

CAPITAL UNIVERSITY OF SCIENCE AND
TECHNOLOGY, ISLAMABAD



**Development of a Framework for
Sustainable Building
Construction in Developed Cities
of Pakistan**

by

Asfar Ayub

A thesis submitted in partial fulfillment for the
degree of Master of Science

in the

**Faculty of Engineering
Department of Civil Engineering**

2025

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I dedicate my work to my wife, for believing in my abilities and tendering every support, to my kids for their undeterred emotional support and to my teachers who made me what I am today



CERTIFICATE OF APPROVAL

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Acknowledgement

All praise is due to Allah, the Most Merciful and the Most Beneficent. I am deeply grateful to Almighty Allah, who has blessed humanity with countless favors—one of the greatest being the gift of knowledge. I also extend my sincere gratitude to the Holy Prophet Muhammad (Peace Be Upon Him), whose teachings emphasized the pursuit of knowledge for the betterment of all creation.

My heartfelt thanks go to my supervisor, Dr. Muhammad Usman Farooqi, for his insightful guidance, unwavering support, and exceptional wisdom. His consistent encouragement and dedication throughout my MS program greatly influenced my growth as a student and researcher. It has been a privilege to work under his supervision. I also express my profound gratitude to Engr. Prof. Dr. Majid Ali, whose inspiration and steadfast support were pivotal in shaping my research journey and helping me overcome numerous challenges.

I am thankful to Engr. Kamran Jameel Bhatti for his valuable input and to all the industry professionals who generously participated in my survey—your practical insights significantly enriched this study. I also appreciate the constructive feedback of my thesis committee and the supportive academic environment provided by the Department of Civil Engineering at Capital University of Science and Technology. Finally, I owe heartfelt thanks to my family and friends for their constant support, patience, and encouragement throughout this academic journey.

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Abstract

The construction industry plays a vital role in shaping the built environment and driving economic growth. However, it also introduces significant environmental and social challenges, particularly in rapidly urbanizing areas. In cities such as Islamabad and Rawalpindi, the increasing strain on natural resources and ecosystems highlights the urgent need to adopt sustainable construction practices that promote long-term project viability and enhance community well-being.

To address these challenges, this research aimed to identify and prioritize sustainability indicators relevant to building construction in Pakistan's urban context. A mixed-methods approach was employed, beginning with a comprehensive literature review to gather indicators from both global benchmarks and local practices. A Delphi-based survey was then conducted with 50 experienced professionals from the construction industry. The collected data were analyzed using SPSS, applying Cronbach's Alpha, Shapiro-Wilk, and Kruskal-Wallis tests for reliability and significance. The Relative Importance Index (RII) was used to rank the indicators, and Confirmatory Factor Analysis (CFA) via AMOS software validated the framework's structure.

The study finalized 49 sustainability indicators, categorized under economic, environmental, and social dimensions. The resulting framework is both empirically grounded and statistically validated, offering practical value for developers, contractors, consultants, urban planners, and policymakers. It serves as a decision-support tool to guide sustainable practices in construction planning and policy implementation. By promoting informed decision-making and integrating key indicators into development processes, the framework supports a shift toward more resilient, equitable, and environmentally responsible construction in Pakistan's urban centers.

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Abbreviations

BCPs	Building Construction Projects
CDA	Capital Development Authority
ECN	Economical
ENVR	Environmental
GRI	Global Reporting Initiative
IRR	Internal Return of Return
KPIs	Key Performance Indicators
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MMC	Modern Methods of Construction
NPV	Net Present Value
PEC	Pakistan Engineering Council
RII	Relative Importance Index
ROI	Return on Investment
SC	Sustainable Construction
SCA	Strategic Choice Approach
SCL	Social
SCPs	Sustainable Construction Practices
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
WOS	Web of Science

Chapter 1

Introduction

1.1 Background of the Study

The construction industry in Rawalpindi and Islamabad, while pivotal to urban development and economic growth, has significantly contributed to environmental degradation through unsustainable practices. Rapid urbanization in these twin cities has led to substantial land-use changes, with Rawalpindi experiencing a 16.49% annual increase in built-up areas and Islamabad a 26.72% increase between 1990 and 2020, resulting in the loss of green spaces and a decline in forest carbon stocks in Rawalpindi[1]. Furthermore, improper solid waste management exacerbates environmental challenges; in Rawalpindi, only 17% of the city has adequate access to waste collection bins, leading to increased pollution and health hazards[2]. Occupational exposure to heavy metals among construction workers in Rawalpindi has also been documented, indicating inadequate safety measures and environmental controls within the industry[3]. These factors collectively threaten ecological stability and underscore the urgent need for sustainable construction practices and effective urban planning in the region. Sustainable building designs and practices are increasingly being adopted as a framework for creating environmentally friendly and cost-effective structures that improve occupants' quality of life[4]. In the light of increasing population growth and environmental degradation, the effective management of construction and infrastructure projects has become imperative to mitigate ecological impacts and curb pollution. Within this framework, sustainable development serves as a strategic approach to reduce environmental harm, enhance the economic

viability of projects, and advance social equity and occupant well-being[5]. There is a clear necessity for extensive development of the built environment and physical infrastructure in the so-called 'developing countries.' However, it is imperative that such development is undertaken in a manner that is both socially equitable and environmentally sustainable. There is a pressing need to implement sustainable interventions during the initial stages of built environment development, rather than attempting retroactive modifications. Nonetheless, the adoption of sustainable construction technologies and practices faces several challenges, necessitating the development of specific enablers to facilitate a transition toward a more sustainable trajectory in developing countries [6]. In recent years, sustainable building practices encompassing design, construction, and operation have garnered increasing attention. During the operational phase of a building's lifecycle, occupants and facility managers exert significant influence over energy consumption, water usage and waste generation, factors that substantially impact the building's overall environmental performance. Nonetheless, various obstacles may hinder the attainment of green building certification during a facility's operational phase, making the pursuit of sustainable development during this period particularly challenging. A critical initial step toward advancing sustainable construction practices and achieving long-term sustainability in the building sector involves identifying these challenges and formulating effective strategies to address them[7]. Survey results identified the five most significant barriers to the adoption of Modern Methods of Construction (MMC) as follows: limitations in design flexibility, elevated bidding prices demanded by contractors (resulting in higher initial costs), client skepticism and resistance to innovation and change, transportation constraints, and the absence of a universal design tool[8]. Furthermore, Gini's mean of dispersion indicated that a persistent concern hindering MMC adoption is the fear that architectural creativity may be compromised.

Securing green certification during the operational phases is essential for realizing the intended benefits of green buildings. The overarching objective of sustainable building development cannot be fulfilled if these structures fail to perform as designed or deliver the projected resource savings. Consequently, this study introduces a novel approach to identifying the factors that hinder the effective operationalization of green buildings[9]. The building sector continues to be a significant contributor to rising energy consumption and greenhouse gas emissions. Simultaneously, the transition toward clean energy sources is introducing greater complexity into the energy system. Existing tools and policy frameworks are often inadequate for managing this complexity, as

current infrastructure was not originally designed to accommodate large-scale, dynamic, and distributed energy resources. This situation underscores the urgent need to integrate emerging technologies to advance building energy management systems. The building sector contributes significantly to rising energy demand and emissions. Building footprints increase annually because of urbanization and population growth, which affects the environment with pollution and increases global warming. The major theme for the energy transition is the decentralization of the electrical grid due to the increase in small-scale distributed renewable energy sources, wind, solar, and electrical vehicle technologies[10].

