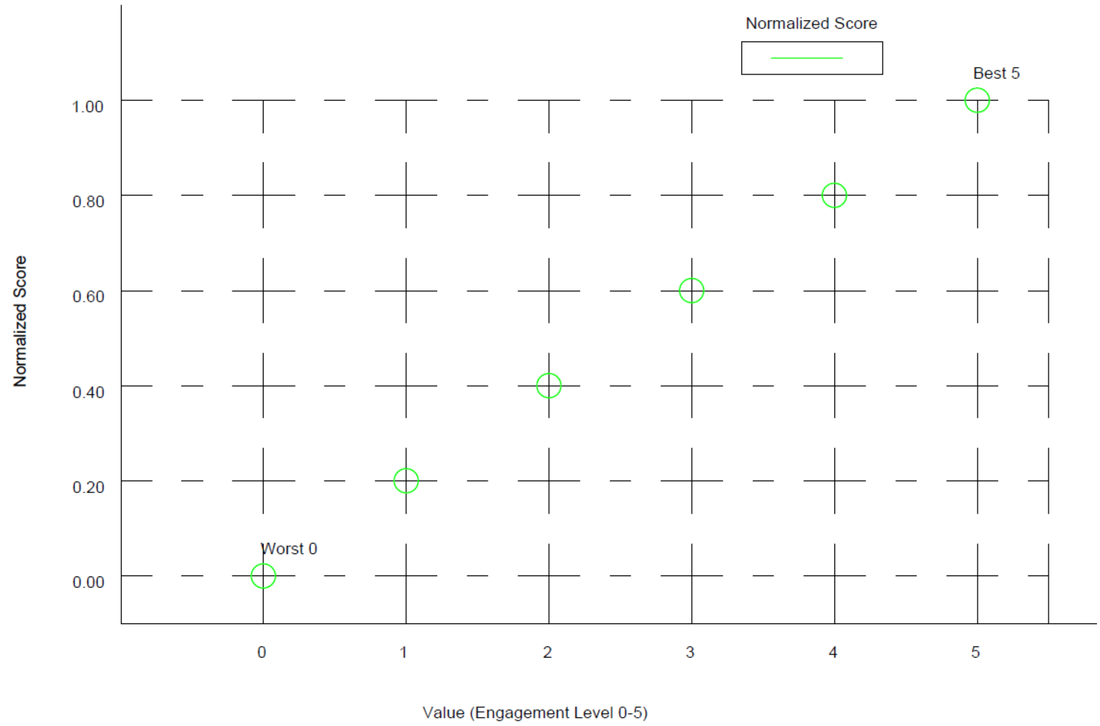

Table 36 *Stakeholder engagement and public involvement normalization*

5.2.1.11 Governance and management systems normalization

The Governance and Management Systems criteria measures a green infrastructure project has clear and structured systems for planning, decision-making, and implementation. It also checks how good these systems are organized. How they are following the official standards. This shows that that the project is managed in a transparent and reliable way.

This indicator is used in several sustainability frameworks such as DGNB (2018), Envision (ISI, 2020), and UNI/PdR 13:2019. According to these frameworks, projects usually score between 0 and 3, depending on how strong and complete their management systems are (DGNB, 2018; ISI, 2020; UNI, 2019). Based on this, the normalization range was set from 0 to 3, using this formula.

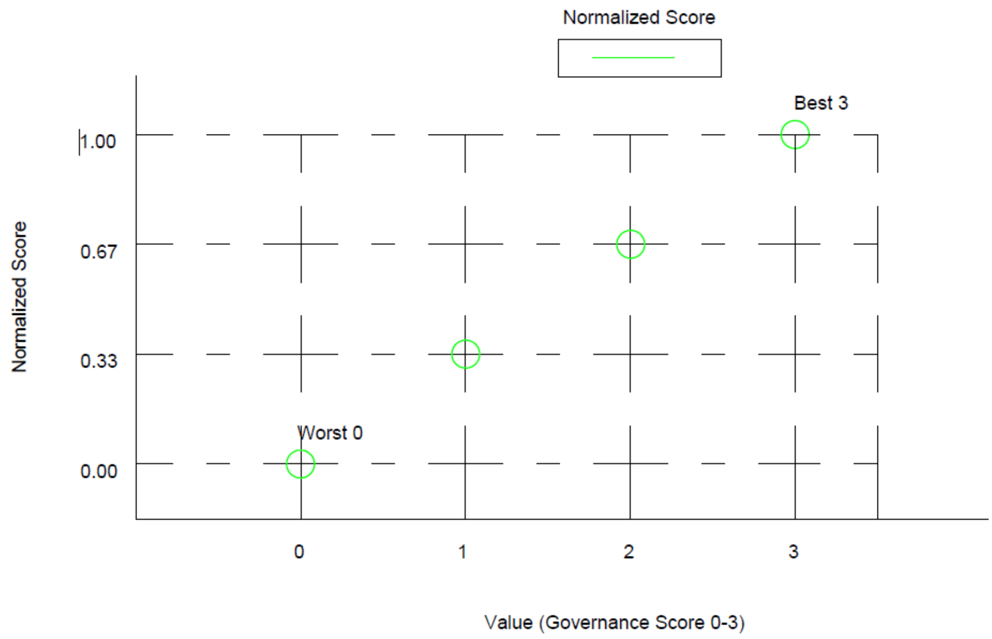

Table 37 *Governance and management systems normalization*

5.2.1.12 Transparency and reporting normalization

Transparency and reporting criteria evaluates how openly a green infrastructure project shares its objectives, performance metrics, and progress with the public. Indicators include the percentage of documentation made public and the frequency of reporting.

This criterion is found in sustainability frameworks such as LEED (USGBC, 2019), Envision (ISI, 2020), and DGNB (2018). According to these frameworks, 'transparency levels typically range from 0% to 100%'' (USGBC, 2019; ISI, 2020; DGNB, 2018). Therefore, the normalized score is calculated using a direct which is between 0 and 1 scale. In this approach, projects that publish more documentation and report more frequently receive higher scores.

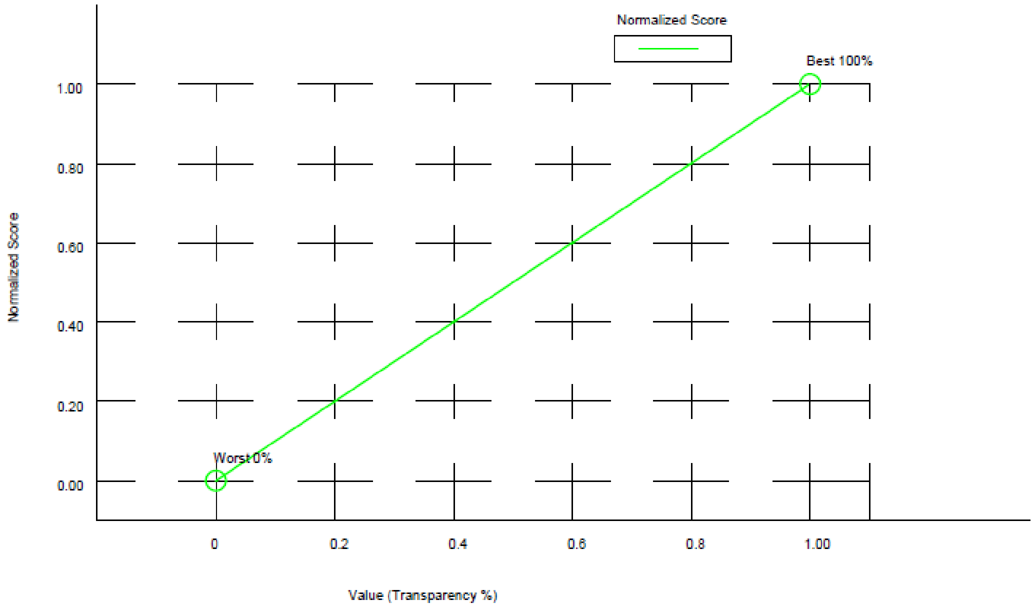

Table 38 *Transparency and reporting normalization*

5.2.2 Dimensional weighting using ROC (Rank Order Centroid)

To assign weights between the four main sustainability dimensions which are Environmental, Economic, Governance, and Social the Rank Order Centroid (ROC) method was applied. The ROC method was chosen instead of alternative MCDM methods such as AHP or TOPSIS because it belongs to SMARTER (Simple Multi-Attribute Rating Technique Exploiting Ranks) family. It offers a practical way to transform expert ratings into numerical weights. For instance, AHP needs a lot of pairwise comparisons and is more difficult to use for larger groups of criteria. ROC, on the other hand, allows experts to say whatever they want by ranking, and this ranking converted into weights while preserving relative importance. This approach ensures mathematical consistency, while expert validation process is more efficient. Based on expert prioritization, the following ranking and corresponding ROC weights were calculated:

Below you can see how the ROC weights are distributed:

Rank	Number of Criteria								
	2	3	4	5	6	7	8	9	10
1	0,7500	0,6111	0,5228	0,4567	0,4083	0,3704	0,3397	0,3143	0,2929
2	0,2500	0,2777	0,2708	0,2567	0,2417	0,2276	0,2147	0,2032	0,1929
3		0,1111	0,1458	0,1567	0,1583	0,1561	0,1522	0,1477	0,1429
4			0,0625	0,0900	0,1028	0,1106	0,1106	0,1106	0,1096
5				0,0400	0,0611	0,0728	0,0793	0,0828	0,0846
6					0,0278	0,0543	0,0543	0,0606	0,0646
7						0,0204	0,0334	0,0421	0,0479
8							0,0156	0,0262	0,0336
9								0,0123	0,0211
10									0,0100

Table 39 *ROC weights table*

Below you can see how ESG weights are distributed according to ROC weights. The reliability of the method has been increased by ranking the importance according to the comments of the experts.

Dimension	Rank (1=Best 4=Worst)	ROC Weight
Environmental	1	0,520
Social	3	0,145
Economic	2	0,256
Governance	4	0,040

Table 40 *ESG+ tables according to expert validation*

5.2.3 Criteria weighting using ROC

The ROC method is also used to determine the relative importance of indicators within each sustainability dimension. Rankings were again defined based on expert validation.

Ranking according to experts is from most important to least important. Accordingly, for the environmental dimension the most important criteria is energy efficiency, second important carbon footprint, and thirdly water management. For social dimension the most important criteria is community benefits, second most important is health and well-being and the third one is equity. For the economic dimension, the most important criteria is cost efficiency, second most important is life cycle cost, and thirdly economic resilience. For the last dimension governance, the most important criteria is transparency, second most important is stakeholder engagement and third most important is risk management. In the table that is placed below it can be seen as a graphical representation.

Dimension	Criteria	Rank	ROC Weight
Environmental	Energy and Carbon Emissions	1	0,611
	Water Efficiency and Water Management	3	0,111
	Climate Adaptation and Resilience	2	0,277
Social	Social Equity and Access	2	0,277
	Health and Wellbeing	1	0,611
	Community cohesion and social infrastructure	3	0,111
Economic	Life Cycle Costs Efficiency	2	0,277
	Cost effectiveness and Operational Savings	1	0,611
	Economic Performance	3	0,111
Governance	Stakeholder Engagement and Public Involvement	1	0,611
	Governance and Management systems	2	0,277
	Transparency and Reporting	3	0,111

Table 41 *Criteria table according to expert validation*

5.2.4 MAVT based aggregation of weighted score

The final score for each sustainability dimension is calculated using the Multi Attribute Value Theory (MAVT). Each indicator's normalized score is multiplied by its ROC weight and the resulting weighted scores are summed.

Dimension Score = ∑ (normalized Score x ROC Weight)

This process ensures that both the performance value and the relative importance of each criterion are proportionally reflected in the final dimension score. It provides a consistent and comparable structure across all dimensions and case studies.

5.3 Aggregation approach

The aggregation process represents the final stage in the evaluation model. All the normalized and weighted data are integrated into a aggregated sustainability score. The previous section detailed the procedures for assigning relative importance to criteria and transforming data into values. In this section aiming to how those values are logically combined to generate overall ratings. The purpose of this stage is not only to compute scores but also ensure that the structure of the model, transparent, replicable and scalable assessments between multiple case studies. The approach relies on a structured multi criteria logic that reflects expert informed preferences and systematically integrates various layers of analysis.

5.3.1 MCDA methods

The aggregation process in this model is based on the rules of Multi-Criteria Decision Analysis (MCDA), which provides a structured framework for combining multiple sustainability indicators. This study uses the Multi-Attribute Value Theory (MAVT) as the main aggregation, as it is particularly well-suited to cases where both expert-informed weights and normalized indicator scores are available. MAVT allows for a transparent and additive combination of individual scores, with each criterion contributing proportionally to the final result according to its assigned weight. This approach aligns directly with the ROC based weighting structure and min-max normalization process already applied in earlier stages. This format of MAVT also shows replicability, interpretability, and methodological clarity, especially in comparative sustainability assessments between different case studies.

5.3.2 Integration of environmental, social, economic and governance dimensions in rating model

The rating model is designed as a hierarchical system that integrates multiple layers of evaluation in a structured and consistent manner. It has been examined in three different layers. These are:

1) Individual indicator scores
2) ESG+ dimension level aggregation
3) Overall ESG+ performance scores

Firstly, each indicator is normalized and weighted using the procedures explained in earlier sections. These weighted scores are aggregated with MAVT principles. A dimension score is created for each ESG+ dimension by combining the criteria values according to their criteria ROC weights. Subsequently, dimension scores are aggregated using their respective criteria ROC weights to generate a final, composite score representing the overall ESG+ performance of a given project. The model keeps the analytical differentiation between various ESG+ aspects while still generating a comprehensive evaluation result thanks to this layered combination. Each layer can be separately analyzed, allowing specific benchmarking, sensitivity analysis or scenario testing. This shows that the model is flexible for different cases and it gives reliable results.

By keeping a clear analytical flow from raw data to final score, the model provides transparency, traceability, and scalability. These are key requirements for practical application in real world projects and policy settings.

5.3.3 Final rating system structure

The final ESG+ performance score, built through the aggregation of weighted and normalized indicators across all dimensions, provides a single composite value ranging from 0 to 1. To improve the interpretability and practical applicability of this score, a categorical rating system is designed. This system classifies the final score into defined performance rankings and it allows for communication of project outcomes.

The rating scale is defined as follows:

0.0 – 0.2	Low ESG+ Performance
0.2 – 0.4	Medium – Low ESG+ Performance
0.4 – 0.6	Medium ESG+ Performance
0.6 – 0.8	Medium – High ESG+ Performance
0.8 – 1.0	High ESG+ Performance

Table 42 *Rating scale table*

This classification not only assists in comparison analysis across case studies, but also enables stakeholders to identify strengths and weaknesses within sustainability strategies. Moreover, the clear thresholds allow decision makers to set performance targets and track progress over time.

6Case studies

This chapter explains the analysis of various architectural and urban scale projects for the Green Infrastructure Sustainability Performance Assessment Model (GISPAM) and test to feasibility and validity of the GISPAM. The goal is to evaluate how the proposed model performs in diverse real world contexts and to demonstrate the measurability of sustainability performance through practical examples.

The selected projects contain Environmental Social Economical and Governance (ESG+) principles. The selection shows a diversity of geographic locations, scales, and typologies, providing a comprehensive assessment of the model's adaptability and scope.

The case studies are measured based on the selection criteria and methodology explained in Section 6.1. In Section 6.2, each project is briefly introduced and then assessed according to the GISPAM framework.

6.1 Selection criteria and methodology

The selection of case studies was guided by the objective of evaluating the feasibility and flexibility of the GISPAM model between different types of green infrastructure projects. To ensure meaningful and relevant analysis, a set of selection criteria was established below:
ESG+ dimension coverage: Projects were selected based on their relations with environmental, social, economic, and governance aspects of sustainability.

Data availability: Only projects with accessible and verifiable qualitative and / or quantitative information were included.

Diversity of scale and typology: The selection includes a variety of projects such as public spaces, infrastructures. Although the focus projects were on an urban scale, projects from both scales were taken because they were also applicable at the smaller scales.

Geospatial diversity: GISPAM projects selected from various countries demonstrated the adaptability of the method to different contexts.

Sustainability innovation leadership award: This recognition was reserved for sustainable projects awarded due-integrated frameworks and recognized innovative multi-tier solutions across diverse disciplines.

Each project is measured using the criteria and structure defined in the GISPAM. The evaluation process includes both qualitative interpretation and quantitative scoring, aiming to provide a comprehensive understanding of each project's sustainability performance.

6.2 Case study analysis

This chapter explains the individual analysis of the selected case studies using The Green Infrastructure Sustainability Performance Assessment Model (GISPAM). Each project is introduced with a background. Then, an assessment structured according to the four main dimensions which are environmental, social, economic, and governance of the model.

The goal of this analysis is to observe how different types of green infrastructure projects perform under the same set of criteria, and to identify strengths, weaknesses, and patterns between diverse urban and architectural contexts. The evaluation contains not only qualitative comments but also where possible, quantitative scoring built from available data and documentation.

In this context, the GISPAM model has been applied by evaluating each project across a defined set of sub criteria under the ESG+ dimensions. The performance of the projects was assessed using a combination of qualitative interpretation and quantitative scoring, based on the availability and clarity of data. Where applicable, scores were normalized using the min-max method, and weighted through the Rank Order Centroid (ROC) approach at both the dimensional and criteria levels. Finally, an overall sustainability score was derived using Multi-Attribute Value Theory (MAVT), allowing a comparative understanding of each case.

Each case is presented under a dedicated subsection, allowing for a clear and consistent structure. This facilitates comparison and supports the broader discussion in the following chapter.

6.2.1 The Highline (the USA)

The High Line is an elevated linear park and urban revitalization project located in New York City, United States. Developed on a former rail line which was built in 1930's. The project repurposes the former infrastructure into a multifunctional public space. Reaching approximately 2.3 kilometers along Manhattan’s West Side, the park passes through residential, commercial, and cultural zones.

Started in the early 2000s, the project was under the leadership of a collaboration between the City of New York and the non-profit organization Friends of the High Line. Designed by James Corner Field Operations in partnership with Diller Scofidio + Renfro and planting design Piet Oudolf.

The High Line combines different aspects in their design. These are ecological restoration, art, leisure, and pedestrian connectivity within a intense urban context. It has become an internationally recognized example of adaptive reuse, landscape urbanism, and public-private cooperation in city-making. Until today, it has attracted millions of visitors annually and significantly influenced surrounding urban development patterns.

Figure 3 *The Highline*[i]

6.2.1.1 Energy and carbon emissions criteria

The value for energy- related carbon emissions in The High Line projects was founded as 15 $kgCO_2e/m^2$ per year. This data provided by the Landscape Architecture Foundation's Case Study Investigation (CSI), which also included modeled emissions calculations for the park's first phase (Plunz & Moskalenko, 2017).

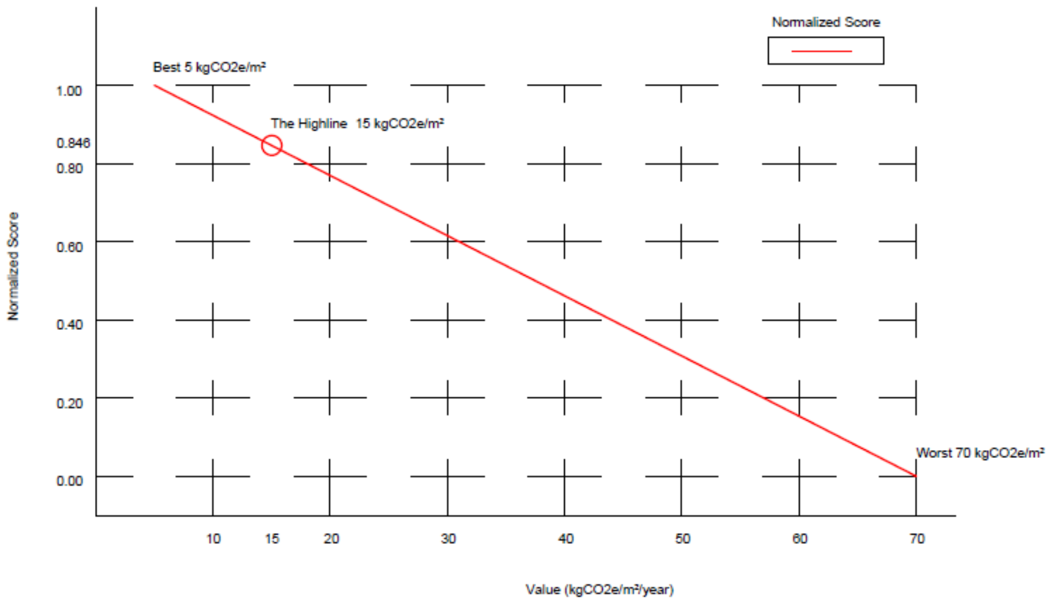

***Table 43** Energy and Carbon emission normalization for The Highline*

The data obtained from expert validation was multiplied by the normalization result with the appropriate weight in the ROC table. This value provided the energy and carbon emission score. As explained in the previous chapter, the normalization value was found as 0.846.

According to expert validation, this criteria was selected as the most important, so it was multiplied by the ROC value of 0.611 and the result was 0.516.

6.2.1.2 Water efficiency and management criteria

The value of water efficiency and management is found to be 72%. This value reflects the estimated percentage of storm water retained or managed through the site's green infrastructure implementation such as permeable surfaces, native vegetation. The values was provided from the Landscape Architecture Foundation's Case Study Investigation (CSI), which documented the hydrological performance of the park's first section (Plunz & Moskalenko, 2017).

As explained in the previous chapter, the normalization value was found as 0,775 and according to expert validation this criteria was selected third most important. So it was multiplied by the ROC value of 0,111 and result was 0.086

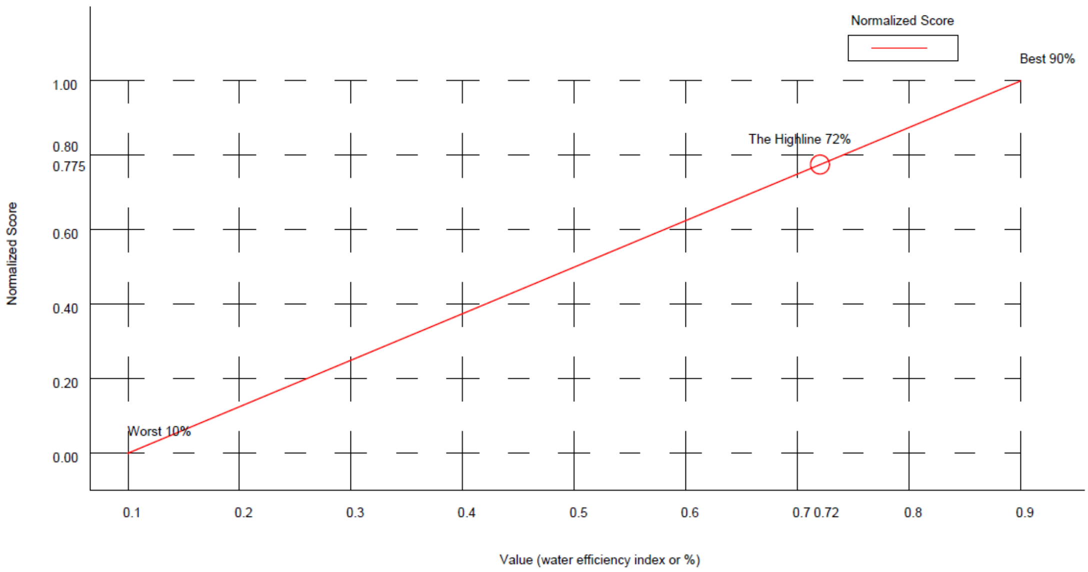

Table 44 *Water efficiency and management normalization for The Highline*

6.2.1.3 Climate adaptation and resilience criteria

The value of climate adaptation and resilience is found as 4 different implementations. These are, permable paving, rain gardens, drought and flood tolerant plantation and heat island mitigation. These strategies were provided in the Landscape Architecture Foundation's Case Study Investigation (CSI), which explained the project's environmental performance features (Plunz & Moskalenko, 2017).

The normalization value was found as 0,500 and according to expert validation this criteria was selected second most important. So it was multiplied by the ROC value of 0,277 and result was 0.138.

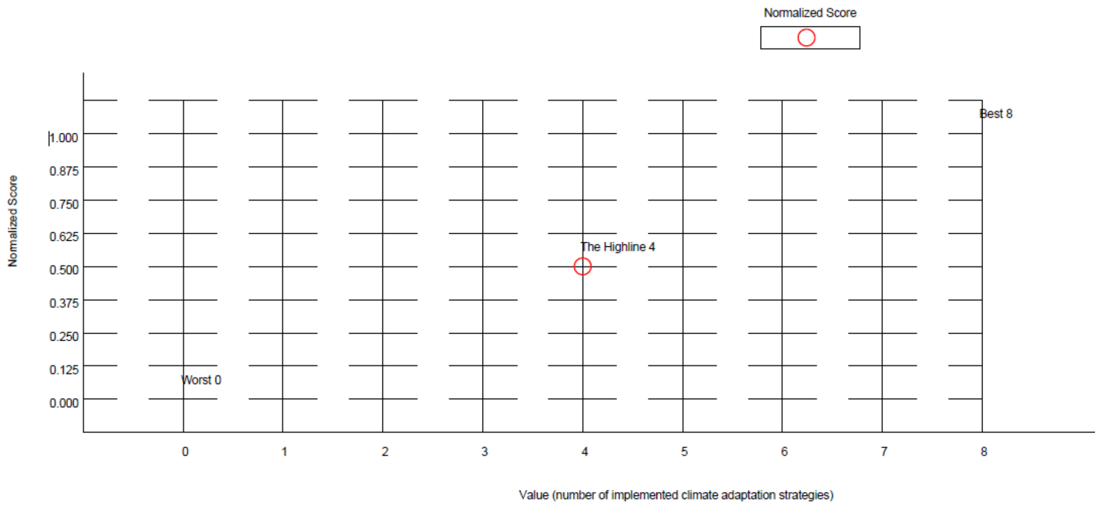

Table 45 *Climate adaptation and resilience normalization table for The Highline*

6.2.1.4 Social equity and access criteria

The value of social equity and access criteria in The Highline project was found as 90% population accessibility. This value was provided from spatial accessibility analyses conducted by the NYC Department of City Planning and supported by findings from the High Line Economic Impact Study, which emphasized the park's integration within the surrounding urban fabric (HR&A Advisors, 2011).

The normalization value calculated as 0.878. According to expert validation this criteria was selected as second most important which equals 0.277 ROC weight. Then to find the criteria score, normalization value and ROC weight multiplied. The results calculated as 0.243.

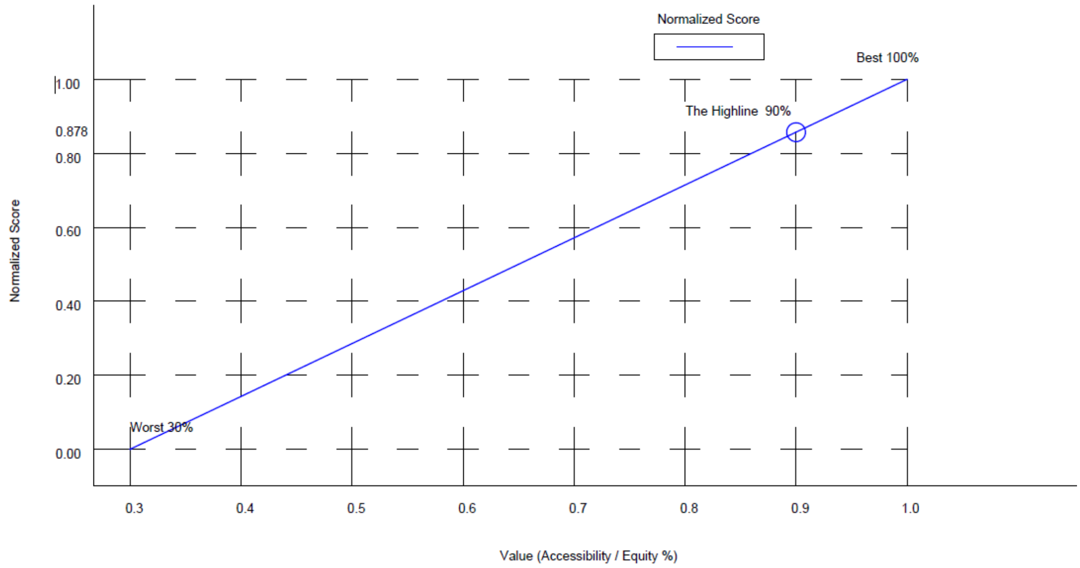

Table 46 *Social equity and access for Highline*

6.2.1.5 Health and Well-being Criteria

The value of health and wellbeing in The Highline was recorded as 80% perceived health benefit, provided by community surveys and post occupancy evaluations completed by Friends of the High Line. These surveys indicated that a significant majority of visitors reported improved mental and physical well-being because of spending time in the park (Friends of the High Line, 2019).

The normalization value calculated as 0.667. According to expert validation for this criteria was selected as the most important which means 0.611 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.407.

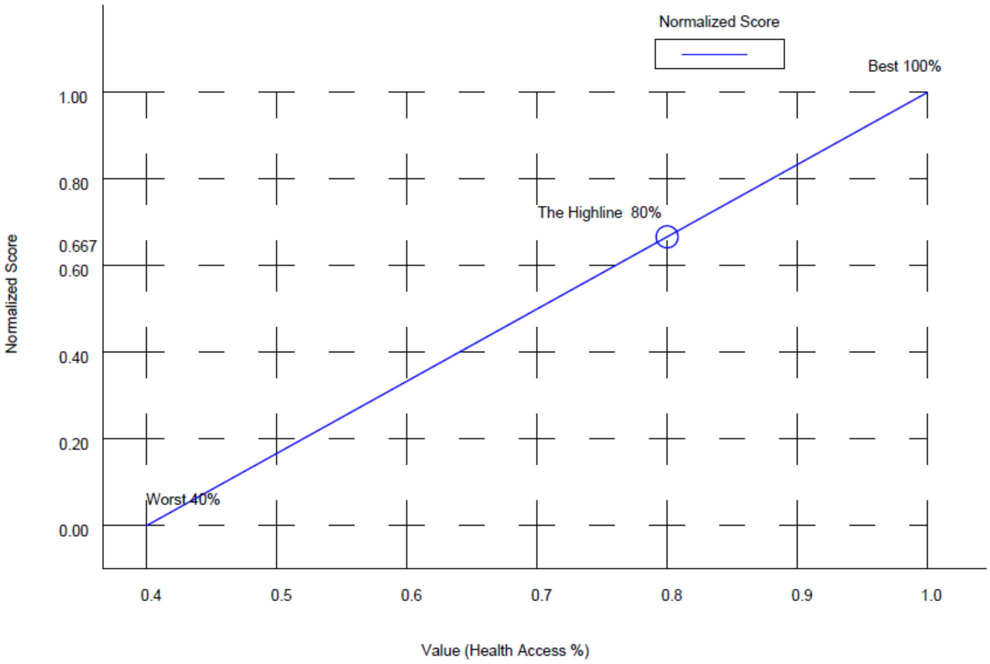

Table 47 *Health and wellbeing for Highline*

6.2.1.6 Community cohesion and Social Infrastructure criteria

The value of community cohesion for the Highline project was measured as 85%. This data was obtained from annual engagement reports published by Friends of the High Line (Friends of the High Line, 2019).

The normalization value measured as 0.786. According to expert validation for this criteria was selected the third most important. The ROC weight is 0.111. To find the criteria score normalization value and ROC weight multiplied. The results announced as 0.087.

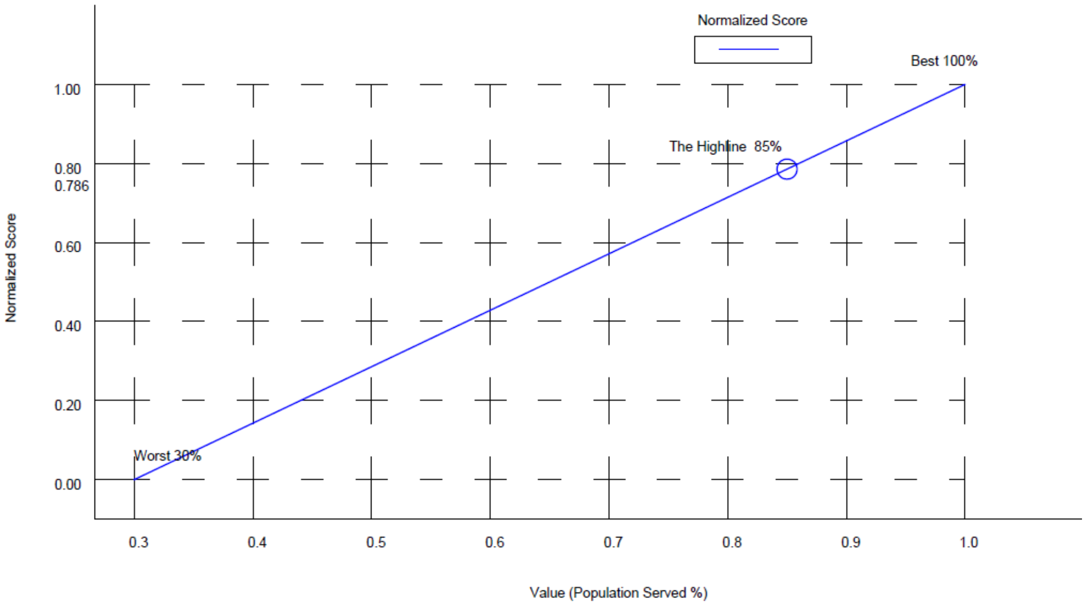

***Table 48** Community cohesion and social infrastructure for Highline*

6.2.1.7 Life cycle cost efficiency criteria

The value for this life cycle cost efficiency was estimated at 600 €/m². This amount has construction. Maintenance and operational costs for the project's life span. This value was calculated by dividing the reported "total cost of the project which is around $153 million by its area which is around 23,000 m², and adjusting for maintenance and currency equivalence using DGNB and Envision-based methodologies" (Plunz & Moskalenko, 2017).

The normalization value measured as 0.750 and based on reversed normalization. According to expert validation scores, this criteria defined as second most important criteria which equals of 0.277 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.207.

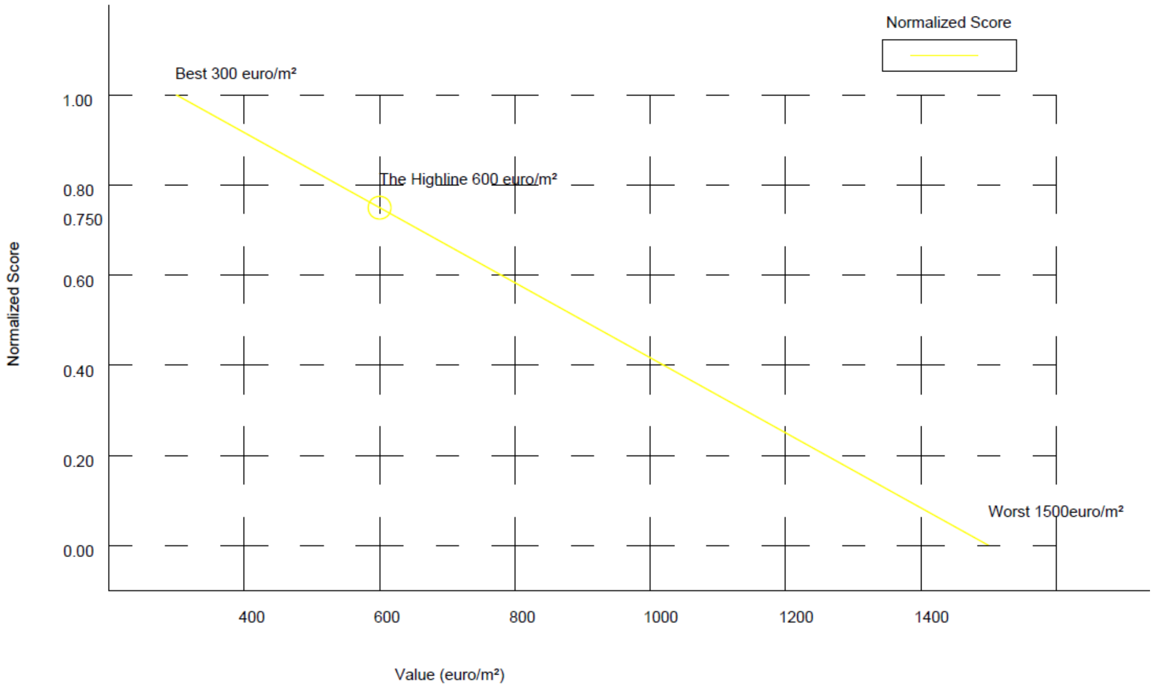

Table 49 *life cycle cost efficiency for The Highline*

6.2.1.8 Cost effectiveness and operational savings criteria

The value for operational savings for the highline project identified as 25%. According to project documentation, these strategies significantly reduce water use and contribute to overall operational savings compared to conventional urban parks (Friends of the High Line, 2023).