As urbanization accelerates, particularly in developing countries like Pakistan, the need for sustainable construction practices in major cities is more urgent than ever. Developed cities such as Rawalpindi and Islamabad are experiencing rapid infrastructure growth, often at the expense of environmental sustainability. Despite growing awareness of green building initiatives, the adoption of sustainable construction practices in Pakistan remains limited due to high costs, lack of expertise, and weak regulatory enforcement. This study aims to explore the current state of sustainable building construction in developed cities of Pakistan, identify key barriers, and propose a comprehensive framework to enhance its adoption. This research is focused on identifying the key barriers and enablers associated with the implementation of sustainable construction practices in the developed urban centers of Pakistan. As cities continue to experience rapid urbanization and infrastructure growth, ensuring sustainability across the life cycle of buildings; design, construction, and operation, has become increasingly critical. However, despite growing awareness, numerous challenges impede the adoption of sustainable practices, while enabling factors remain underexplored or underutilized. The primary objective of this study is to develop a comprehensive framework that can guide project managers and other stakeholders in integrating sustainability principles at various stages of building development. This includes the design phase, where critical decisions about materials and energy efficiency are made; the execution phase, where construction techniques and project management practices come into play; and the operational phase, which influences the long-term environmental performance of the building. To achieve this, the research will employ a systematic data collection approach through surveys targeted at construction industry professionals, consultants, and policy makers operating in Pakistan's developed urban centers, such as Islamabad, and Rawalpindi. The aim of these surveys is to gather insights on existing sustainability barriers, identify effective enabling

factors, and understand the practical challenges faced on the ground. Based on the findings, the study will propose a practical and adaptable framework designed to support sustainable building construction practices in the context of Pakistan's urban environment. This framework will aim to equip project managers with actionable tools, techniques, and decision-making strategies that are context-specific, feasible, and scalable within the local construction industry. Ultimately, this research aspires to contribute to the national discourse on sustainable urban development by offering evidence-based recommendations that can enhance policy, improve construction practices, and promote long-term environmental stewardship in the built environment of Pakistan's developed cities.

1.2 Research Motivation and Problem Statement

The growing global emphasis on sustainable construction in developed cities of advanced countries has demonstrated significant success in minimizing environmental degradation, optimizing resource utilization, and enhancing urban livability. Countries such as Germany, United States, and Singapore have widely adopted green building certifications like LEED, BREEAM, and DGNB, integrating sustainability at both policy and practice levels [11–13]. These successful models have inspired to investigate how similar frameworks and technologies can be adopted for implementation in Pakistan. Recognizing the environmental challenges and rapid urbanization in cities like Islamabad and Rawalpindi, this research is motivated by the need to bridge the gap between global best practices and local construction realities, fostering a shift toward more sustainable urban development in Pakistan [14, 15].

Figure 1.1 shows the Bosco Verticale (Vertical Forest) in Milan, Italy—an exemplary model of urban sustainable architecture. The image captures two high-rise towers densely covered with vegetation, where trees, shrubs, and various plants are integrated into the building's balconies at every level. This vertical greenery not only creates a striking visual impact but also serves functional purposes such as improving air quality, reducing urban heat, providing noise insulation, and supporting biodiversity in a dense urban setting. The façade appears to blur the boundary between built and natural environments, symbolizing a harmonious coexistence between architecture and ecology. The image highlights how high-rise residential buildings can transform into living ecosystems



FIGURE 1.1: Bosco Verticale (Vertical Forest), Milan – a model of sustainable high-rise architecture integrating over 900 trees and 20,000 plants on its facade, enhancing biodiversity, air quality, and energy efficiency [16].

by rethinking the role of greenery in architectural design [16]. The problem statement is as follows: *The construction industry in Rawalpindi and Islamabad, though vital for urban development, has contributed to significant environmental degradation. Rapid urbanization has resulted in land-use changes, loss of green spaces, and a decline in forest carbon stocks, particularly in Rawalpindi. Additionally, inadequate solid waste management has led to increased pollution and public health risks. These issues highlight the urgent need for sustainable construction practices and integrated urban planning in the region.*

1.2.1 Research Questions

This study addresses the following research questions:

1. What are the barriers in implementation of sustainable building construction practices in Pakistan?
2. What are the enablers for implementation of sustainable building construction?
3. What kind of Framework for building construction in developed cities of Pakistan would be viable?

1.3 Overall Aim of the Research Program, Objectives and Specific Aim of this MS Thesis

The primary aim of this research is to promote sustainability across construction projects of varying scales by developing a comprehensive framework of sustainability indicators. However, the specific objectives of this study are to:

- Identify and categorize key sustainability indicators relevant to building construction in developed urban centers of Pakistan.
- Develop a context-specific sustainability framework based on four dimensions: strategic-economic, social, environmental, and long-term value.
- Validate and refine the framework using expert input (Delphi technique), statistical analysis, and stakeholder feedback for practical applicability.

1.4 Scope and Limitations

The scope of this research is confined to building construction projects currently underway or recently completed in the urban regions of Rawalpindi and Islamabad. The study includes both commercial and residential developments initiated by public sector bodies (e.g., government departments, development authorities) as well as private sector entities (e.g., real estate developers, contractors, and housing societies). Key focus areas include:

- The extent of integration of sustainability principles in planning, design, construction, and operation phases.
- Identification of sustainability indicators relevant to the local context.
- Evaluation of regulatory compliance and stakeholder awareness related to sustainable construction.
- Development of a sustainability framework tailored to the needs of building construction in urban Pakistan.

The research is limited by the availability of reliable data, financial constraints, and the willingness of industry stakeholders to participate in surveys and interviews.

1.4.1 Rationale for Variable Selection

Sustainability indicators have gained increasing prominence in the context of construction projects due to their critical role in promoting sustainable development. These indicators serve as essential tools for assessing and guiding the integration of sustainability principles throughout the lifecycle of a project. By capturing multiple interrelated effects through a single measurable variable, sustainability indicators help monitor and evaluate the broader impact of construction practices. Previous research in developed countries has demonstrated the effectiveness of sustainability indicators in addressing key challenges faced by building construction projects (BCPs). However, similar issues persist in developing countries, such as Pakistan, where the adoption of sustainability indicators remains limited. There is a pressing need to explore and adapt these indicators to the local context in order to address the unique problems associated with BCPs in developing urban environments. This study aims to identify and utilize the most relevant sustainability indicators that have the potential to enhance sustainability performance in building construction projects, thereby contributing to more environmentally responsible and resource-efficient building practices.

1.5 Novelty of Work, Research Significance and Practical Implementation

To date, limited research has been conducted on the development of sustainability frameworks specifically in the context of building construction within the developed cities of Pakistan. While numerous studies have explored sustainability in construction projects more broadly, often through the identification of critical success factors and relative sustainability indicators, there remains a noticeable gap in addressing the unique challenges of building construction projects (BCPs) in urban centers such as Rawalpindi and Islamabad. Achieving sustainability in BCPs remains particularly challenging due to the absence of a structured framework tailored to the local context. Without such a

framework, construction activities may continue to contribute to environmental degradation, inefficient resource use, and increased project risks. Therefore, this study aims to develop a comprehensive and context-specific framework of sustainability indicators that can be implemented during the design, execution, and operational phases of construction projects in Pakistan's developed cities. The implementation of relevant and well-defined sustainability indicators has the potential to enhance project performance by fostering environmentally responsible construction practices, minimizing waste generation, reducing delays and cost overruns, and addressing hidden inefficiencies. Such indicators can also support the creation of high-performance, energy-efficient, and environmentally sustainable urban environments, which are essential for long-term national development. Although various studies have been conducted to address the construction industry's sustainability challenges in developing countries, progress has often been hindered by insufficient monitoring mechanisms and a narrow focus on organizational planning alone. In the context of Pakistan, there is still a lack of awareness and practical knowledge regarding the role of sustainability indicators, particularly within small-scale building projects in major cities. This research seeks to bridge that gap by identifying and promoting the most relevant sustainability indicators for use in urban construction projects. By doing so, it aims to support industry stakeholders in improving project outcomes and achieving higher sustainability performance. The findings of this study are expected to serve as practical guidelines and strategic tools for construction professionals, policymakers, and researchers. They will offer a clearer understanding of how sustainability can be integrated effectively into building practices, ultimately contributing to a more resilient and sustainable construction sector in Pakistan.