The normalization value calculated as 0.571. According to expert validation this criteria selected as the most important criteria which equals 0.611 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.348.

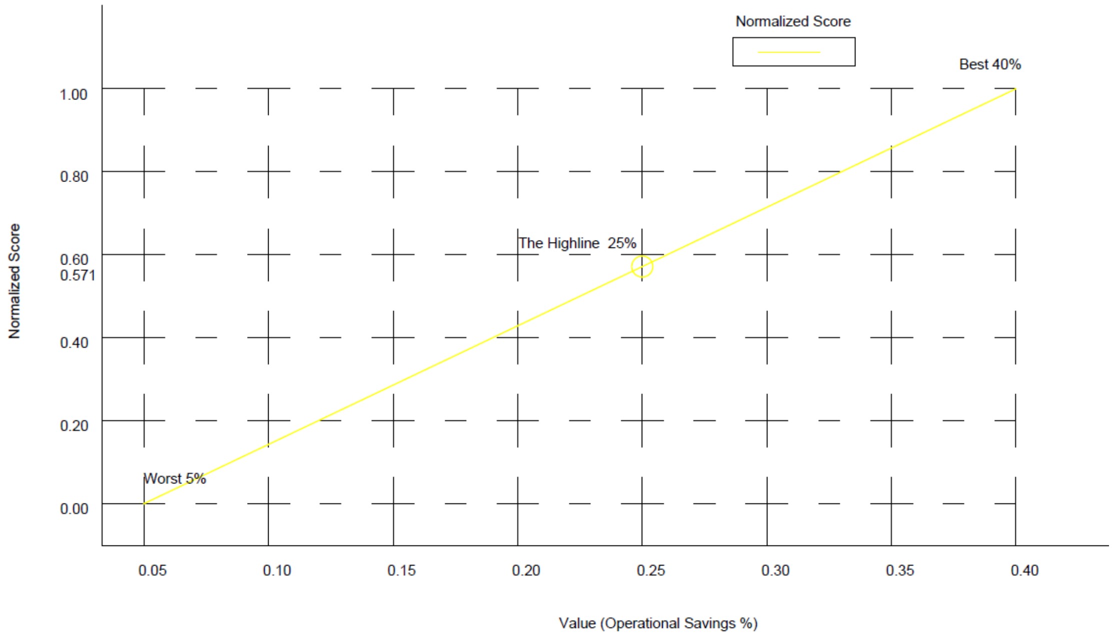

Table 50 *Cost effectiveness and operational savings for The Highline*

6.2.1.9 Economic Performance criteria

The value for economic performance was recorded as 2% for The Highline. This estimate is based on findings from the High Line Economic Impact Study, which assessed the project's role in attracting private investment and supporting economic growth within the West Side of Manhattan (HR&A Advisors, 2011).

The normalization value is measured as 0.600. According to expert validation this criteria selected as the third most important criteria which equals 0.111 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.066

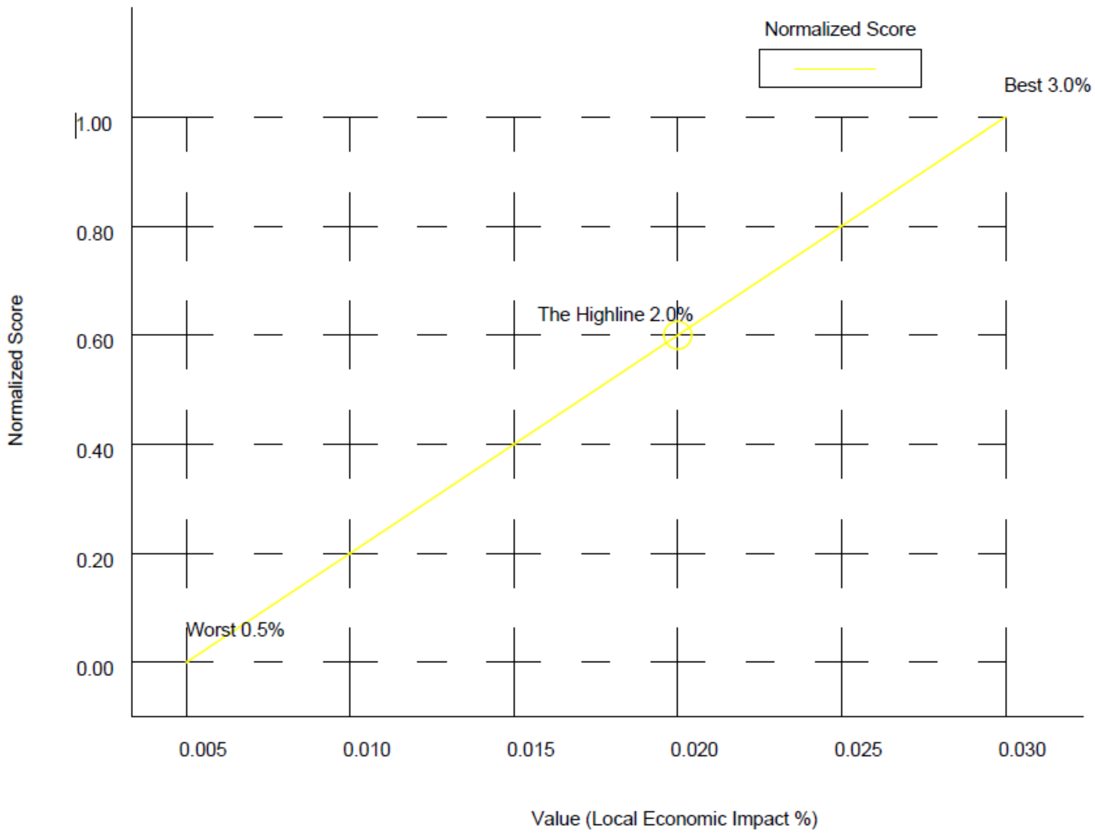

Table 51 *Economic performance for The Highline*

6.2.1.10 Stakeholder Engagement and Public Involvement

The value of stakeholder engagement defined as 4 out 5 participatory steps completed. During the project development, Friends of Highline and City of NY organized a workshops, forums. Ensuring that local residents and stakeholders were actively involved. “The biggest takeaway … was that it’s crucial to do whatever you can to gather the resources to engage the community most fully” (“High Line Magazine: Creating a More Equitable High Line,” 2017).

The normalization value is 0.800. According to expert validation this criteria selected as the most important criteria which equals 0.611 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.488.

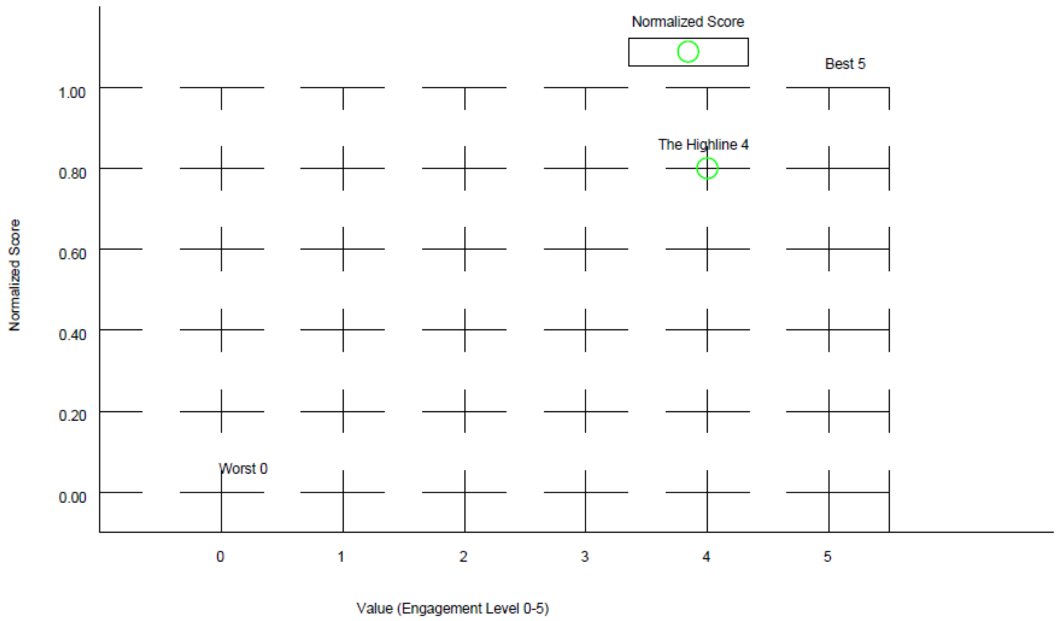

Table 52 *Stakeholder engagement and public involvement for the Highline*

6.2.1.11 Governance and management systems criteria

The value of this criteria is defined as 2 out of 3 governance components completed. This condition mentioned in The Highline official website as "Owned by the City of New York, is a public park programmed, maintained, and operated by Friends of the High Line, in partnership with the New York City Department of Parks & Recreation" (Friends of the High Line, n.d.; NYC Parks, n.d.)

The normalization value is 0.667. According to expert validation this criteria selected as the second most important criteria which equals 0.277 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.184.

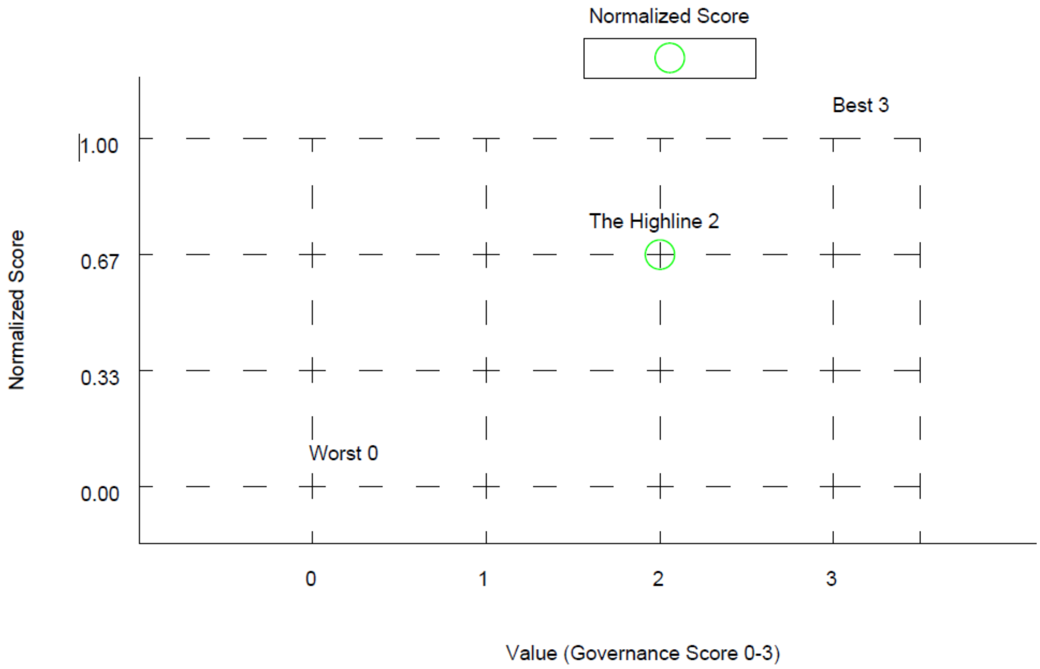

Table 53 *Governance and management systems for The Highline*

6.2.1.12 Transparency and reporting criteria

The value of this criteria assessed as 60%. It is reflecting regular publication of financial statements and limited environmental performance reports. FHL annually discloses detailed financial documents, including independent auditor reports and statements of activities and expenses (Friends of the High Line, 2023).

The normalization value is 0.600. According to expert validation this criteria selected as the third most important criteria which equals 0.111 ROC weight. To find the criteria score normalization value and ROC weight multiplied. The results were announced as 0.066.

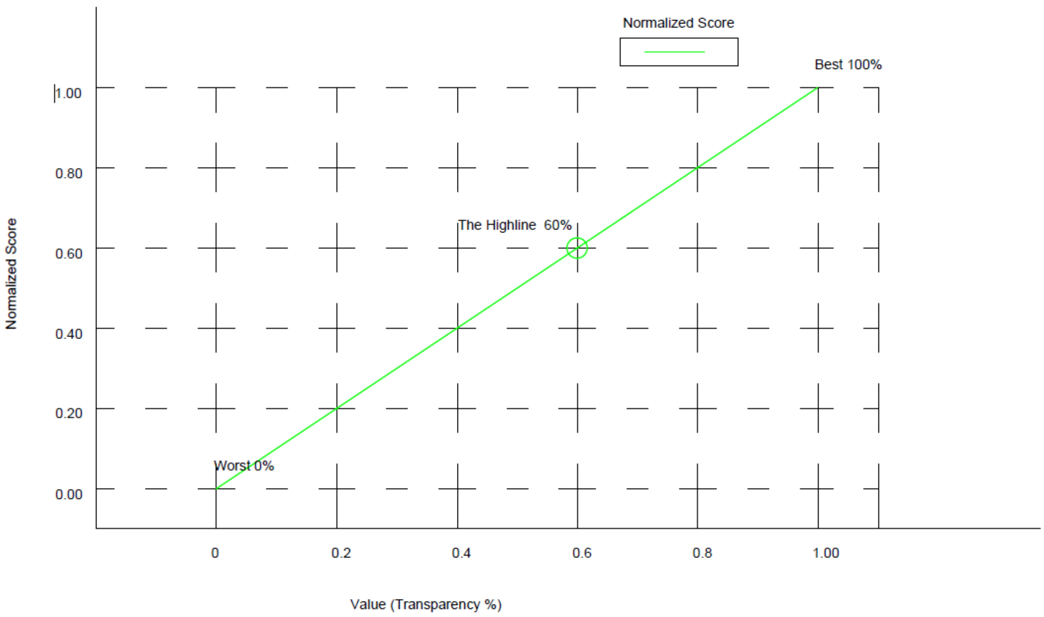

Table 54 *Transparency and reporting for The Highline*

6.2.1.13 GISPAM scores of The Highline

To calculate the GISPAM final scores, the normalized criteria scores on each dimension are first aggregated. These aggregated scores are then weighted according to the dimension weights acquired from the expert validation using ROC method. This process provides combined score for all four dimensions which are environmental, social, economic and governance. Finally, the weighted scores of the four dimensions aggregate to define the overall GISPAM score for the project.

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Project	En1	En2	En3	EN ∑
The High Line (NYC, USA)	0,516	0,086	0,138	0,740
	So1	**So2**	**So3**	**so∑**
	0,243	0,407	0,087	0,737
	Ec1	**Ec2**	**Ec3**	**Ec∑**
	0,207	0,348	0,066	0,621
	Go1	**Go2**	**Go3**	**Go∑**
	0,488	0,184	0,066	0,738

Table 55 *Dimension Scores of The Highline*

Project Name	Dimension Score	ROC Weight	ROC Weighted Dimension Score
The High Line (NYC, USA)	**Environmental ∑** 0.740	0.520	0.385
	Social ∑ 0.737	0.145	0.106
	Economic ∑ 0.621	0.256	0.159
	Governance ∑ 0.738	0.040	0.030

Table 56 *ROC weighted dimension scores*

As a finals step all the ROC weighted dimension scores are aggregated. The GISPAM ranking is completed according to the results.

Final GISPAM Score	Rating
0,680	Medium High

Table 57 *Final GISPAM rating of The Highline*

6.2.2 Cheonggyecheon Stream Restoration (South Korea)

Located in the center of Seoul, South Korea, the Cheonggyecheon stream restoration is a massive urban redevelopment project and linear urban ecological corridor. The projects main goal was to expose and restore the historic Cheonggyecheon stream by deconstructing a highway. ''This approach transformed the area from heavily populated and polluted region to dynamic, multipurpose green infrastructure. This 5.7 km road in the center of Seoul aims to connect residential, commercial, cultural streets and reconnecting urban landscape'' (Seoul Metropolitan Government, 2024; European Commission, 2013).

The project started in early 2000's and was led by Seoul Metropolitan Government in collaboration with different public and private stakeholders which included urban designers, ecologists, and community groups. The interdisciplinary team's main goals were to create high-quality public spaces for residents and tourists while combining ecological restoration with flood management, urban cooling, and water purification. The design established a standard for extensive, nature-based urban change by giving equal weight to natural processes and public accessibility.

Cheonggyecheon gathers different aspects in its design. For example, river restoration, biodiversity enhancement, recreation, within a densely built urban environment. Now, it became an internationally recognized example of ecological urbanism, adaptive infrastructure reuse, and collaborative governance in city planning. ‘‘Until today, millions of visitors visited the Cheonggyecheon’’(Landscape Architecture Foundation, 2012).

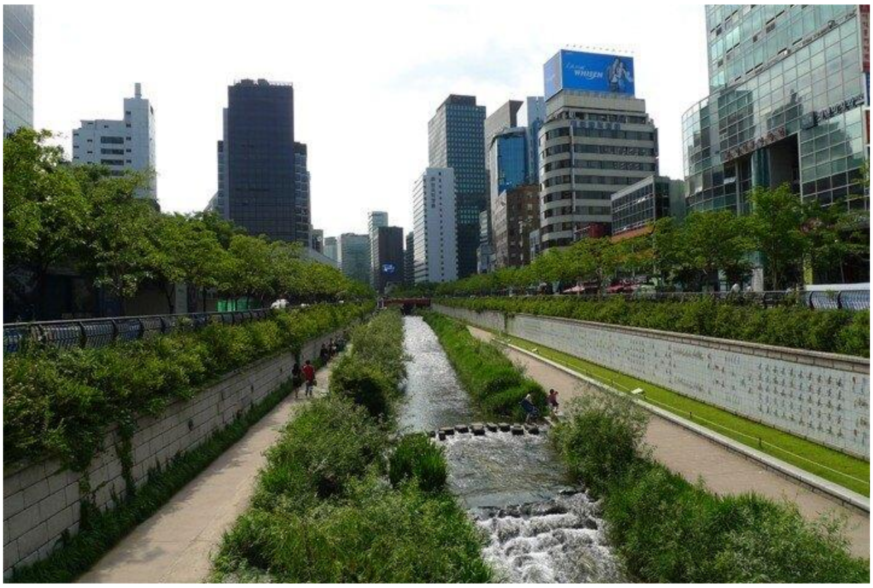

Figure 4 *Cheonggyecheon*

6.2.2.1 Energy and Carbon Emissions criteria

The value for energy related carbon emissions for Cheonggyecheon Stream Restoration was estimated as 12 $kgCO_2e/m^2$ per year. Based on post-project environmental monitoring reports and academic studies evaluating the park's impact on urban energy consumption and emissions reduction. (Lim, S., Kim, H., & Park, M., 2014).

The data obtained from expert validation was multiplied by the normalization result with the appropriate weight in the ROC table. This value provided the energy and carbon emission score. The normalization value was found as 0.892. and according to experts, this criteria is the most important criteria in the environmental dimension which equals 0.611 ROC weight. And when we multiply normalization value and ROC weight we reach the criteria score which is 0,545.

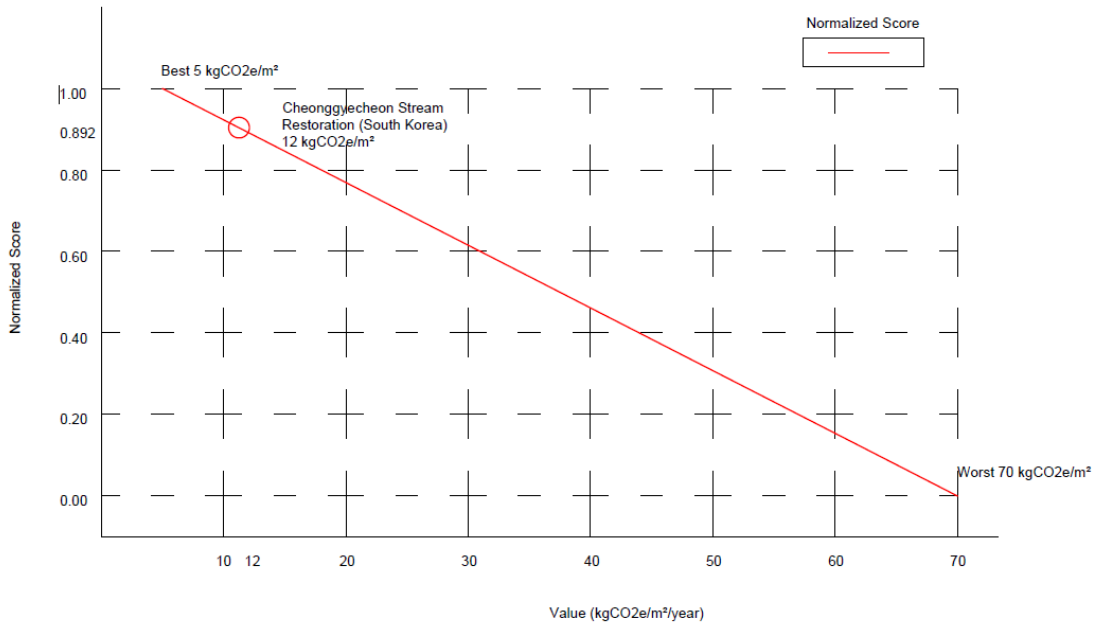

Table 58 *Energy and carbon emissions normalization for Cheonggyecheon*

6.2.2.2 Water efficiency and management criteria

The value for water efficiency and management was recorded %80 stormwater management effectiveness. (Seoul Metropolitan Government, 2010). According to the Seoul Metropolitan Government's environmental assessment reports, Combination of infrastructure for flood control, groundwater resupply and stormwater collection in 5.8 km project long.

As explained in the previous chapter, the normalization value was found as 0,875 and according to expert validation this criteria was selected third most important. So it was multiplied by the ROC value of 0,111 and result was 0.097.

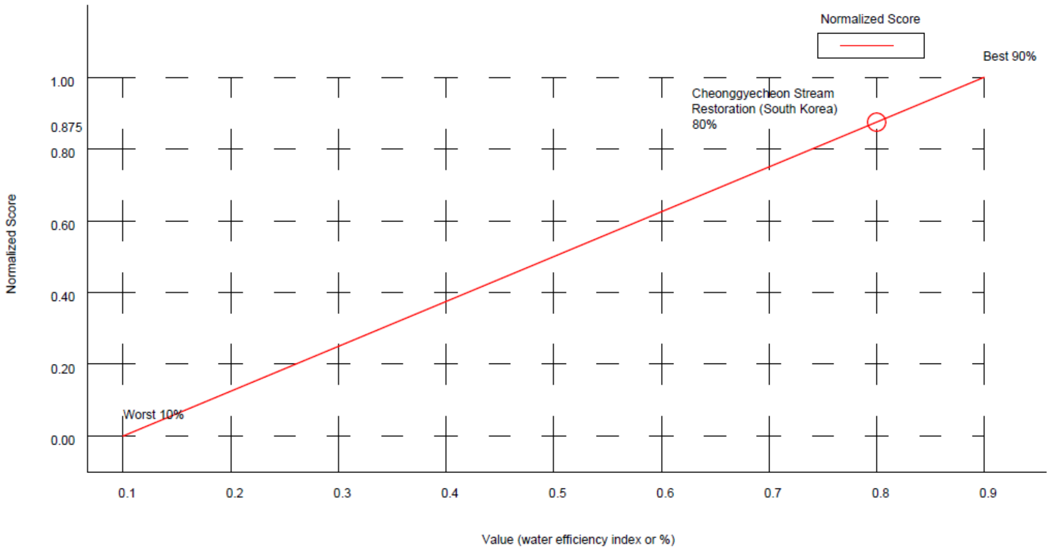

Table 59 *Water efficiency and management normalization for Cheonggyecheon*

6.2.2.3 Climate adaptation and resilience criteria

The value for climate adaptation and resilience criteria defined as the implementation of 7 distinct adaptation strategies. ''These strategies include floodplain restoration, permeable pavement installations, green corridors for heat island mitigation, drought-tolerant vegetation, water retention basins, real-time water level monitoring, and integration with Seoul's broader climate resilience master plan'' (Kim & Jung, 2015).

The normalization value calculated as 0,875. And according to expert validation this criteria is second most important of environmental dimension which equals the 0,277 ROC weight. Based with these value criteria score calculated as 0,242.

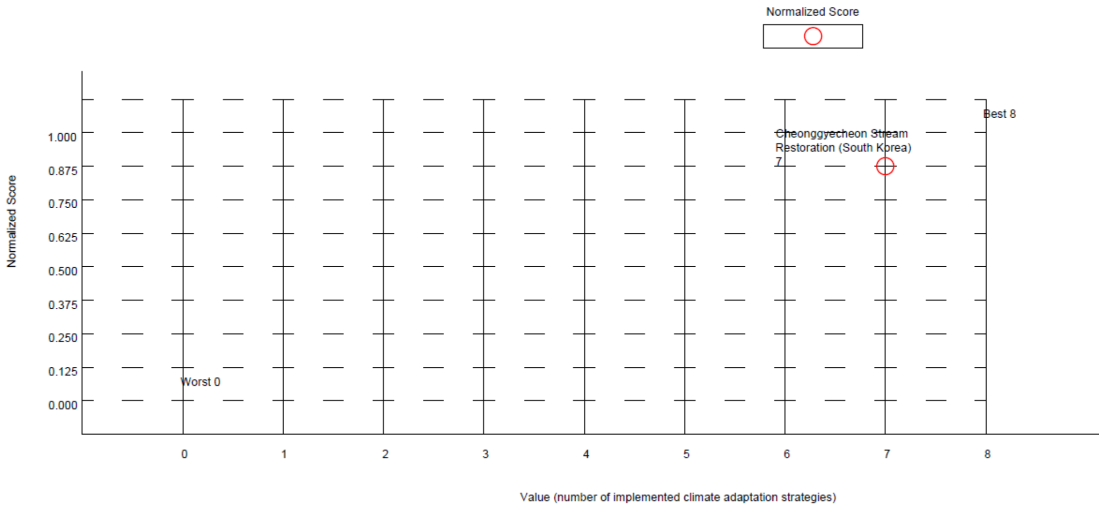

Table 60 *Climate adaptation and resilience normalization for Cheonggyecheon*

6.2.2.4 Social equity and access criteria

The value for social equity and access criteria was estimated as 95% population accessibility. ''The project reconnected previously fragmented urban districts, provided universal access to green space, and significantly enhanced mobility for residents, including those with disabilities, through barrier-free design interventions.'' (Lee, J., & Anderson, P. 2013).

The normalization value calculated as 0.929. According to expert validation this criteria was selected the second most important with 0.277 ROC weight. Based with these values criteria score calculated as 0.257

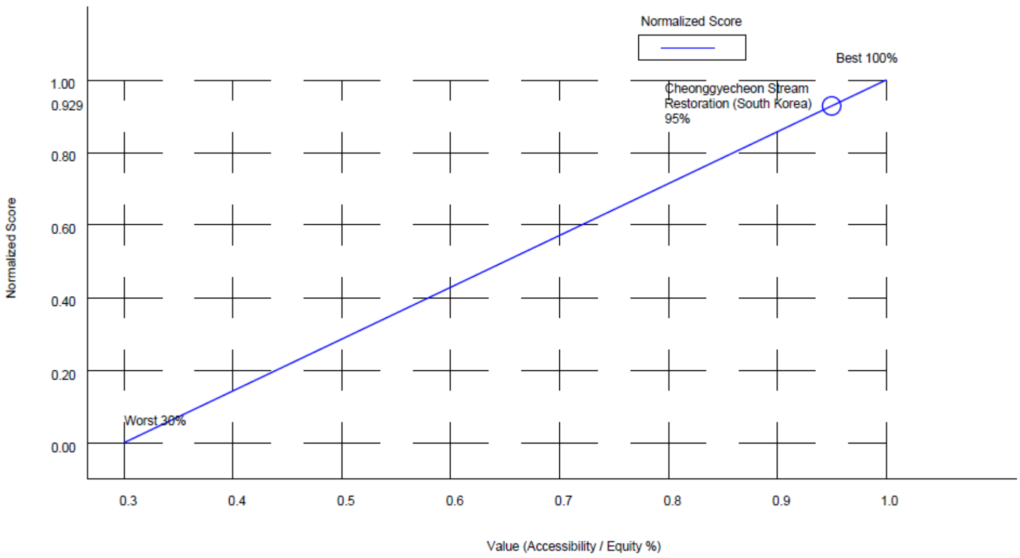

Table 61 *Social equity and access normalization for Cheonggyecheon*

6.2.2.5 Health and wellbeing criteria

The value for health and wellbeing was measured as 85% perceived health benefit. ''The stream restoration led to increased physical activity levels, improved mental well-being, and a significant reduction in self-reported stress among local residents. Approximately 85% of surveyed participants indicated that access to the restored stream and surrounding green spaces positively contributed to their overall health and well-being.'' (Park, Y., Kim, H., & Lee, S.2014).

The normalization value calculated as 0.750. According to expert validation this criteria was selected as the most important criteria of Social dimension which equals to 0.611 ROC weight. Based with these values criteria score calculated as 0.458.

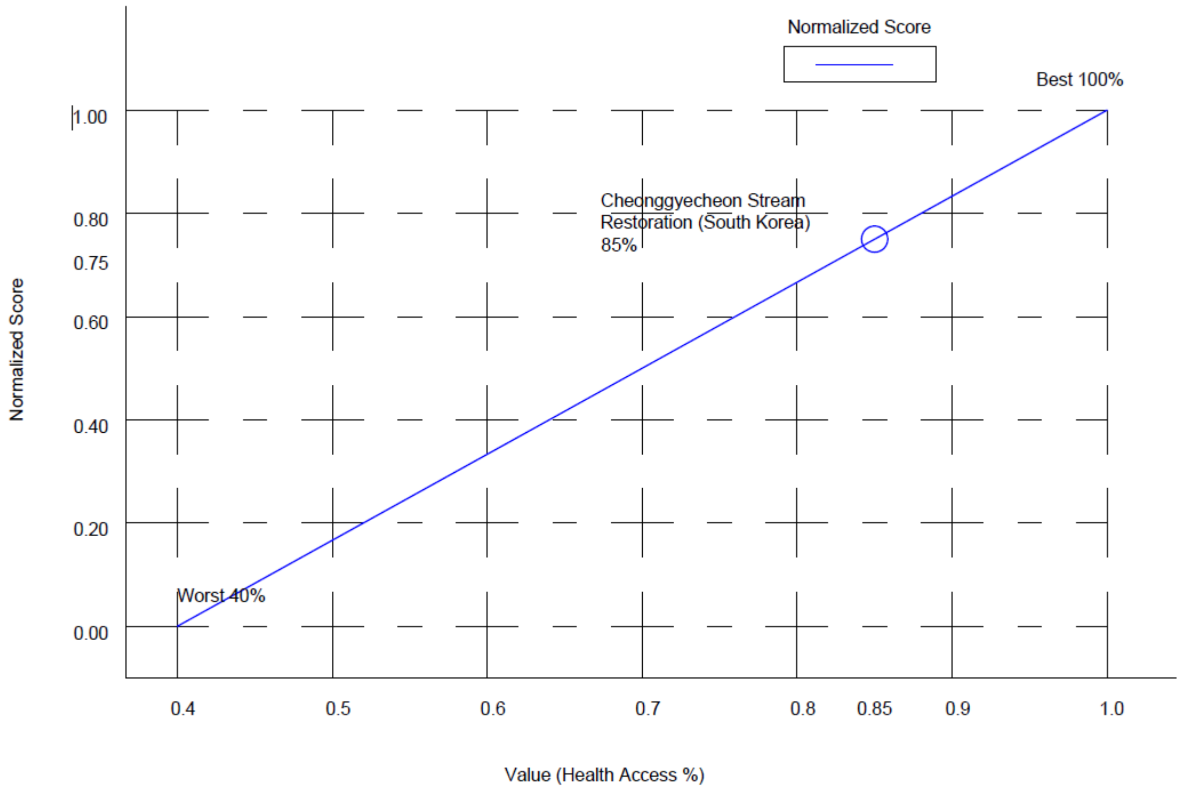

Table 62 *Health and well-being normalization for Cheonggyecheon*

6.2.2.6 Community cohesion and social infrastructure criteria

The value for community cohesion and social infrastructure criteria assessed as 90% community used and programming engagement. "The area experienced a surge in daily visitors and frequent community activities following the project's completion, with over 90% of local residents reporting active use or participation in stream-related events" (Cho, M. 2012).

The normalization value calculated as 0.857. According to expert validation this criteria is selected as third most important which equals 0.111 ROC weight. Considering this data, we find the criteria score by multiplying the two values which is 0.097.

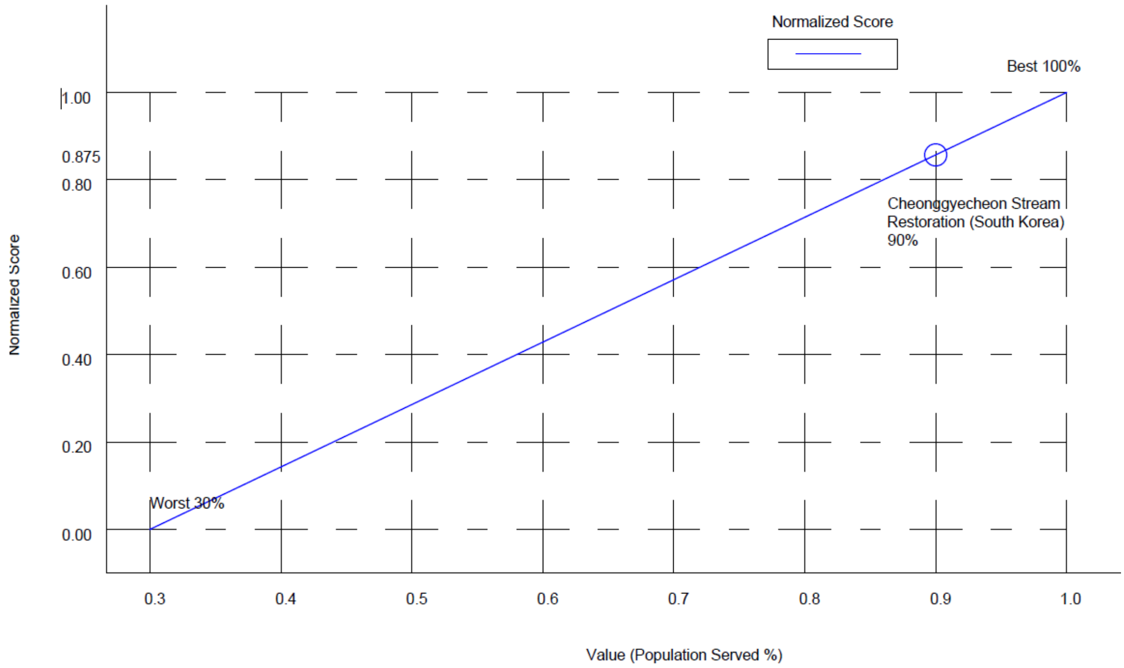

Table 63 *Community cohesion and social infrastructure normalization for Cheonggyecheon*

6.2.2.7 Life cycle cost efficiency criteria

The value for life cycle cost efficiency criteria was estimated around 700euro/m². ''The overall restoration cost was approximately $386 million USD, with continuous investments in ecological maintenance and monitoring''(Kim, S., & Lee, Y. 2011).