1.6 Brief Research Methodology

The research methodology is structured in a series of systematic steps. Initially, a comprehensive review of existing literature is undertaken to identify the research gap and to establish a theoretical foundation for the study. This is followed by the identification of key sustainability indicators relevant to the construction sector. Based on these indicators, a structured questionnaire survey is developed and administered to industry professionals to gather empirical data for the formulation of an appropriate sustainability indicator framework. The collected data is analyzed using statistical tools in SPSS to

derive meaningful insights. Finally, conclusions are drawn and recommendations are proposed based on the analytical findings

1.7 Thesis Outline

This research study is organized into six chapters, each addressing a key component of the overall investigation:

- Chapter 1 provides an introduction and background to the research, outlining the problem statement, research objectives, scope, limitations, and a brief overview of the methodology, along with the structure of the thesis.
- Chapter 2 presents a comprehensive review of relevant literature. It explores the concept of sustainability in construction, challenges faced by building construction projects in both developed and developing countries, and the role of sustainability indicators. This chapter also highlights the research gap that this study aims to address.
- Chapter 3 details the research methodology. It outlines the research design, data collection methods, and analytical techniques employed in the study.
- Chapter 4 presents the results obtained through data analysis and provides a critical discussion of the findings in relation to the research objectives.
- Chapter 5 offers practical guidelines and implications derived from the research, with a focus on the implementation of sustainability indicators in construction projects.
- Chapter 6 concludes the study by summarizing key findings and providing recommendations for future research and policy development.
- The thesis also includes a list of references and relevant appendix to support the content presented in each chapter.

Chapter 2

Literature Review

2.1 Background

In the current era, developed cities in Pakistan are undergoing significant expansion to meet the growing demands of their increasing populations. This urban growth is closely linked to construction activities, which consequently generate construction waste, emit pollutant gases, and pose threats to the surrounding flora and fauna. Numerous studies have been conducted to gain a deeper understanding of the challenges encountered during execution of building construction projects(BCPs), particularly in the areas of managerial competence, planning, and safety. These challenges significantly influence the overall success or failure of construction projects, particularly for building construction. As a result, there is a pressing need to integrate sustainable construction principles and practices to ensure long-term viability and resilience. Research aimed at minimizing the environmental impact of the construction industry has identified several key areas for further exploration. Sustainable construction practices primarily focus on reducing environmental degradation and often incorporate strategies such as waste minimization, reuse, and efficient resource management. While these practices deliver substantial societal benefits, they tend to prioritize ecological sustainability over profit maximization. To effectively assess the sustainability performance of building construction projects(BCPs), it is essential to establish a comprehensive framework of sustainability indicators. These indicators should encompass various dimensions, including energy consumption, waste management, cost control mechanisms, planning efficiency, and water

usage. Such a framework will enable a more structured evaluation of sustainability in construction and support the transition toward more responsible and environmentally conscious building practices.

2.2 Sustainable Construction Practices in Building Construction Projects

In recent years, sustainable building practices, encompassing the design, construction, and operational phases, have received increasing attention. During the operational phase of a building's lifecycle, occupants and facility managers play a critical role in influencing key factors such as energy consumption, water usage, and waste generation. These operational choices significantly impact the overall environmental performance of the building[7]. Building contractors face a range of obstacles across several domains, including financial, political, managerial, operational, human resources, and material and equipment-related constraints. Among the most significant barriers identified by respondents are the high initial costs associated with acquiring advanced technologies and equipment, extended payback periods for sustainability-related investments, inadequate enforcement of sustainable building codes and regulations, uncertainty regarding the consistent availability of projects in the sustainable construction domain, and the absence of a structured framework for implementation[17]. Malik et.al [18] investigated that sustainability has emerged as a fundamental aspect of contemporary construction practices, driven by the imperative to reduce the negative impacts of construction on the environment, society, and the economy. Achieving sustainability in construction involves the efficient management of buildings, organizations, and resources to satisfy both present and future needs, while proactively addressing potential challenges over the short and long term[19]. One of the primary concerns in achieving infrastructure sustainability within the construction industry is the adoption of sustainable construction practices. The analysis results indicated that all 25 identified challenges were critical and significantly affected the adoption and implementation of sustainable construction practices (SCPs) within Malawi's construction sector. Among the most prominent challenges were the high costs associated with sustainable building processes and materials, as well as a lack of accessible information on sustainable construction products[15]. These findings highlight the urgent need for government intervention in the form of financial

incentives and support mechanisms to encourage contractors to integrate sustainable practices during project execution.

Furthermore, the establishment of a centralized national construction database to disseminate reliable information, along with targeted awareness campaigns, could greatly enhance the uptake of SCPs across the industry. Factor analysis revealed five key challenge components, institutional limitations, insufficient technical expertise, lack of knowledge and information, and operational and financial constraints. Institutional limitations emerged as the most significant barrier, followed by limited technical experience, while financial issues were found to be the least critical among the five[20]. This underscores the importance of policy reforms and capacity-building initiatives for professionals, aiming to develop a supportive regulatory environment and strengthen institutional capabilities for promoting sustainable construction. Training programs tailored to SCPs, delivered through governmental and professional bodies, are essential to improve industry expertise and bridge existing knowledge gaps. Overall, the study not only contributed to the limited body of knowledge on SCP-related challenges in low-income nations but also offered valuable insights for advocates and international organizations working to promote sustainable infrastructure development in Malawi. These findings can inform strategic planning and policy formulation aimed at fostering resilient and environmentally responsible construction practices. Aghimien et al.[21] conducted a study that employed a quantitative survey methodology, utilizing a structured questionnaire to gather data from quantity surveyors, construction professionals, and project managers in Nigeria and South Africa. The collected data was analyzed through a four-step analytical process, incorporating appropriate descriptive and inferential statistical methods. The study indicated a significant level of awareness and engagement with sustainable construction practices (SCPs) among the professionals surveyed. It was found that SC materials are predominantly utilized in surface finishing and masonry works. Additionally, the research identified key challenges to the adoption of SCPs, including resistance to change, client preferences, concerns over higher investment costs, and limited knowledge and understanding of sustainability concepts in the respective countries. These insights underscore the urgent need for enhanced training programs to bridge knowledge gaps in sustainability. Encouraging innovation and cost-effective alternatives could also mitigate clients' concerns regarding investment. Furthermore, policymakers must play an active role in creating incentives and robust frameworks that support sustainable transitions.

Cross-country collaborations may also be very effective in sharing successful strategies and overcoming common implementation barriers.

2.2.1 Barriers in Adoption of Sustainable Building Construction in Developed Countries

Vaghefi-Rezaee et al. [22] investigated that although the concept of sustainability has been applied across various industries for decades and brings added value to construction, sustainable building practices are still in the early stages of adoption. Notably, there are clear differences in how sustainability is defined, prioritized, and approached between developed and developing nations. While rising energy costs have contributed to increased support for sustainable technologies, the implementation of such practices continues to face significant obstacles[23, 24].

The challenges associated with sustainable construction span the design, execution, and operational phases of projects. A key issue is the limited awareness among stakeholders regarding these barriers, which has led to hesitancy in adopting sustainable approaches. Therefore, detailed investigations into the challenges and a clearer roadmap for implementation are essential for advancing sustainability within the industry. The study highlighted the extent and complexity of issues surrounding sustainable construction, offering insights into how the topic is approached in different contexts. Despite being in a relatively early stage, sustainable construction presents a promising alternative to traditional practices. The integration of renewable energy sources into building designs is essential for creating resilient infrastructure that prioritizes environmental harmony, human health, and the well-being of future generations. As shown in Figure 2.1 , the most significant barriers to industrialised building adoption relate to collaboration, financial, and technological challenges[25].