The normalization value calculated as 0.667. According to, expert validation this criteria selected as second most important which equals to 0.277 ROC weight. Considering this data, Criteria score found as 0.184.

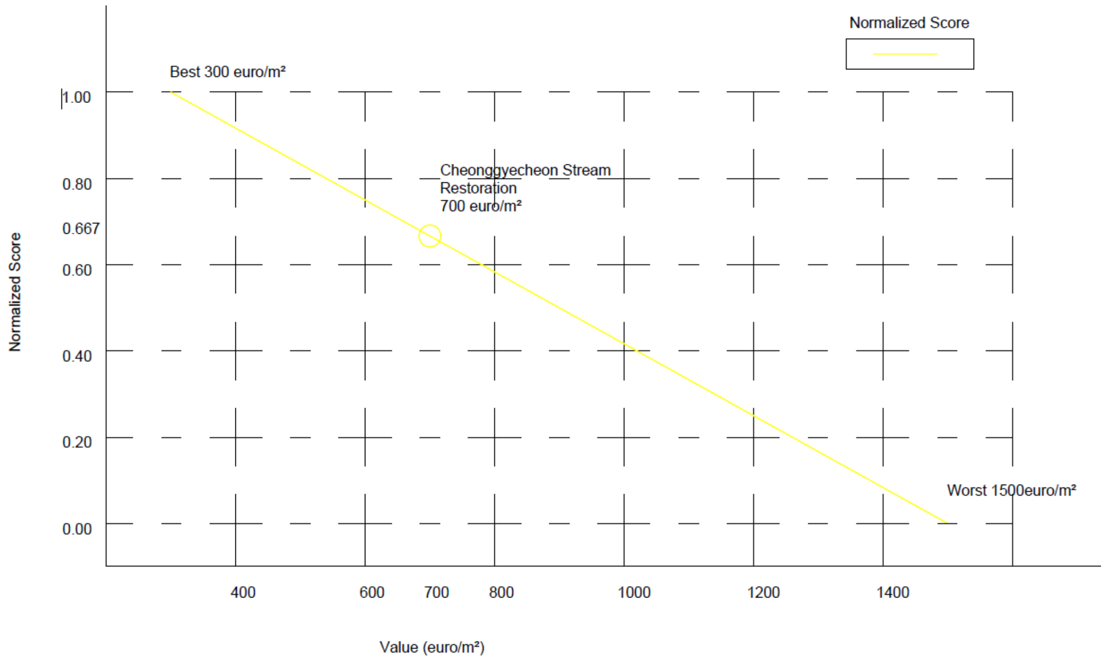

Table 64 *Life cycle cost efficiency normalization for Cheonggyecheon*

6.2.2.8 Cost effectiveness and operational savings criteria

The value for cost effectiveness and operational savings reported as 30%. ”The project achieved substantial savings by utilizing nature-based flood control, self-sustaining vegetation, and passive cooling effects along the stream corridor, which collectively reduced the energy, irrigation, and maintenance needs’ (Seoul Metropolitan Government. 2010).

The normalization value measured as 0.714. According to, expert validation this criteria selected as the most important which equals to 0.611 ROC weight. Considering this data, Criteria score found as 0.436.

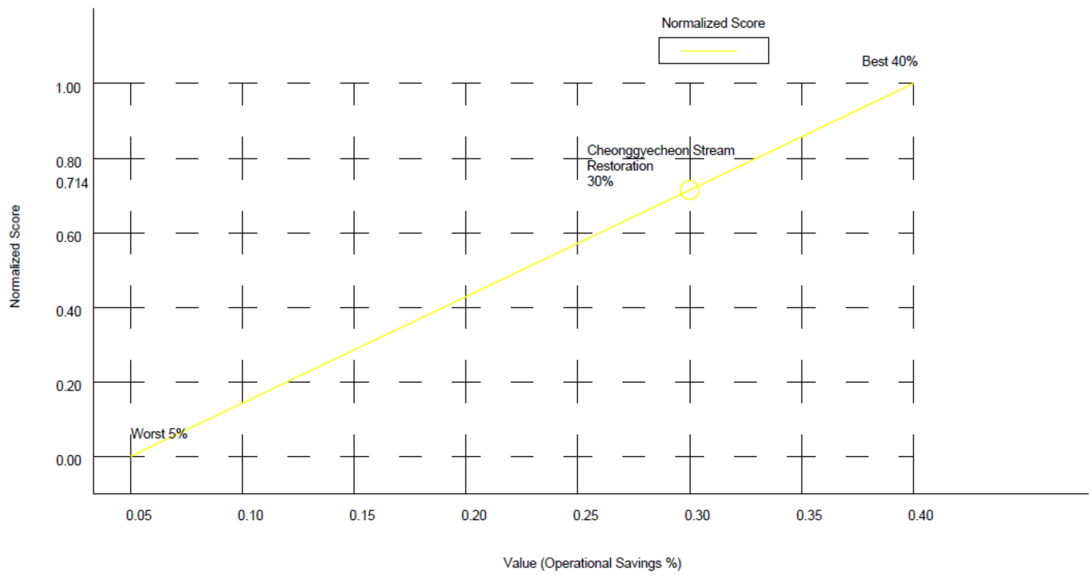

Table 65 *Cost effectiveness and operational savings normalization for Cheonggyecheon*

6.2.2.9 Economic performance criteria

The value for economic performance was measured as 2.5% contribution to local GDP. ''The stream restoration stimulated economic revitalization in the surrounding areas, leading to significant increases in commercial activity and municipal tax revenues, with a measurable 2.5% contribution to the local GDP during the first years after project completion' (Lee, J., & Anderson, P. 2013).

The normalization value calculated as 0.800. According to, expert validation this criteria selected as third most important which equals to 0.111 ROC weight. Considering this data, Criteria score found as 0.088.

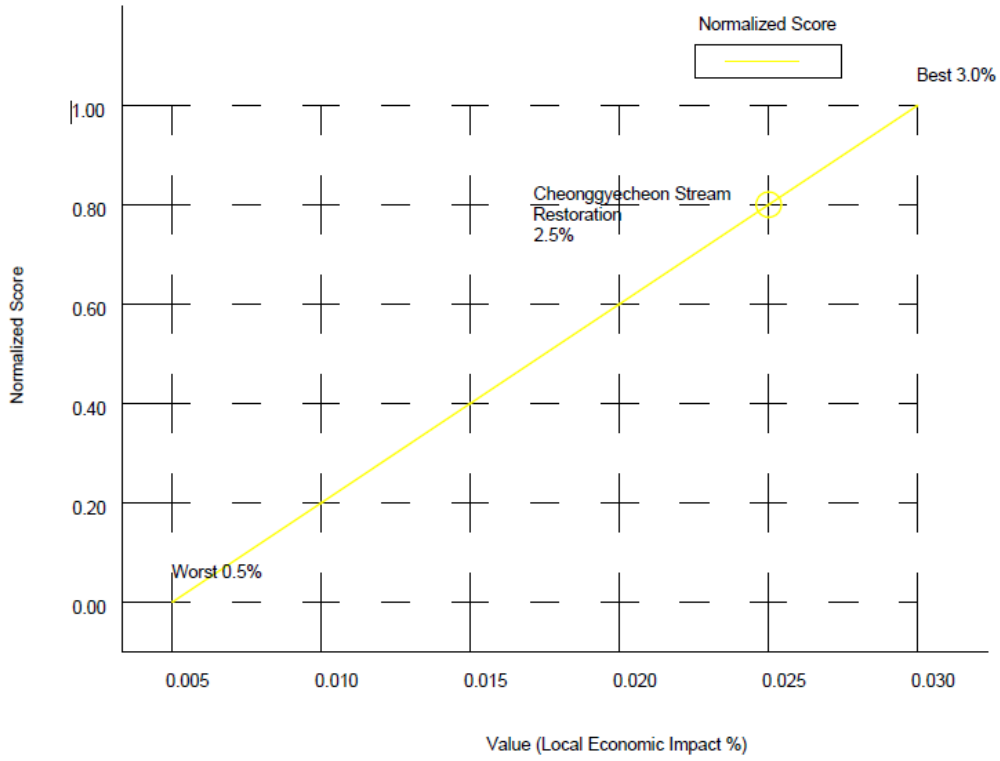

Table 66 *Economic performance normalization for Cheonggyecheon*

6.2.2.10 Stakeholder engagement and public involvement criteria

The value for stakeholder engagement and public involvement as identified as 5 out of 5 participatory steps completed. "The project incorporated a comprehensive public engagement strategy, including multiple phases of community consultation, participatory design workshops, stakeholder advisory committees, public information sessions, and long-term community involvement in project monitoring' (Cho, M. 2012).

The normalization value calculated as 1.000 According to, expert validation this criteria selected as most important which equals to 0.611 ROC weight. Considering this data, Criteria score found as 0.611.

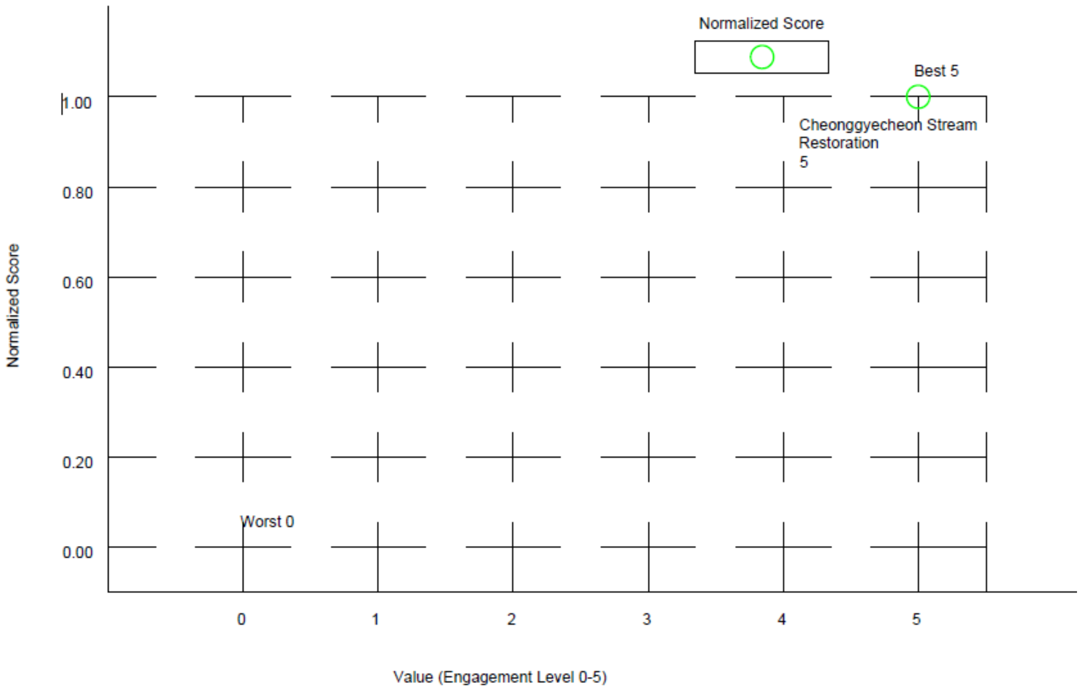

Table 67 *Stakeholder engagement and public involvement normalization for Cheonggyecheon*

6.2.2.11Governance and Management systems criteria

The value for governance and management systems was assessed 3 out of 3 governance components fulfilled. ''The project was managed by the Seoul Metropolitan Government in collaboration with multiple agencies, including the Seoul Institute of Environmental Policy, and incorporated:

1. A clear multi-stakeholder decision-making structure
2. Formal monitoring and evaluation mechanisms
3. Full policy integration within Seoul's urban sustainability and climate resilience strategies
   These components ensured institutional continuity, transparency, and alignment with broader municipal policies' (Seoul Metropolitan Government, 2010).

The normalization value calculated as 1.000. According to expert validation this criteria selected as the second most important which equals to 0.277 ROC weight. According to this data, Criteria score found as 0.277.

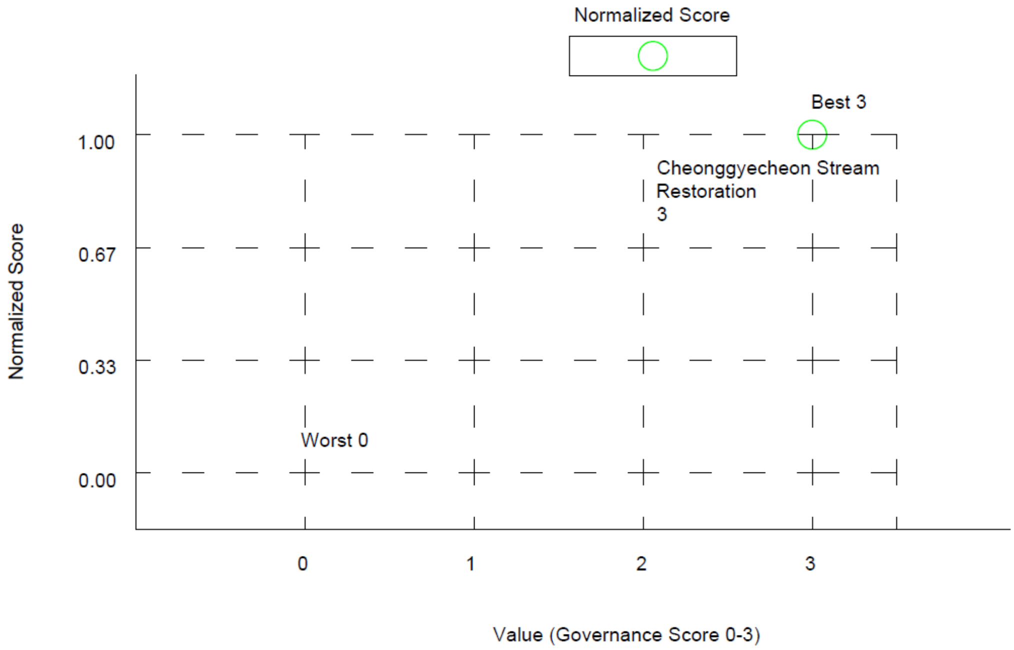

Table 68 *Government and management systems normalization for Cheonggyecheon*

6.2.2.12 Transparency and reporting criteria

The value for transparency and reporting criteria was recorded as 85%. ''The Seoul Metropolitan Government has published comprehensive documentation on the project's environmental, social, and economic impacts, including annual updates and performance assessments, which are publicly available through official platforms' (Seoul Metropolitan Government, 2010).

The normalization value calculated as 0.850. According to, expert validation this criteria selected as third most important, which equals to 0.111 ROC weight. Considering this data, criteria score was found as 0.087.

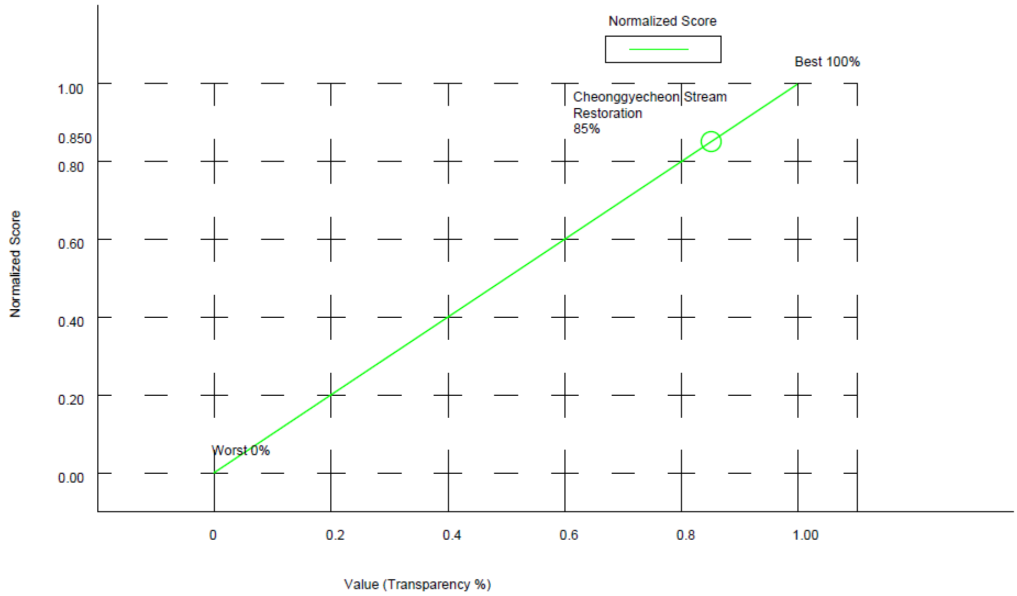

Table 69 *Transparency and reporting normalization for Cheonggyecheon*

6.2.2.13 GISPAM scores of Cheonggyecheon Stream Restoration

To calculate the GISPAM final scores, the normalized criteria scores on each dimension are first aggregated. These aggregated scores are then weighted according to the dimension weights acquired from the expert validation using ROC method. This process provides combined score for all four dimensions which are environmental, social, economic and governance. Finally, the weighted scores of the four dimensions aggregate to define the overall GISPAM score for the project.

Project Name	En1	En2	En3	En∑
Cheongyeccheon Stream Restoration (Seoul, South Korea)	0.534	0.097	0.242	0.873
	So1	**So2**	**So3**	**So∑**
	0.257	0.458	0.097	0.812
	Ec1	**Ec2**	**Ec3**	**Ec∑**
	0.184	0.436	0.088	0.708
	Go1	**Go2**	**Go3**	**Go∑**
	0.611	0.277	0.094	0.982

Table 70 *Criteria and dimensions score of Cheonggyecheon*

Project Name	Dimension Score	ROC Weight	ROC Weighted Dimension Score
Cheonggyecheon Stream Restoration (Seoul, South Korea)	**Environmental ∑** 0.873	0.520	0.454
	Social ∑ 0.812	0.145	0.118
	Economic ∑ 0.708	0.256	0.181
	Governance ∑ 0.982	0.040	0.039

Table 71 *ROC weighted dimension scores*

As a finals step all the ROC weighted dimensions scores are aggregated. The GISPAM ranking is completed according to the results.