A survey conducted by Zhang, Y et al.[26] revealed that The United States, the United Kingdom, Europe, and other Western nations have entered a mature phase in sustainable building development. Their current focus is on integrating intelligent green building (GB) technologies to create smart and "healthy" buildings—an approach championed by the International WELL Building Institute (IWBI). These efforts aim to address economic and social challenges that arise from technological mismatches and limited public



FIGURE 2.1: Barriers for Sustainable Construction in Australia [25]

awareness. Japan, while already equipped with a comprehensive set of laws, regulations, and policies, continues to refine its framework in response to ongoing advancements. In China, green building has emerged as a national strategic priority, playing a key role in steering the construction sector toward sustainable development. However, there exists a regional disparity in the adoption of green building practices due to uneven economic development across provinces. Eastern nations like Japan and China primarily promote green building through centralized government initiatives[26].

In contrast, Western countries, including the United States, rely on a combination of federal, state, and local zoning regulations, as well as building standards set by independent organizations. Despite notable progress across various regions, a shared challenge persists: the absence of a structured social education framework. Such a framework is crucial to raising awareness and equipping stakeholders with the knowledge necessary to effectively integrate green building concepts throughout the entire building lifecycle. During a study conducted by Dalirazar et al.[27] it was revealed that the construction industry experienced rapid growth and played a crucial role in the economic development of nations. It significantly enhanced the quality of life by providing essential socio-economic infrastructure, such as roads, hospitals, schools, and other basic and advanced facilities. However, this growth also brought environmental and social challenges. Many construction projects were designed in a traditional manner, often without considering energy efficiency, environmental impacts, or the conservation of natural resources. As a result, this led to excessive waste generation and posed a threat to ecological integrity. Throughout its life cycle, the construction industry consumed vast amounts of resources

and produced substantial waste and pollution. Buildings, in particular, contributed significantly to carbon dioxide (CO₂) emissions, which accelerated global warming and triggered more extreme weather conditions worldwide. Abdullah et al.[28] investigated that the construction industry in developing countries continues to grapple with enduring challenges such as inadequate funding, underdeveloped infrastructure, limited technological integration, and ineffective quality management. These factors contribute to diminished productivity, compromised safety standards, and reduced operational efficiency, frequently leading to project delays, budget overruns, and subpar construction outcomes.

2.2.2 Barriers in Adoption of Sustainable Building Construction in Developing Countries

The construction industry in developing countries continues to face persistent challenges, including inadequate funding, poor infrastructure, limited adoption of modern technologies, and weak quality management practices. These issues contribute to reduced productivity, compromised safety, and lower efficiency, often resulting in project delays, cost overruns, and substandard construction outcomes. Among the top five risk factors identified are: insufficient green construction codes and regulations, limited knowledge and awareness of sustainable practices, skill shortages, and funding gaps primarily driven by low market interest, all of which deter meaningful investment in sustainable construction[29]. The study further highlights that the most severe challenges have been observed in Qatar, along with similar patterns in the UAE, Singapore, Ghana, the United States, Turkey, and Oman.

Ranking analysis in recent studies has identified 20 critical barriers to sustainable construction. The three most significant among them are: high costs of green building technologies (GBTs), lack of government incentives, and limited access to financing options such as bank loans. A comparative analysis revealed that, although the barriers differ across countries, such as Ghana, the United States, Canada, and Australia, the high cost of GBTs remains a consistent challenge[30]. In many developing countries, sustainability is often overlooked due to unstable economies, monopolistic practices, and insufficient or poorly implemented policies. Emerging research underscores the urgent need for sustainable construction, noting that traditional practices in these regions frequently lead

to resource depletion, environmental degradation, and negative health impacts for stakeholders. Venezuela serves as a case in point, where political and economic crises further compound these issues[31]. In addition, sustainability is not yet fully embraced or understood in much of the construction sector in developing nations. Statistical analyzes have identified five key barriers: project manager incompetence, lack of access to sustainable materials and technologies, resistance to change, lack of government incentives, and low adoption of sustainable practices[32]. A comprehensive literature review suggests that developed countries are far more advanced in adopting sustainable construction practices compared to their developing counterparts. Successful implementation in these regions often hinges on strong stakeholder collaboration. In Nigeria, five major barriers have been highlighted: inadequate government support, absence of relevant laws, low client demand, limited public awareness, and perceived high implementation costs. Factors such as inadequate training and weak local institutional structures were considered less significant[33].

Another critical challenge is the volume of construction and demolition waste (C&DW) and its poor management, which negatively impacts sustainability. Barriers to effective C&DW management have been identified in the UK, Saudi Arabia, Egypt, and Ghana. Eleven key obstacles, classified using the relative importance index (RII), include institutional fragmentation, lack of C&DW data, weak law enforcement, sociopolitical and technological constraints, and inflexible construction practices [34]. Survey results indicate that the most pressing barrier is the general lack of public awareness regarding the benefits of green building. This is followed by the absence of government incentives and the lack of formal green building codes and regulations. The study recommended raising public awareness through seminars and workshops, the enforcement of green codes, and financial incentives such as soft loans and tax benefits[35]. According to Darko et al.[36], government-related issues are a major hindrance to GBT adoption, while company-driven motivations positively impact uptake. Their research suggests that effective strategies include enacting regulatory standards and offering R&D support and incentives. Ametepey et al.[37] categorized barriers to sustainable construction into six groups: financial (e.g., high initial costs, lack of financing), political (e.g., weak legislation, insufficient policies), managerial (e.g., lack of leadership, slow decision-making), technical (e.g., absence of tools, material shortages), socio-cultural (e.g., resistance to change), and knowledge-related barriers (e.g., misconceptions, lack of training). Lastly, Nikyema and Blouin[38] grouped barriers into five overarching categories: government-related, human

capacity-related, informational, market-based, and cost or risk-related barriers. Small and medium-sized building construction practices in developing countries remain largely underdeveloped due to limited access to capital, high financing costs, and insufficient government support programs, making it difficult for them to compete internationally. There is also a notable shortage of skilled labor. The key factors influencing the growth of sustainable construction practices in these regions are access to funding, availability of skilled workers, and adequate government support. The lack of these resources and facilities hinders their ability to adopt sustainable practices. The survival, growth, and expansion of sustainable building construction practices are essential for economic development and job creation in emerging economies. Regulatory processes play a crucial role in distributing resources and opportunities within a country. For example, in Malaysia, the government has proactively implemented procurement policies as strategic tools to foster inclusive development. These policies aim not only to empower local communities but also to enhance workforce capabilities through targeted upskilling programs. Additionally, they facilitate the equitable allocation of resources to ensure that the socio-economic benefits of construction and infrastructure projects are widely distributed across the population[30, 31]. .

2.3 Enablers for Sustainable Construction Practices in Building Construction Projects

Globally, the findings showed a marked increase in research interest over the past decade, especially since 2018, with Asia, Europe, and North America at the forefront. Key enablers identified include advancements in technology and innovation, sustainable and environmental practices, supportive government policies, favorable economic and market conditions, and effective collaboration and stakeholder engagement. Conversely, major barriers include challenges in collaboration and stakeholder engagement, economic and financial constraints, issues related to technology and innovation, and insufficient government support and policy. Notably, factors such as technology and innovation were found to act as both enablers and barriers, underscoring the complex and multifaceted nature of industrialized building (IB) adoption[25]. Firstly, prioritizing a sustainable culture and the use of renewable natural resources has become fundamental in contemporary

organizational strategies. Embedding sustainability and resource management into the core values of an organization greatly influences the development of innovative business models and internal innovation processes. This integration is crucial for fostering both innovation and organizational resilience. The strong impact of a sustainable culture and renewable resources on energy and resource consumption, as well as sustainable design, underscores their vital role in achieving environmental benefits. Additionally, closed-loop systems that emphasize recycling, reusing, and waste reduction are closely aligned with a sustainable culture, significantly contributing to reduced resource use and improved overall sustainability [10].