Final GISPAM Score	Rating Level
0.792	Medium High

Table 72 *Final GISPAM rating of Chenggyecheon Stream Restoration*

6.2.3 The Madrid Rio Project (Madrid, Spain)

''The Madrid Río project is a large-scale urban redevelopment initiative located along the Manzanares River in Madrid, Spain. The project was developed in conjunction with the burial of the M-30 ring road between 2004 and 2007, which involved constructing extensive underground tunnels to divert traffic away from the river corridor' (Garrido et al., 2016). After the underground infrastructure finished, the surface-level public space transformation started. Between 2008 and 2015, the Madrid Río green space and recreational spaces were gradually built. The project aimed to reconnect the city with the Manzanares River by transforming the riverbanks into approximately 1.2 million square meters of new public space, including parks, pedestrian walkways, sports facilities, playgrounds, and landscaped areas (López-Romero et al., 2014).

''Although the project contributed to improving urban mobility, visual landscape quality, and recreational opportunities, several studies have highlighted its limitations regarding ecological restoration, biodiversity, flood resilience, and inclusive social benefits. The river remains largely confined within concrete embankments, and the project has faced criticism for failing to implement comprehensive nature-based solutions or robust community participation mechanisms' (Méndez, 2015).

Figure 5 *The Madrid Rio Project*

6.2.3.1 Energy and Carbon Emissions Criteria

The estimated value of this criteria for The Madrid Rio project is approximately 25 kgCO_2e/m² per year. ''Based on system energy modeling, embodied carbon calculations, and ventilation requirements associated with the extensive underground infrastructure (M-30 tunnels). Multiple studies have highlighted that, while the project contributed to urban greening, the high use of concrete structures and the ongoing operation of tunnel ventilation systems significantly increased the carbon footprint compared to more ecologically restorative green infrastructure projects'' (Garrido et al., 2016; Sánchez & Ortega, 2020).

The normalization value was calculated as 0.692. According to expert validation method, this criteria selected as the most important criteria for environmental dimension which is 0.611 ROC Weight. And to find the criteria score ROC weight multiplied with normalization value. Finally, criteria score found as 0.422.

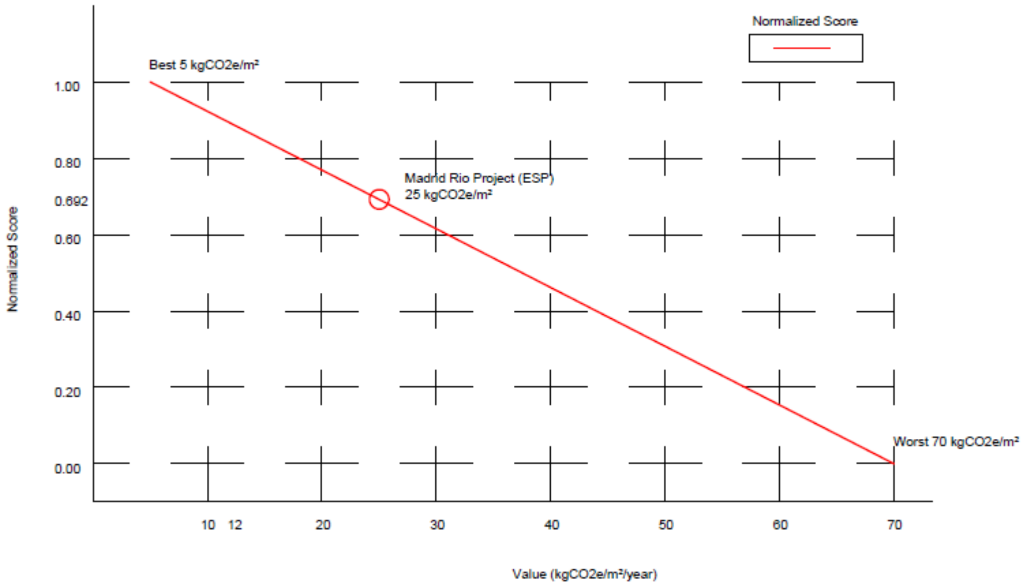

Table 73 *Energy and carbon emissions normalization for The Madrid Rio Project*

6.2.3.2 Water efficiency and management criteria

The value of water efficiency and management criteria is estimated as 40%. Although, there are huge green areas, the project has been criticized for insufficient integration of permeable surfaces and natural water retention systems. ''Most of the riverbanks remain confined within concrete channels, and significant portions of the surrounding park area are composed of impermeable surfaces such as paved walkways and plazas. Although some improvements were made in stormwater redirection and irrigation efficiency, the project falls short of high-performance green infrastructure standards.'' (Garrido et al., 2016).

The normalization value was calculated as 0.375 for this criteria. According to expert validation this criteria selected as third most important criteria in environmental dimension which equals 0.111 ROC weight. The purpose of find the criteria score this two value multiplied and criteria score calculated as 0.041.

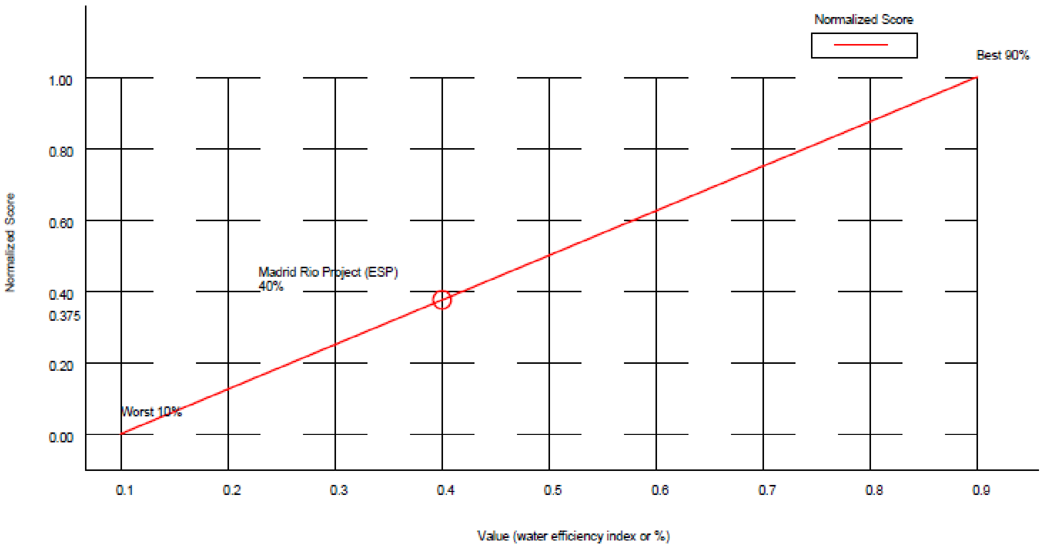

Table 74 *Water efficiency and management criteria for The Madrid Rio*

6.2.3.3 Climate adaptation and resilience criteria

The value of climate adaptation and resilience criteria found as 2 out of 8 adaptation strategies implemented. Although the project has affect improving urban microclimate with treen planting and green areas, it strongly failed to incorporate nature based solutions for flood mitigation, biodiversity corridors, or climate resilience. ''The river remains confined within artificial channels, and the surrounding green space focuses more on recreational use rather than ecological restoration or adaptive capacity building' (Garrido et al., 2016).

The normalization value was found as 0.250. and according to expert validation this criteria is selected as the second most important of environmental dimension which equals 0.277 ROC Weight. Based with these values, criteria score calculated as 0.069.

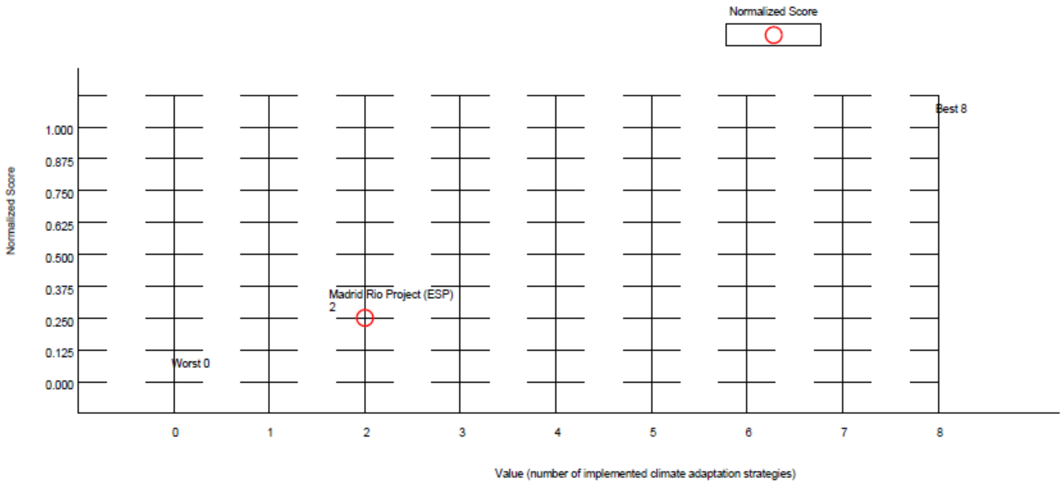

Table 75 *Climate adaptation and resilience normalization for The Madrid Rio*

6.2.3.4 Social equity and access criteria

The value of social equity and access criteria was estimated as 60% population accessibility, based on proximity analysis and social impact assessment. Although the project proposes serious amount of recreational spaces and pedestrian walkways along river, accessibility remains uneven, especially for marginalized communities. ‘’Lower-income neighborhoods located beyond the immediate vicinity of the river face physical and social barriers limiting their access to the new public spaces. Furthermore, gentrification processes following the project contributed to social displacement, reducing inclusiveness over time’’ (López-Romero et al., 2014; Méndez, 2015).

The normalization value was calculated is %60 for this criteria. According to expert validation this criteria is selected as the second most important with 0.277 ROC Weight. To find the criteria score ROC weight multiplied with normalization value. Finally, criteria score found as 0.118.

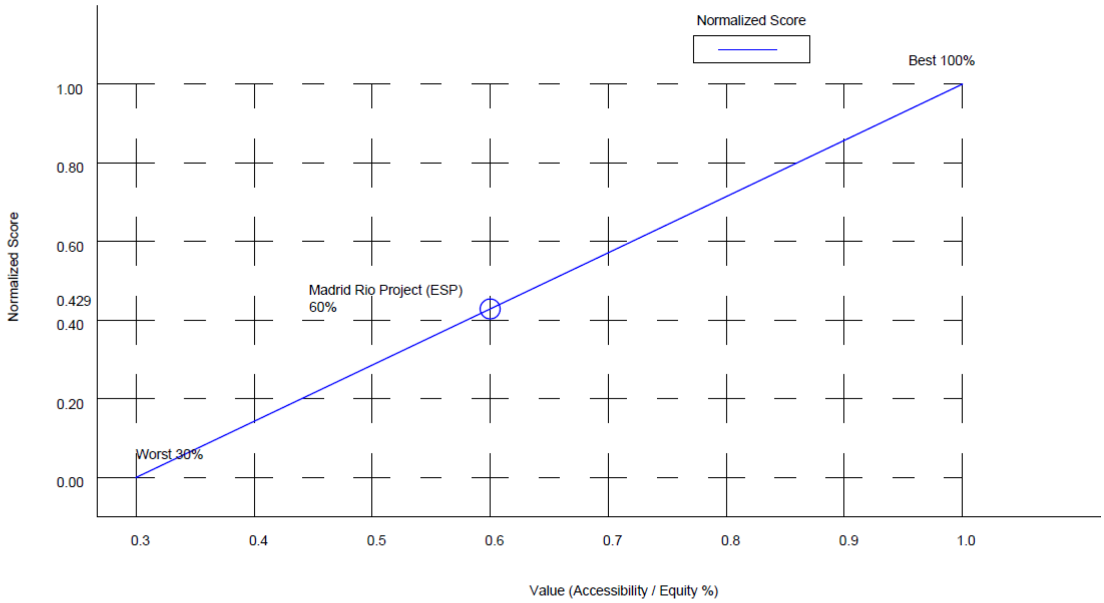

Table 76 *Social equity and access normalization for The Madrid Rio*

6.2.3.5 Health and well-being criteria

The value for health and well-being criteria was estimated as 70%, based on resident satisfaction surveys studies. ''Many residents reported improvements in physical activity levels, mental well-being, and social interaction following the opening of the park. However, the limited ecological restoration, lack of biodiversity, and uneven accessibility reduce the potential health benefits, particularly for vulnerable populations'' (Galiana-Martín, 2022; López-Romero et al., 2014).

The normalization value calculated as 0.500. According to expert validation this criteria is selected as the most important criteria of social dimension with 0.611 ROC weight. Based with these values criteria score calculated as 0.305.

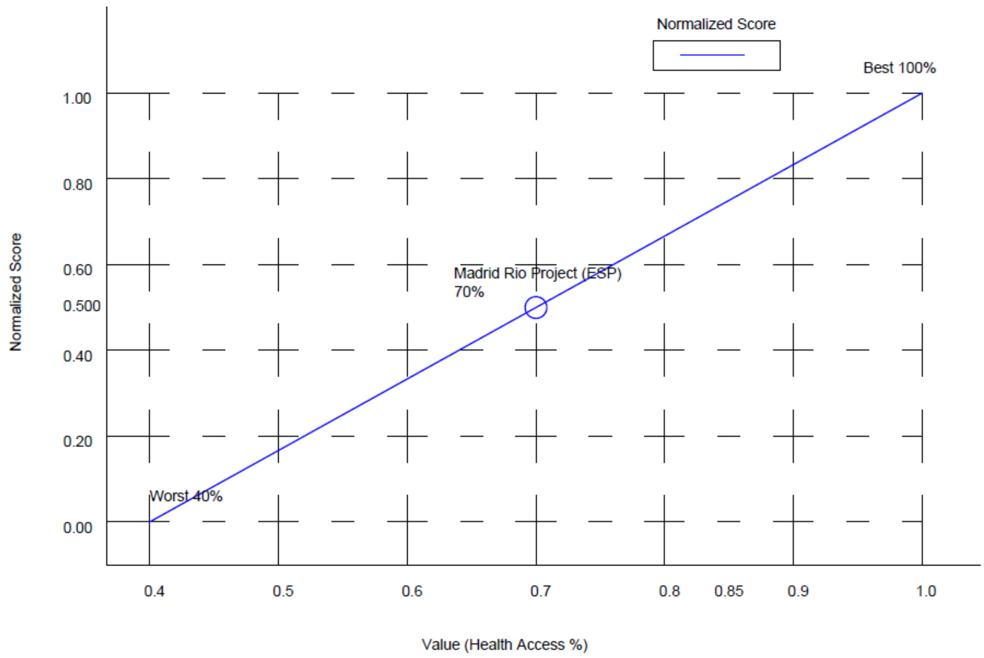

***Table** 77 Health and wellbeing normalization for Them Madrid Rio*

6.2.3.6 Community cohesion and social infrastructure criteria

The value for this criteria was estimated as 50%, , reflecting moderate levels of public participation in events and recreational use. Although the Madrid Rio project provides spaces for leisure activities, walking, and social interaction, studies shows that these area insufficient. ''Community programming remains sporadic and access to certain facilities tends to favor higher-income groups. Additionally, the project has been criticized for contributing to socio-spatial inequalities and gentrification, limiting its potential for fostering inclusive community cohesion.'' (Galiana-Martín, 2022; Méndez, 2015).

The normalization value calculated as 0.286. According to, expert validation this criteria selected as third most important which equals to 0.111 ROC Weight. Considering this data, criteria score found as 0.031

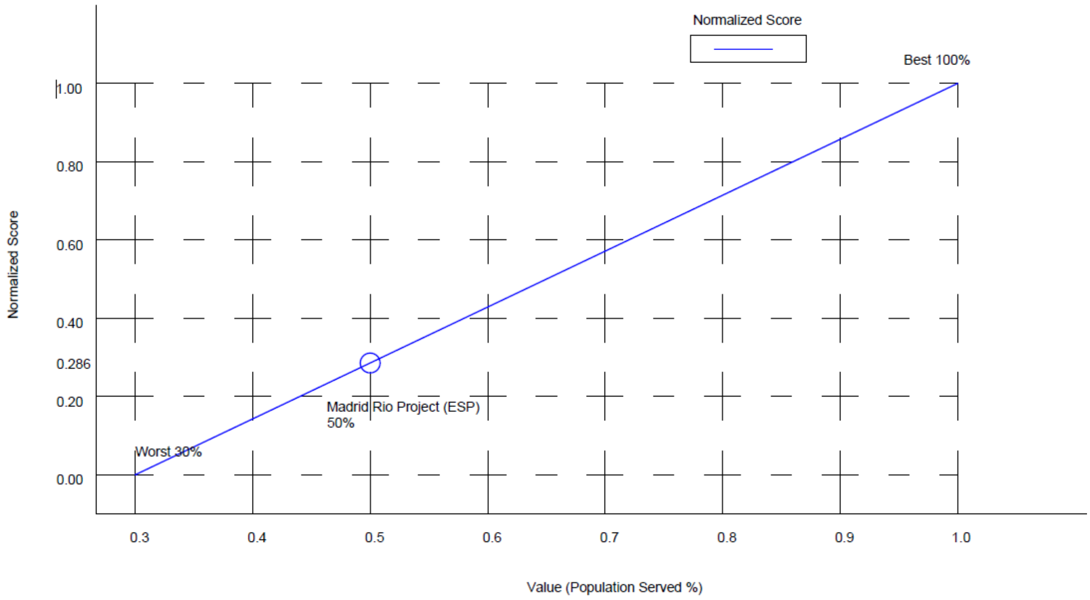

Table 78 *Community cohesion and social infrastructure normalization for The Madrid Rio Project*

6.2.3.7 Life cycle cost efficiency criteria

The value for life cycle efficiency criteria is estimated as 950 euro/m². This value includes the total investment, construction, long term maintenance. ''The project incurred exceptionally high costs due to the extensive tunneling of the M-30 highway, complex engineering works, and high-end landscape design. Although the upper layer of the project functions as a green space, the overall life cycle cost remains substantially higher than typical green infrastructure projects, largely due to the subterranean infrastructure component'' (Garrido et al., 2016).

The normalization value calculated as 0.458. According to expert validation this criteria selected as second most important with 0.277 ROC Weight. Considering this data criteria score announced as 0.126.

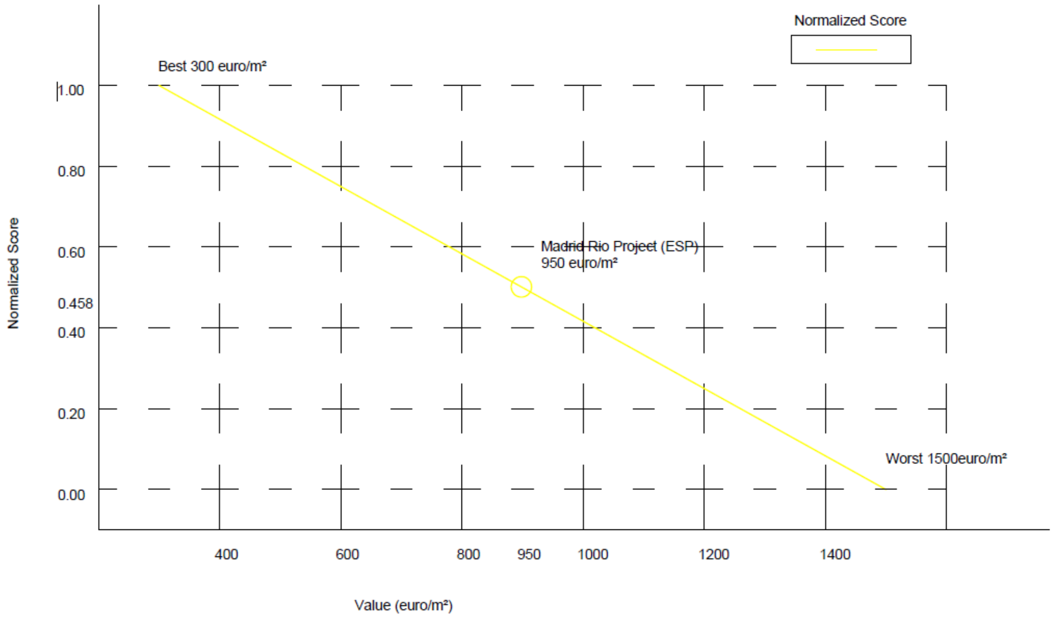

Table 79 *Liife cycle cost efficiency normalization for The Madrid Rio*

6.2.3.8 Cost effectiveness and operational savings criteria

The value of this criteria is estimated as 15%. This value shows limited long term reductions in maintenance, irrigation and energy costs related to conventional urban infrastructure. Although the project provides green areas and tree planting, intensive use of artificial surfaces, concrete riverbanks and high maintenance landscaping features contribute to increased operational expenses. ''Ongoing maintenance requirements, including cleaning of paved areas and operation of the M-30 tunnel ventilation systems, limit the project's overall cost-effectiveness' (Garrido et al., 2016; Méndez, 2015).

The normalization value measured as 0,286. According to expert validation this criteria is selected as the most important criteria with 0.611 ROC weight. Considering this data, criteria score calculated as 0.174.

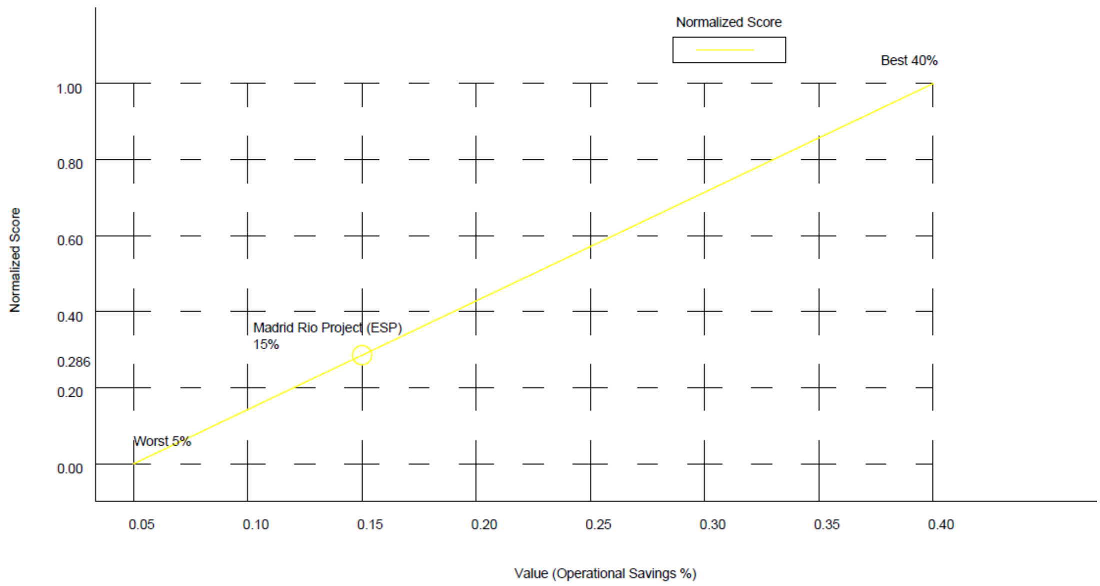

Table 80 *Cost effectiveness and operational savings for The Madrid Rio Project*

6.2.3.9 Economic Performance Criteria

The value of economic performance criteria was measured as 1.5% contribution to local GDP. It is based on studies that evaluating the project's role in attracting investment, increasing property values, enhancing tourism and generating employment opportunities. "The project contributed to the revitalization of surrounding areas and stimulated economic activity, particularly in real estate development. However, critics argue that these economic benefits have been unevenly distributed, with significant gentrification effects and displacement of low-income residents" (Galiana-Martín, 2022; Garrido et al., 2016).

The normalization value calculated as 0.400. According to expert validation this criteria is selected the third most important criteria with 0.111 ROC weight. Considering this data, criteria score calculated as 0.044.

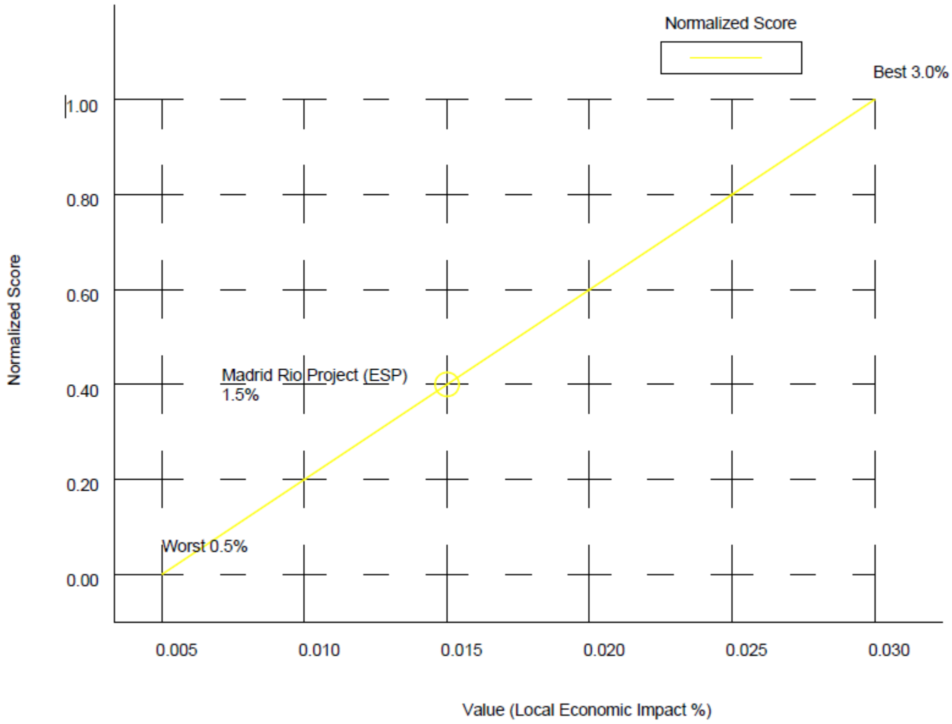

Table 81 *Economic performance normalization for The Madrid Rio project*

6.2.3.10 Stakeholder engagement and public involvement criteria

The value of this criteria was assessed as 2 out of participatory steps completed. The project, although publicly funded and intended as large-scale urban intervention, faced criticism for limited community involvement during the key phases of planning and design. ''Decision-making was largely top-down, driven by political and institutional actors, with minimal opportunities for early-stage citizen input. However, limited information sessions and post-construction feedback mechanisms were organized, accounting for partial stakeholder involvement'' (López-Romero et al., 2014; Méndez, 2015).

The normalization value of this criteria is selected as 0.400. According to, expert validation this criteria is selected as the most important with 0.611 ROC weight. Considering this data, criteria score calculated as 0.244.

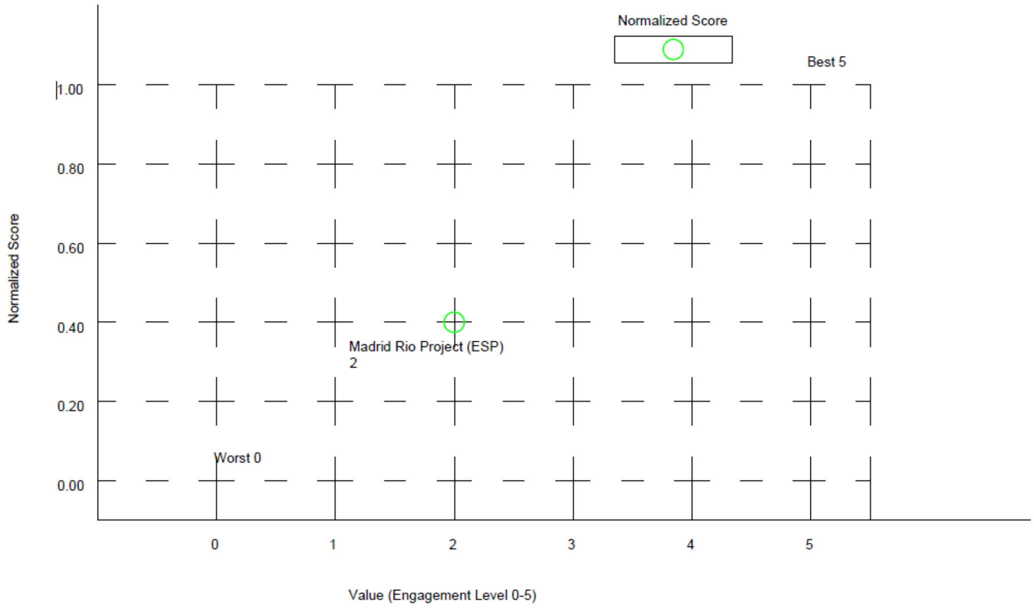

Table 82 *Stakeholder engagement and public involvement normalization for The Madrid Rio*

6.2.3.11 Governance and management systems criteria

The value of this criteria was assessed as 1 out of 3 governance components fulfilled. Despite the actions taken with the Madrid City Council and involving a number of government agencies, the project lacked institutional procedures for open, multi-stakeholder governance and lacked systematic integration with broader urban sustainability strategies. ''Most decisions were centralized within political institutions, with minimal long-term monitoring and public oversight structures in place'' (Garrido et al., 2016; Méndez, 2015).

The normalization value measured as 0.333. According to, expert validation, this criteria selected as the second most important criteria with 0.277 ROC Weight. According to this data, criteria score found as 0.092.

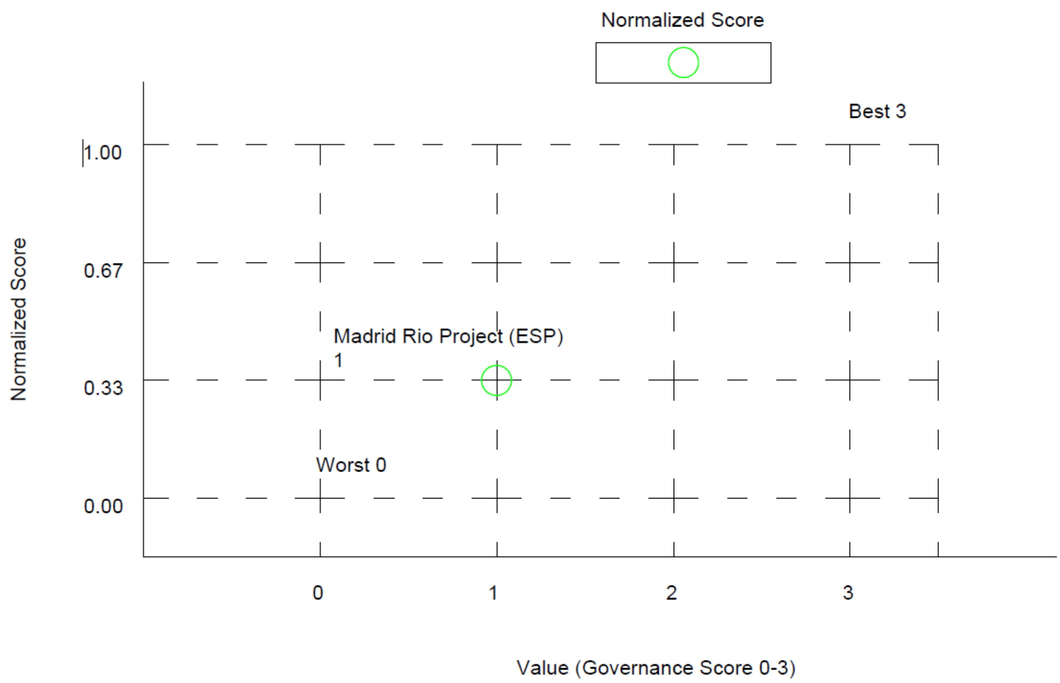

Table 83 *Governance and management systems normalization for The Madrid Rio*

6.2.3.12 Transparency and reporting criteria

The value of this criteria was assessed as 40%. Based on publicly available information regarding project financing, environmental performance, and socio-economic impacts. "Although the Madrid City Council released basic reports and updates about the project, comprehensive and systematic performance evaluations—particularly concerning environmental outcomes, long-term sustainability, and social equity—were lacking. Moreover, much of the available information focused on visual aspects and urban design achievements, while critical sustainability indicators were underreported" (Galiana-Martín, 2022; Méndez, 2015).

The normalization value of this criteria calculated as 0.400. According to, expert validation, this criteria is selected as the third most important criteria with 0.111 ROC weight. Considering this data, criteria score calculated as 0.044.

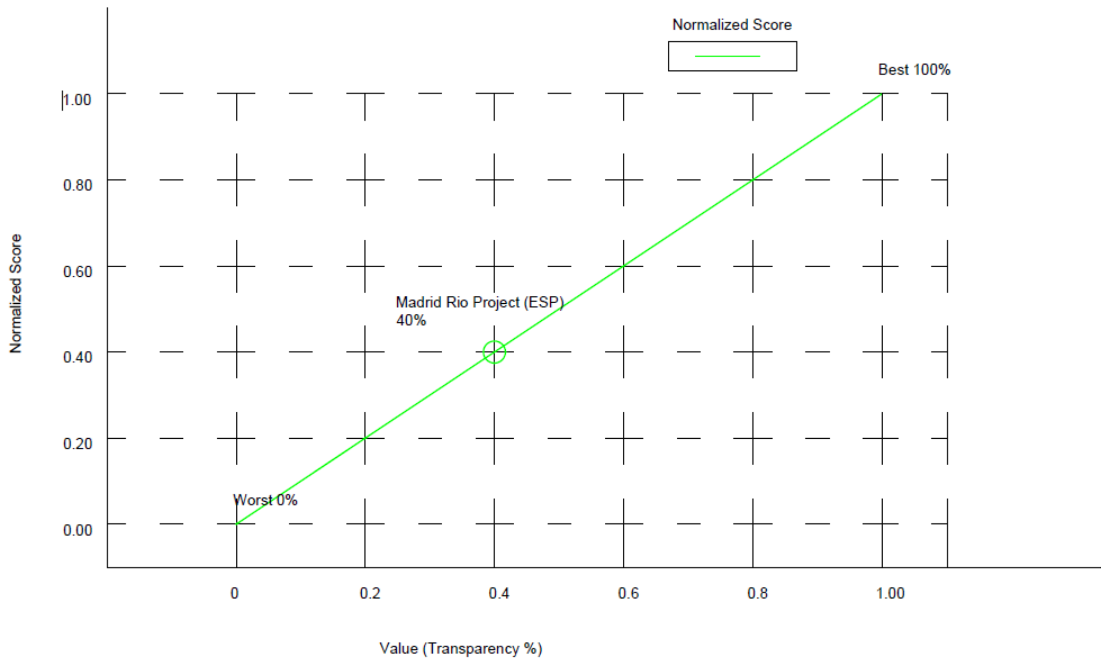

***Table 84** Transparency and reporting normalization for The Madrid Rio*

6.2.3.13 GISPAM score of The Madrid Rio

To calculate the GISPAM final scores, the normalized criteria scores on each dimension are first aggregated. These aggregated scores are then weighted according to the dimension weights acquired from the expert validation using ROC method. This process provides combined score for all four dimensions which are environmental, social, economic and governance. Finally, the weighted scores of the four dimensions aggregate to define the overall GISPAM score for the project.

Project Name	En1	En2	En3	En∑
The Madrid Rio (Madrid, Spain)	0.422	0.041	0.069	0.532
	So1	**So2**	**So3**	**So∑**
	0.118	0.305	0.031	0.454
	Ec1	**Ec2**	**Ec3**	**Ec∑**
	0.126	0.174	0.044	0.344
	Go1	**Go2**	**Go3**	**Go∑**
	0.244	0.092	0.044	0.380

***Table 85** Criteria and dimension score of The Madrid Rio*

Project Name	Dimension Score	ROC Weight	ROC Weighted Dimension Score
The Madrid Rio (Madrid, Spain)	**Environmental ∑** 0.532	0.520	0.276
	Social ∑ 0.454	0.145	0.065
	Economic ∑ 0.344	0.256	0.088
	Governance ∑ 0.380	0.040	0.015

Table 86 *ROC weighted dimension scores*

As a finals step all the ROC weighted dimensions scores are aggregated. The GISPAM ranking is completed according to the results.