Data security and the maintenance of consistent data flow are essential for effective communication and strategic alignment within organizations. Reliable and secure data management supports robust communication channels and ensures that strategic objectives are aligned across all levels. This highlighted the need for strong IT infrastructure and sound data governance policies to enable smooth information exchange and coordination. For example, blockchain technology, with its decentralized ledger, enhances data security by making information tamper-proof and transparent, thereby reducing the risk of data breaches. This is critical for boosting operational efficiency and profitability by protecting sensitive information and ensuring dependable data flow. Internal innovation processes and the adoption of innovative business models are key drivers of various organizational benefits[39].

Cultivating an innovative internal environment leads to improvements in energy efficiency, resource management, and profitability. Business models that incorporate circular economy principles not only enhance profitability but also support sustainability, though their direct impact on flexibility and job quality may require more focused strategies to improve operational adaptability and workforce engagement[40]. The commitment of top management and the development of collaborative networks are crucial for the successful implementation of sustainable and innovative practices. Leadership from top management provides the necessary direction and resources, while collaborative networks bring diverse perspectives and shared expertise, facilitating effective implementation and ongoing improvement. Top management's commitment is particularly important for ensuring high quality and profitability, highlighting its central role in advancing sustainable and innovative initiatives[41]. Strategic alignment and effective communication are among the most significant enablers for achieving organizational

benefits. Aligning strategies with market needs and internal strengths is essential for delivering high quality, profitability, and timely responses to market changes. Effective communication ensures that all organizational efforts are coordinated toward achieving strategic objectives. For instance, blockchain technology can enhance strategic alignment by providing a transparent and secure platform for communication, ensuring all stakeholders have access to accurate and current information. These factors emphasize the importance of aligning internal processes and communication systems with broader organizational strategies to achieve optimal results. Finally, collaborative networks have a moderate to high impact, especially in strengthening workforce capabilities and improving societal outcomes. External partnerships and collaborations are vital for generating societal benefits and enhancing workforce skills.

However, to maximize their effectiveness, these partnerships must be strategically integrated with internal processes[39]. The study identified three key enablers for Design outWaste (DoW) practices: effective communication and coordination, the use of Building Information Modelling (BIM), and the adoption of prefabrication, precast, and 3D printing technologies. Among these, effective communication and coordination stood out as the most impactful, highlighting the importance of clear and collaborative channels among multidisciplinary design teams. Strong communication helps bridge gaps between stakeholders, ensuring smooth integration of design changes and waste reduction strategies throughout the project lifecycle. It also has the potential to address and reduce negative perceptions among designers, encouraging greater acceptance of DoW practices. Similarly, BIM serves as a collaborative platform that enables project teams to share detailed design and construction information, improving coordination and minimizing errors. By facilitating real-time updates and design modifications, BIM streamlines the process of implementing design changes and reduces the likelihood of mistakes or conflicts that can occur with manual revisions. Additionally, BIM supports the management of complex designs by providing a virtual model, allowing stakeholders to better visualize and analyze the project[42]. The structural analysis of the resulting CBM system model highlighted the critical importance of three key factors: effective information dissemination, certification of projects and products, and comprehensive professional training and education[43].The discussion by Sajane, S.S., et al. underscores the link between green construction and energy-efficient design in the context of resource depletion and climate change. It addresses the environmental issues associated with conventional building methods and emphasizes the growing movement toward

sustainable development. The advantages of energy-efficient building design and green construction are explored, highlighting economic, environmental, and social benefits. Key topics discussed in research include smart home technologies, Building Information Modeling (BIM), life cycle assessment, water efficiency strategies, and certification systems such as LEED and BREEAM[44].

2.3.1 Enablers for Sustainable Building Construction Practices in Developed Countries

Daoud, A.O., et al. emphasized critical enablers like digital transformation skills, eco-innovation, and active government support. The findings showed that these Industry 5 factors play a significant role in improving environmental resilience, promoting social inclusivity, and increasing economic efficiency in infrastructure projects[45]. The five most influential smart city components impacting the construction industry were identified as technology and IT infrastructure, the environment, people, the economy, and governance[46]. The findings by Ahmed, S., et al. indicated that the most critical enablers of Data-driven sustainable quality management are enthusiasm and commitment from top management, crowdfunding, the use of advanced quality analytics, and the implementation of data-driven lean and green initiatives[47]. Incorporating comprehensive lifecycle assessments, innovative technologies, and advanced building materials is essential for achieving global carbon reduction targets and minimizing the environmental impact of buildings. While there has been significant progress in understanding NZCB (Net Zero Carbon Building) strategies, further research and practical initiatives are needed to address existing gaps and challenges across various building types, life-cycle stages, and regional contexts. Effective policies can shape public behavior and influence stakeholder practices, driving demand for sustainable construction. Robust policy frameworks should provide clear definitions, financial incentives, technological support, and strong enforcement measures. Figure 2.2 illustrates the distribution of enabling factors, highlighting the dominant role of technology and innovation, alongside sustainability, policy, and stakeholder engagement in facilitating industrialised building uptake [25]. Additionally, ongoing monitoring, adaptive policy approaches, and collaborative efforts are vital for realizing long-term sustainability objectives[48]. The key actions to advance sustainable building include raising client awareness of its benefits,

Enablers

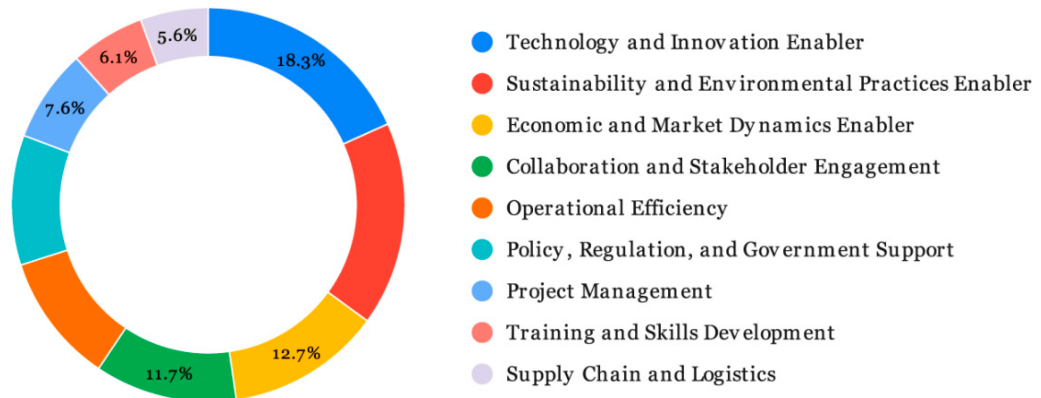


FIGURE 2.2: Enablers of Sustainable Construction in Australia[25]

adopting effective methods for managing sustainability requirements, utilizing sustainable building tools, enhancing designers' skills and collaboration, and developing innovative concepts and services[49]. Melchert examined how the Netherlands developed and implemented a successful sustainable building policy framework, and the lessons that developing countries could draw from this experience. In his review, he demonstrated how policies evolved from a somewhat controversial discourse on 'de-modernization' to a more widely accepted approach rooted in the rationale of 'ecological modernization.' Drawing on empirical cases of green buildings, he argued that, while in the 1970s green building solutions in the Netherlands were often locally based, low-tech, and designed to disconnect from existing infrastructure networks, contemporary green building practices focus more broadly on improving environmental performance, regardless of technological complexity or the degree of connectivity to main infrastructure systems[50]. Circular building design incorporates strategies like design for disassembly (DfD) to enable future repairs, remanufacturing, and reuse of components, as well as adaptive reuse of buildings and the integration of salvaged materials into new construction[51].

2.3.2 Enablers for Sustainable Building Construction Practices in Developing Countries

Construction management by incorporating sustainable planning, design, and building practices within the built environment; and sustainable construction by promoting the use of integrated project delivery methods and encouraging sustainable training and

practices, particularly in developing countries[31]. The Agenda 21 for Sustainable Construction in Developing Countries proposed a strategy to tackle these challenges by formulating a Research and Development Agenda structured around a matrix of short, medium, and long-term technological, institutional, and value-based enablers[6]. To ensure that a district functions as the highest administrative and legislative authority at the local level in promoting socio-economic development, the establishment of new districts must be carried out comprehensively, with all key departments in place. Strengthening the financial resilience of these districts is essential to secure the necessary resources for implementing development projects and programs. Additionally, the capacity of key institutions must be developed to effectively manage all aspects of local gov concepts, making them widely understood and accepted by all. As a vital tool, education enhances the public's capacity to address environmental and developmental challenges, thereby raising awareness among stakeholders throughout the construction process as well as the general public. To further support sustainable practices, planning and construction initiatives should be guided by adapted regulations, standards, fiscal measures, and incentives. Building owners and clients have a crucial role in promoting and disseminating sustainable construction practices. A shared understanding of sustainable construction, supported by common definitions and language, is essential for effectively addressing related issues. Designers are encouraged to adopt an integrated design approach, while improvements to traditional construction methods should focus on enhancing overall process efficiency. Building users should recognize environmental responsibility as a component of productivity. Manufacturers of building materials and products should base development on life cycle considerations, and maintenance organizations must view environmental awareness as a competitive advantage. Additionally, developing practical tools to support decision-making is key to advancing sustainability in the built environment[52]. The results of this investigation indicated that agility, information sharing, strategic risk planning, corporate social responsibility, and visibility were the primary enablers of resilience in Rural Supply Chain Management (RSSCM) in developing countries. These enablers played a vital role in enabling organizations to develop proactive strategies for mitigating the impacts of disruptions in supply chains, thereby enhancing their resilience and adaptability in construction projects[53].

The findings signified that the most significant driving enablers were government support and incentives, availability of financial resources, top-management determination to enhance sustainability, and organizational capability and quality maturity level for

GLS operations[54]. The findings of the study signified that the most significant driving enablers for Green Logistics Services (GLS) operations were government support and incentives, availability of financial resources, top-management determination to enhance sustainability, and organizational capability and quality maturity level. These enablers played a crucial role in facilitating the successful implementation of GLS operations, and their presence was found to have a positive impact on the overall sustainability of the organization. The government support and incentives provided a favorable environment for the adoption of GLS practices, while the availability of financial resources enabled organizations to invest in the necessary infrastructure and technology. Furthermore, the top-management determination to enhance sustainability was found to be a key driver of GLS operations, as it demonstrated a commitment to reducing the organization's environmental footprint. Finally, the organizational capability and quality maturity level were also found to be essential enablers, as they enabled organizations to effectively manage and improve their GLS operations over time[55].

2.4 Building Construction Projects in Developed Cities

Cities must implement comprehensive urban policies that emphasize sustainability by integrating eco-friendly construction methods and community-oriented design principles. Such policies should holistically address the environmental, social, and economic dimensions of urban development to foster resilient and sustainable environments[56]. To encourage widespread adoption of green practices, governments and local authorities can introduce financial incentives, such as tax reductions, grants, or subsidies, linked to the attainment and maintenance of recognized green building certifications. These measures can stimulate active participation from the private sector in sustainable urban initiatives. Urban planners and architects are encouraged to conduct inclusive design workshops involving community stakeholders. This participatory approach ensures that diverse needs and perspectives are incorporated into planning processes, fostering a sense of ownership and pride among residents. Sustainable urban development should also prioritize investment in efficient, accessible public transportation networks[57]. Enhancing public transit reduces dependency on private vehicles, mitigates carbon emissions, eases traffic congestion, and improves overall mobility. Moreover, zoning laws should support

mixed-use developments that integrate residential, commercial, and recreational facilities. This strategy reduces commuting requirements and cultivates dynamic, walkable neighborhoods that enhance social cohesion and community interaction. Finally, sustained investment in research and innovation is essential[58]. Governments and academic institutions should support initiatives exploring novel eco-friendly materials, energy-efficient technologies, and creative design solutions aimed at enhancing quality of life within urban environments. As urban populations expand, the demand for sustainable strategies becomes ever more critical to mitigate environmental issues, improve community well-being, and advance social equity. Incorporating renewable energy systems, environmentally friendly building materials, and energy-efficient technologies reflects a strong commitment to minimizing the ecological impact of urban development[59]. Cities should implement comprehensive urban policies that prioritize sustainability through the integration of environmentally friendly building practices and community-centered design. These policies must consider the interdependence of environmental, social, and economic dimensions to foster resilient and well-rounded urban ecosystems[60].

Governments and municipal authorities can promote the adoption of green building practices by offering financial incentives—such as tax relief, grants, or subsidies—tied to the attainment and upkeep of certified green standards. These strategies serve to actively engage the private sector in driving sustainable urban development. Urban planners and architects should engage local communities through inclusive design workshops, ensuring that diverse perspectives and needs are incorporated into the planning process and fostering a sense of ownership and community pride[61]. Prioritizing investment in efficient and accessible public transportation systems is essential for sustainable urban design, as it reduces reliance on private vehicles, lowers carbon emissions, alleviates traffic congestion, and improves mobility. Zoning regulations should support mixed-use developments that combine residential, commercial, and recreational spaces, thereby minimizing commuting needs while creating dynamic, walkable neighborhoods that encourage social interaction and community engagement. Additionally, governments and institutions must allocate resources for research and innovation in sustainable urban design, supporting initiatives that explore new eco-friendly building materials, energy-efficient technologies, and creative strategies for enhancing well-being in urban environments, ultimately driving the development of more sustainable and equitable cities[60]. The research utilized the structural equation modeling (SEM) approach to analyze key drivers influencing the adoption of sustainable construction technologies

(SCTs). The results revealed that cost-efficiency, energy savings, economic viability, environmental considerations, and industry-related dynamics serve as significant motivators for adopting these technologies. The study also confirmed the growing popularity of smart technologies, largely due to their potential to reduce costs, minimize energy consumption, and lessen environmental impact. Based on these insights, the study recommends that government bodies take a proactive role in promoting the widespread implementation of SCTs[62]. The research provided stakeholders with a practical and accessible tool to assess the feasibility of implementing a Construction Consolidation Centre (CCC) in urban settings, particularly in connection with building construction projects. This tool enhances understanding of the sustainability implications associated with such implementations. Among the evaluation criteria, two attributes emerged as particularly significant: the projected operational costs for construction companies (A2) and the potential demand level within the area (A3). Construction managers can gain valuable insights into the sustainability performance of their projects through the analysis of 14 attributes and 45 indicators. Case study findings revealed that Paris was the only construction project deemed suitable for CCC implementation, with all attributes meeting or exceeding recommended thresholds. However, improvements were still necessary in areas related to sustainability—economic, social, and environmental—as well as technological advancements[63].