Final GISPAM Score	Rating Level
0.444	Medium

Table 87 *Final GISPAM rating of The Madrid Rio*

7 Results and discussions

7.1 Introduction to Results and Discussion

This chapter explains the results of the application of the GISPAM (Green Infrastructure Sustainability Performance Assessment Model) framework to selected three case studies which are The Highline (USA), Cheonggyecheon (South Korea) and The Madrid Rio (SPA). The analysis emphasizes the sustainability performance of each project, assessed according to ESG+ dimensions which are environmental, social, economic and governance. The goal is to demonstrate practical applicability, differentiating the capacity and value of GISPAM by systematically comparing outcomes between all case studies.

7.1.1 Methodological Rationale for Comparative Analysis

GISPAM is designed as a standardized multi-criteria rating system. This allows consistent assessment of diverse green infrastructure projects. GISPAM provides each case study is evaluated using same set of criteria, normalization procedures, and weighting methodology. Comparative analysis of case study results is widely recognized in the literature as a critical step in demonstrating the validity, utility and selection of rating frameworks. Although the GISPAM model provides individual sustainability ratings for each case study, thanks to a standardized framework enables a comparative analysis between different green infrastructure projects. Through comparative assessment, this study not only identifies strengths and weaknesses within each project, but also reveals general patterns and best practices relevant for future green infrastructure planning.

7.2 Overview of Case Study Results

7.2.1 GISPAM Score Outcomes

Project	En	So	Ec	Go	GISPAM Score	Rating Level
The Highline	0.385	0.106	0.159	0.030	0.680	Medium - High
Cheonggyecheon Stream Restoration	0.454	0.118	0.181	0.039	0.792	Medium - High
The Madrid Rio	0.276	0.065	0.088	0.015	0.444	Medium

Table 88 *Final GISPAM scores of the case studies*

The final GISPAM clearly shows that there are significant differences in sustainability performance in three case studies. Cheonggyecheon Stream Restoration achieved the highest GISPAM score with 0.792. Which means to medium – high level. Cheonggyecheon Stream Restoration indicating a well-integrated and balanced approach to environmental, social, economic and governance dimensions. The Highline also received a medium – high level rating with 0.680. The Highline reflects effective sustainability strategies, but some areas need improvement. In the contrast, The Madrid Rio Project scored significantly lower rating level which is medium with 0.444. The Madrid Rio project highlights considerable gaps in meeting the comprehensive set by GSIPAM. These results shows the model's capacity to distinguish projects with strong, multi dimensional sustainability strategies from those with more limited or fragmented interventions.

7.2.2 ESG+ Dimensions Outcomes

Project	Environmental	Social	Economic	Governance
The Highline	0.385	0.106	0.159	0.030
Cheonggyecheon Stream Rest+oration	0.454	0.118	0.181	0.039
The Madrid Rio	0.276	0.065	0.088	0.015

Table 89 *Dimension scores of the case studies*

At the dimension level, Cheonggyecheon Stream Restoration performed better than the other projects in all ESG+ dimensions. The Highline showed its best performance in environmental with 0.385. The Highline also achieved high scores in other dimensions such as social dimension with 0.106, economic dimension with 0.159 and governance dimension with 0.030, although not as high as Cheonggyecheon Stream Restoration. The Highline reflects transparent management and stakeholder participation. The Madrid Rio project, however, remained low scores in every dimension, shows that its need improvements for all the four dimensions. The analysis suggests that success in green infrastructure projects depends on achieving balanced progress across all four ESG+ dimensions.

To provide a clearer and more immediate comparison between the three case studies, radar charts were created. Compared to numerical tables, radar charts allow for quick visual assessment of each project’s strengths and weaknesses. This chart make the job easier for decision makers to identify priorities for improvement.

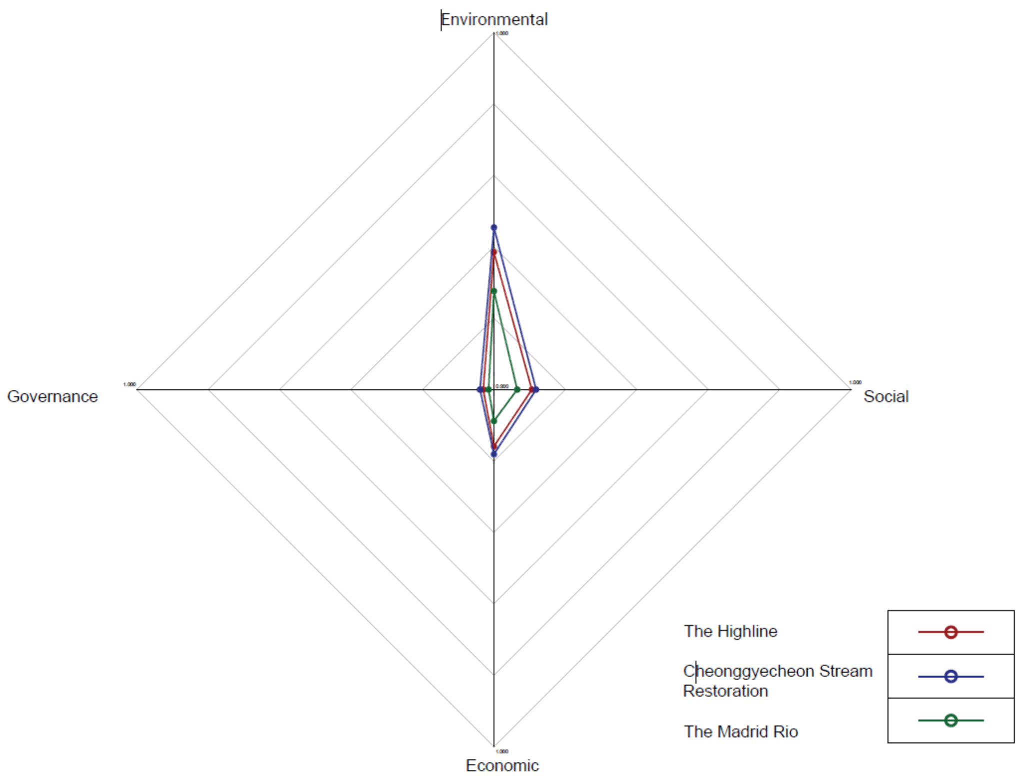

Figure 6 *ESG+ dimensions radar chart*

7.3 Criteria Scores Outcomes

A closer look at the individual criteria highlights the specific strengths and weaknesses of each project. Cheonggyecheon draw attention in criteria such as water management, accessibility, and life cycle cost efficiency. Cheonggyecheon benefiting from extensive public engagement and effective public urban transformation. The Highline performs better in biodiversity enhancement, transparency and community engagement. However, It can be improved in cost effectiveness and climate adaptation measures. On the other hand, The Madrid Rio, scored lowest in several criteria. For example, resource efficiency, stakeholder involvement and operational savings. This unbalanced performance at the criteria level significantly influenced its overall GISPAM rating. And it is showing that reinforcing the necessity for integrated approaches that address all key sustainability indicators.

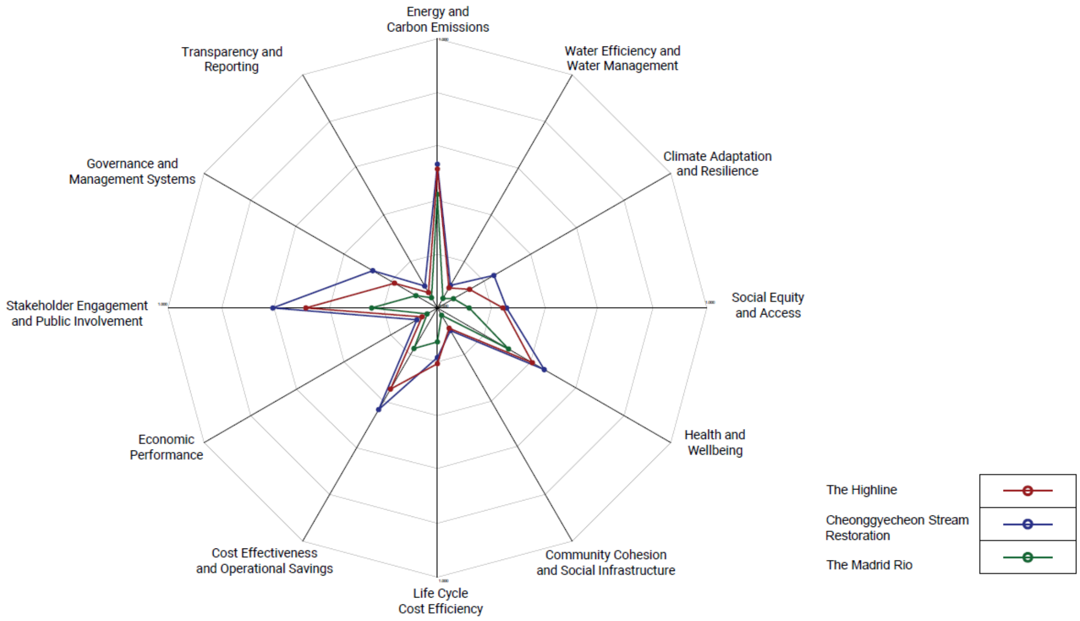

***Figure 7** Criteria radar chart*

Figure 7 illustrates a radar chart comparing criteria of three case studies. The visual highlights the how each project performs across the 12 criteria of ESG+ dimensions. It is clearly seen that Cheonggyecheon Stream Project (blue) performed higher scores in all criterias. The Madrid Rio, performed lower scores in all criterias in between three case studies. Radar chart provides immediate visual comparison, making it easier to identify strengths and weaknesses of each project.

7.3.1 Environmental Dimension Criteria Performance

The environmental performance analysis shows clear differences in between the three projects. Cheonggyecheon Stream Restoration reached the highest score which is 0.454. Cheonggyecheon Stream Restoration primarily due to, its comprehensive approach to water management, biodiversity enhancement and climate adaptation measures. The project effectively restored ecological functions to compare with the former situation, creating a benchmark for green infrastructure projects.

The High Line scored 0.385, performing good in biodiversity but showing relatively limited success in resource efficiency and climate adaptation. Because, The Highline is linear, elevated structure and the constraints of upgrading an existing railway. However, The Highline is a innovative reuse of infrastructure and contribution to urban ecology are significant achievements.

Madrid Río Project, had score of 0.276. The Madrid Rio stayed behind because of insufficient biodiversity initiatives and lower efficiency in resource use. Although the project provided new green space along the river, environmental interventions remained basic and inadequate the transformative impact that can be seen in the other two cases.

Overall, the results show that the most successful environmental outcomes were achieved by projects that combined ecological restoration, water management, and climate resilience strategies within an integrated planning process.

7.3.2 Social Dimension Criteria Performance

Cheonggyecheon Stream Restoration reached the highest social performance score which is 0.118. Cheonggyecheon Stream Restoration has a good quality of accessibility, community engagement, created inclusive public spaces and improved overall wellbeing in a previously ignored. The inclusive planning process, which integrated public input, was a significant driver of social success for green infrastructure.

The Highline followed with a score of 0.106. It revitalized a neglected area and created a vibrant urban park that enhanced social life, promoted cultural activities, and increased the sense of safety in the district which is a very important for a green infrastructure. However, limited accessibility for some user groups causes criticisms about social equity prevented it from achieving a higher score.

The Madrid Rio had the lowest score of social dimension with 0.065. This score shows the gaps in community engagement, inclusivity and health and wellbeing. Although the projects provides public green areas, the lack of insufficient focus on social diversity limited its social impact for green infrastructure.

Overall, these results emphasize that inclusive planning, strong community engagement, and a focus on public health and wellbeing are key to maximizing the social sustainability of urban green infrastructure projects.

7.3.3 Economic Dimensions Criteria Performance

Cheonggyecheon Stream Restoration scored the highest in the economic dimension with 0.181. Cheonggyecheon Stream Restoration shows effective long-term investment, high cost efficiency, and significant economic resilience for the local community. The project's transformation has good effects the surrounding area such as increased property values, enhanced tourism and generated new business opportunities, justifying the high initial costs with sustained economic benefits.

The Highline also performed notable well in economic dimensions and criteria. The Highline achieved score of 0.159. It became an important impact for local economic activity, attracting millions of visitors annually and increasing nearby real estate values. However, some concerns about gentrification and rising costs for existing residents slightly decreased its overall economic benefits.

The Madrid Rio got the lowest score of economic dimensions with 0.088. The Madrid Rio firstly, due to limited cost effectiveness and modest impacts on local economic development. Although the projects created public areas, the economic returns were less significant compared to substantial beginning investments, and broader economic revitalization stayed limited.

Overall, these results shows the importance of considering life cycle cost efficiency, cost effectiveness and operational savings and economic performance criteria of implementation of green infrastructure.

7.3.4 Governance Dimension Criteria Performance

Cheonggyecheon Stream Restoration achieved the highest score of Governance dimensions with 0.039. Cheonggyecheon Stream Restoration reflects the strong stake holder involvement, transparent decision-making processes, and effective multi-level coordination among government agencies. The success of the project was largely attributed to inclusive planning and regular monitoring. This shows ensured accountability and responsiveness to public needs.

The Highline achieved the score of 0.030. This shows that a well-structured governance approach with clear institutional roles, active community participation, and a degree of transparency. However, some limitations were observed in stakeholders diversity and mechanisms for long term integration.

The Madrid Rio Project scored the lowest of this dimension with 0.015. The Madrid Rio reflects major deficiencies in transparency, stakeholder engagement, and inter-institutional collaboration. The lack of structured participation processes and insufficient feedback mechanisms reduced both project accountability and public trust.

These results shows that effective governance which characterized by stakeholder engagement and public involvement, governance and management systems and transparency and reporting is crucial for achieving high and sustainable performance in green infrastructure.

7.4 Cross Case Analysis and Key Findings

The comparative analysis of The Highline, Cheonggyecheon Stream Restoration and The Madrid Rio shows significant differences in sustainability performance in the four ESG+ dimensions. Cheonggyecheon performed better than other projects. Particularly due to good quality integration of environmental restoration, community engagement, long term economic planning and strengthening the governance. The Highline shows strengths in innovative reuse, biodiversity and stakeholder participation, however, less balanced in some social and economic criteria. In contrast, The Madrid Rio left behind in almost all dimensions.

The results show that projects which adopt a multi dimensional integrated approach which are environmental, social, economic and governance, are significantly more successful in achieving high overall sustainability.
The application of GISPAM proved effective in distinguishing strengths and weaknesses at both dimension and criteria levels. GISPAM has a comprehensive structure highlighted the necessity for balance between all sustainability indicators, rather than doing perfect in a single area. However, some limitations which are the available data and need for local adaptation in certain criteria.

Finally, there are key findings of substance for The GISPAM. These are integrated approaches and participatory governance in sustainable green infrastructure to gain from the environment, society and economy. The GISPAM gives solid tool to implement and guide such initiatives in future green infrastructure projects.

7.4.1 Project Specific Actions

Based on the comparative analysis and identified gaps in ESG+ performance, there are some actions that can be taken to improve criteria for each case studies.

The Highline:

- To improve climate adaptation, extension of use of permeable paving and improving of native, drought tolerant vegetation.
- Enhance the social inclusivity by upgrading accessible routes and providing more opportunities for people who has disabilities
- Increase transparency and reporting by publishing regular reports and strengthening the power of Friend of Highline.

Cheonggyecheon Stream Restoration

- Enhance economic performance by supporting local entrepreneurship through the corridor.
- Feeding the greater community engagement participatory design workshops and increase the number of public events.
- Adding the real time water management increase the water management

The Madrid Rio Project

- By establishing frequent stakeholder consultation procedures and releasing annual sustainability performance reports will close the governance gaps.
- Although carbon emission values have increased significantly while constructing the stream bed, the impact can be reduced by making the right investments in the future.
- By expanding the area of green spaces and providing equal access for all demographic groups, can improve both health and wellbeing and social equity and access.

7.5 Limitations and Practical Implications

Although, GISPAM provides a comprehensive and systematic approach to evaluating green infrastructure projects. There are several limitations should be considered. First, the model relies on the availability an quality of project data. It can vary between cases and regions. Incomplete or inconsistent data can affect accuracy of scoring. Second of all, some sustainability criteria may require further local adaptation to reflect specific, environmental or regulatory contexts. Thirdly, expert validation used in the model can cause a measurement of subjectivity, even though structured methodologies which are ROC and MAVT used to minimize subjectivity.

Although these limitations, GISPAM offers valuable practical benefits. Its multidimensional structure supports in identifying both particular areas for targeted improvements as well as the project's overall strengths and weakness. The model's clear scoring system can support policymakers, planners, and investors in decision-making, project selection, and resource allocation. Moreover, if the local data provided and priorities properly integrated, the GISPAM can adapt in difference urban context. By promoting balanced sustainability performance, GISPAM contributes to more effective, transparent, and impactful green infrastructure investments in cities.

8 Conclusion

This thesis presented the development and application of the GISPAM framework for assessing the sustainability performance of urban green infrastructure projects. Applied the model to three diverse case studies which are The Highline (USA), Cheonggyecheon Stream Restoration (South Korea), and The Madrid Rio (Spain). It was demonstrated that GISPAM effectively differentiates projects based on their multi-dimensional sustainability outcomes.

The comparative analysis reveled that integrated and strong approaches which are addressing environmental, social, economic and governance dimensions in balance results in the highest overall sustainability performance. Projects with strong community engagement, transparent governance, and strong planning consistently performed well those relying on more fragmented or sectoral strategies. Furthermore, the model's systematic structure allowed for the identification of both dimension and criteria-level strengths and weaknesses, supporting targeted improvement and spreading best practice.

Although GISPAM's effectiveness was explained, the thesis also acknowledged certain limitations, such as data availability. Still, GISPAM provides a valuable tool for policymakers, planners, and investors. Useful tool for design, evaluate and guide sustainable green infrastructure projects.

In the future, research can expand the framework to include more diverse case studies. It is possible to modify criteria for specific urban context, and incorporate new indicators. Continuity of collaboration between academia, government, and local communities can enhance the model and will be essential to advance sustainable urban development and maximize the impact of green infrastructure investments.

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