2.4.1 Building Construction Projects in Developed Cities of Developed Countries

Smart city construction has driven the growth and clustering of emerging industries, providing fresh impetus to the expansion of the digital economy. As the digital economy and information technologies continue to advance, the development of smart cities has increasingly become a key trend shaping the future of urban development[64]. The urban expansion that occurred during the boom period can be characterized as unsustainable development. It was primarily focused on meeting the immediate demands of that era, while compromising the ability of future generations, who are now the present, to fulfill their own needs. In the context of urban development, an equilibrium point in housing production can be defined as the level at which supply aligns with the typical, ongoing demand. When housing production exceeds this equilibrium and is financed through

debt, it effectively means that current growth is being funded at the expense of future resources[65]. Table 2.1 presents a categorized and ranked list of sustainability performance criteria for modular building construction, adapted from[66]. The criteria are organized into three primary sustainability dimensions: Environmental, Economic, and Social, reflecting a comprehensive life cycle approach to assessing modular building performance. Environmental indicators emphasize aspects such as energy efficiency, material use, and emissions; economic indicators focus on cost, durability, and investment risk; while social indicators address health, safety, community impact, and user satisfaction. This structured classification supports the development and evaluation of modular construction practices aligned with sustainability goals. The analysis highlights that the construction sector significantly

TABLE 2.1: Modular Building Sustainability Performance Criteria (adapted and ranked from Kamali, Hewage and Milani [66])

Environmental	Economic	Social
EP = Energy Performance, DCT = Design Time, WHS = Worker Safety, etc.		
Energy performance and efficiency strategies (EP)	Design and construction time (DCT)	Workforce health and safety (WHS)
Waste management (WM)	Design and construction costs (DCC)	Safety and security of building (SSB)
Material consumption in construction (MC)	Investment and related risks (IR)	Affordability (A)
Site disruption and appropriate strategies (SD)	Durability of building (DB)	Community disturbance (CD)
Embodied energy (EE)	Integrated management (IM)	Functionality and usability of the physical space (FU)
Renewable and environmentally preferable products (REP)	Operational costs (OC)	User acceptance and satisfaction (UAS)
Greenhouse gas emissions (GE)	Flexibility of building (FB)	Aesthetic options and beauty of the building (AB)

Environmental	Economic	Social
Renewable energy use (RE)	Maintenance costs (MC)	Influence on the local economy (ILE)
Regional (local) materials (RM)	End of life costs (EC)	Neighbourhood accessibility and amenities (NAA)
Site selection (SS)		Health, comfort and well-being of occupants (HO)
Water and wastewater efficiency strategies (WE)		Influence on local social development (ISD)
Alternative transportation (AT)		Cultural and heritage conservation (CHC)

their own needs. In the context of urban development, an equilibrium point in housing production can be defined as the level at which supply aligns with the typical, ongoing demand. When housing production exceeds this equilibrium and is financed through debt, it effectively means that current growth is being funded at the expense of future resources[65]. Table 2.1 presents a categorized and ranked list of sustainability performance criteria for modular building construction, adapted from[66]. The criteria are organized into three primary sustainability dimensions: Environmental, Economic, and Social, reflecting a comprehensive life cycle approach to assessing modular building performance. Environmental indicators emphasize aspects such as energy efficiency, material use, and emissions; economic indicators focus on cost, durability, and investment risk; while social indicators address health, safety, community impact, and user satisfaction. This structured classification supports the development and evaluation of modular construction practices aligned with sustainability goals. The analysis highlights that the construction sector significantly influences the state of the natural environment, both directly and indirectly. This sector is a major consumer of coal and electricity. Within the household sector, the use of hard coal and electricity continues to rise. Findings indicate that energy industries are responsible for the highest share of carbon dioxide emissions at 53% while the mining and quarrying sector generates the largest proportion of waste at 47%. The industry and construction sector accounts for 24% of hard

coal consumption and over half of the total heat consumption at 54%. In comparison, households consume 14% of hard coal, 36% of heat, and 26% of energy as of 2016[67]

The emission of pollutants from these activities poses a serious threat to environmental sustainability. Therefore, it is essential to propose alternative approaches to organizing all stages of the construction process in ways that minimize environmental harm, with a strong emphasis on large-scale adoption of renewable energy. The study identified several key challenges that impede project management teams from effectively implementing sustainable building practices. These include insufficient training and education, limited familiarity with green technologies, and the higher upfront costs associated with sustainable construction methods and materials. Additionally, the research highlighted important strategies to address these barriers, such as raising stakeholder awareness about the long-term benefits of green buildings, involving professionals with expertise in sustainable construction, and establishing clear sustainability goals early during the feasibility phase. The contribution of this study lies in supporting project management teams by enhancing their understanding of these challenges and enabling them to develop strategies that transform these obstacles into opportunities for advancing sustainability within the construction industry[67].

The construction industry has faced ongoing criticism for its significant role in environmental degradation, which stands in contrast to the core principles of sustainable development. Improving the environmental performance of buildings is essential, as it encourages greater ecological responsibility and emphasizes the importance of safeguarding the well-being of future generations. Green building practices aim to minimize carbon dioxide emissions, foster eco-friendly environments, utilize renewable resources, conserve energy and water, reduce waste, and promote on-site material recycling, all while enhancing the aesthetic appeal of building designs. Environmental assessment methods for buildings are instrumental in achieving sustainability goals within the construction sector. These tools not only support environmental objectives but also consider the long-term impact on living standards for both present and future populations, alongside economic development. In today's context, relying solely on traditional, single-dimensional evaluation approaches is no longer adequate; sustainable development must be a central criterion in project decision-making. Globally, both developed and developing nations are focused on cultivating a more sustainable built environment. To monitor progress in green growth and sustainable development, countries need clear action plans,

well-defined metrics, and policies aligned with international standards. Understanding sustainable development through the lens of the green economy is crucial. Nations must continue refining their national strategies to establish a coherent vision, specific goals, structured methodologies, and effective implementation mechanisms. In developed countries, such efforts have resulted in comprehensive policies, legislation, and the construction of numerous sustainable buildings. However, advancing sustainable construction requires overcoming a range of internal and external challenges. It demands committed efforts from all stakeholders, particularly construction professionals, who carry the responsibility of integrating sustainability principles into their practices and ensuring the industry contributes meaningfully to global sustainable development objectives[68].

2.4.2 Building Construction Projects in Developed Cities of Developing Countries

While conventional construction typically focuses on cost, schedule, and quality, sustainability aspects like environmental, economic, and social impacts often receive less attention. Non-urban land development projects present distinct sustainability challenges due to their long-term nature and significant alterations to natural landscapes and local communities. The absence of a dedicated sustainability evaluation system for these projects makes it challenging for stakeholders to plan, execute, and manage them sustainably [69]. The study's core findings indicate that the adoption of environmentally sustainable (ES) practices is hindered by perceived initial costs, insufficient knowledge of ES, technological difficulties, external pressures, and environmental conditions in developing countries[70]. The construction sector constitutes a critical pillar of national economies globally. Notably, the Organization for Economic Co-operation and Development (OECD) estimates that buildings in developed nations are responsible for over 40% of total energy consumption throughout their lifecycle, encompassing material production, construction, operational use, maintenance, and eventual decommissioning. Sustainable construction, characterized by high-quality processes and outcomes, can be significantly enhanced by addressing existing challenges within the construction management domain. A survey-based study identified several key impediments to quality and, consequently, sustainability in the construction sector. These include deficiencies in the quality of construction works and processes, a scarcity of highly skilled labor within the

construction industry, shortcomings in the educational system at the secondary and vocational levels, gaps in higher education curricula particularly concerning international best practices, issues related to public procurement procedures, challenges in attracting new talent due to comparatively low remuneration for teaching staff, and the presence of a shadow economy which negatively impacts work safety and employee social security, alongside the potential for implementing electronic identification cards for construction workers. Addressing these multifaceted challenges is paramount for fostering a more sustainable construction sector.

To this end, the following recommendations warrant consideration for near-term implementation: streamlining bureaucratic procedures; establishing a robust and well-defined legislative framework, particularly concerning building codes; continuing efforts to simplify the processes for accessing EU funds and providing publicly funded consultancy services for project development at state and local levels; enhancing the robustness and transparency of construction tendering processes, advocating for a shift away from solely cost-based evaluation criteria; promoting the adoption of smart home technologies from a sustainability perspective; and implementing Building Information Management (BIM) system solutions within the public building sector [71]. Advancing Agenda 21 for Sustainable Construction in Developing Countries represents a substantial endeavor demanding significant innovation and unwavering commitment from all stakeholders. The identified research and development priorities, alongside the proposed action strategy, encompass tasks requiring immediate attention as well as those slated for the medium and long term. The immediate imperatives center on capacity-building initiatives, enhancing awareness, securing access to financial resources, fostering collaborative networks and partnerships, and establishing relevant benchmark data tailored to the context of developing countries. These areas constitute the primary focus of effort over the next five years, as they represent critical bottlenecks hindering further progress. Nevertheless, it remains essential to concurrently pursue medium-term and longterm objectives, which include the development of necessary tools, technologies, and other enabling factors to mitigate the sector's impact and guide it toward a new, more sustainable paradigm [72].

The study underscored the importance of informed policy reform to enhance mixed land-use planning (MLUP) in Addis Ababa, calling for clearer regulations, defined objectives, and the integration of ICT solutions. It highlights the need to embed MLUP within broader urban planning frameworks, strengthen institutional capacity, improve

infrastructure, and promote stakeholder collaboration. The research advocates for incentivizing mixed-use development, expanding MLUP beyond residential areas, and encouraging compact, sustainable urban growth. It also stresses the roles of awareness, academic engagement, and coordinated governance in ensuring effective implementation. Overall, the study offers a concise, practical framework for integrating MLUP into urban policy to support inclusive and sustainable development[73].

2.5 Sustainability in Building Construction Projects

The study offered practical guidance for policy makers and industry stakeholders, highlighting the importance of enabling government policies, a robust organizational culture, dedicated financial support for sustainability, and active stakeholder participation. These factors are critical to advance sustainable construction practices in Nigeria and other developing countries [74]. The construction industry faces numerous challenges, such as a non circular economic model, limited access to financial support, inadequate technological advancement, inadequate infrastructure, and a lack of political commitment to sustainable development [75]. Table 2.1 presents a compilation of sustainability indicators published in the academic literature from 2011 to 2025 in various countries. The table categorizes each indicator according to three core sustainability themes, Environmental, Social, and Economic, and further classifies them into specific sustainability categories such as energy efficiency, health and safety, cost efficiency, and stakeholder engagement. Each entry includes the corresponding indicator, the author(s) of the study, and the year of publication. This comprehensive tabulation highlights the diversity and evolution of sustainability concerns in the construction and building sectors. It also reflects the growing emphasis on incorporating not only environmental and economic considerations but also social dimensions into sustainability assessment frameworks. By analyzing trends in published indicators, this table serves as a foundation for identifying gaps in current research and guiding the development of more balanced and context-specific sustainability assessment models in most cities of developing countries. This synthesis provides valuable insights for policymakers and practitioners. Table 2.2 not only serves as a valuable reference for understanding the evolution of sustainability assessment in the construction sector but also provides a solid foundation for the development of customized frameworks in subsequent chapters of this thesis. The

indicators compiled herein will inform the formulation of a region-specific sustainability assessment model tailored to the socioeconomic and environmental context of developing urban centers, ensuring that future construction practices are both equitable and resilient.

TABLE 2.2: Sustainability Indicators for Construction Projects (2011–2025)

Theme	Category	Indicator	Author(s) (Year)
Environmental	Energy Efficiency	Energy Consumption Reduction	Smith et al. (2011)
Environmental	Material Use	Recycled Content in Materials	Kibert (2012)
Social	Health & Safety	Workplace Injury Rate	Lee & Kim (2014)
Economic	Cost Efficiency	Life Cycle Cost Analysis	Zuo & Zhao (2014)
Social	Stakeholder Engagement	Community Consultation Sessions	Ahmed et al. (2016)
Environmental	Carbon Emissions	CO ₂ Emissions per m ²	Chen et al. (2018)
Economic	Resource Optimization	Material Waste Reduction	Nguyen & Tran (2019)
Social	Equity	Access to Public Facilities	Patel & Singh (2020)
Environmental	Water Conservation	Water Reuse Systems	Fernandez et al. (2021)
Social	User Satisfaction	Post-Occupancy Evaluation Score	Ali & Kineber (2022)
Economic	Investment Return	Net Present Value (NPV)	Khalifa & Marzouk (2023)
Social	Labor Practices	Employee Training Hours	Passos Neto et al. (2022)
Environmental	Sustainable Site	Urban Heat Island Reduction	Poorisat et al. (2024)
Economic	Affordability	Cost per m ² vs Local Income	Alawneh et al. (2025)

2.5.1 Environmental Sustainability in Building Construction Projects

Amid the rising emphasis on sustainable development and constructability, the construction industry is increasingly tasked with mitigating energy consumption, carbon emissions, and other environmental impacts, while simultaneously maintaining high standards of economic performance and constructability. This study undertakes a comparative evaluation of reinforced concrete (RC) and structural steel (SS) framed buildings in Singapore, based on economic sustainability, environmental sustainability, and constructability indicators[76]. The findings emphasize the critical role of these factors in the selection of structural materials. RC-framed buildings demonstrate superior performance with respect to structural durability, maintenance expenditures, and financial efficiency, whereas SS-framed buildings offer notable advantages in terms of usable space, internal flexibility, recyclability, waste minimization, water conservation, labor optimization, reduced construction time, and overall construction quality. Both systems show comparable results in terms of noise pollution and construction safety[76]. Building environmental assessment methods are characterized by four key features: comprehensiveness, design guidance, signaling, and communication facilitation. Comprehensiveness refers to the holistic nature of these assessments, which encompass a wide array of sustainability criteria, including energy efficiency, water conservation, material selection, waste management, and indoor environmental quality. This ensures a multidimensional evaluation of a building's environmental performance. Design guidance serves as a practical tool, assisting architects, engineers, and project managers in incorporating sustainable strategies during the planning, design, and construction phases, particularly the energy embodied in construction materials[77].

The study explored the environmental impact of various construction materials by quantifying their embodied energy and associated emissions, specifically carbon dioxide (CO_2) and sulfur dioxide (SO_2), within the context of modern office buildings. A particular focus is placed on comparing the embodied energy of building structures to the operational energy required over the building's lifecycle. The findings indicate that structural materials, such as concrete and reinforcing steel, account for the majority share pertaining to the aggregate embodied energy in the analyzed buildings; ranging from 59.57% to 66.73%. In contrast, materials used in the building envelope, while less dominant, still represent a significant portion of the total embodied energy. Further analysis of

individual construction elements reveals that slabs contribute the highest proportion of embodied energy among structural components. Among the building envelope elements, external walls emerge as the most energy-intensive in terms of their embodied energy contribution. When assessed over a 50-year operational period, the energy embodied within these construction materials corresponds to approximately 12.55% to 18.50% of the total energy required for building operation. These insights underscore the importance of considering material selection not only for structural performance but also for long-term environmental sustainability, particularly in the design and construction of energy-efficient buildings[78].

2.5.2 Economical Sustainability in Building Construction Projects

Economic sustainability in the context of building construction refers to the ability of a building project to maintain long-term financial viability while minimizing costs, maximizing resource efficiency, and generating value for stakeholders[79]. It encompasses not only the initial construction costs but also the operational, maintenance, and end-of-life costs associated with a building. As sustainability principles become increasingly integrated into construction practices, the economic dimension serves as a critical pillar alongside environmental and social considerations. Assessment of economic performance in buildings typically involves a life-cycle cost (LCC) analysis, which evaluates all costs incurred over the building's entire life span. This includes capital costs, operating costs (e.g., energy, water, maintenance), and disposal or demolition costs. By accounting for these elements, LCC analysis provides a more comprehensive picture of a building's financial sustainability than traditional cost estimation methods. Beyond Life Cycle Costing (LCC), financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period are also employed to assess the economic feasibility of sustainable initiatives[80]. To facilitate a holistic evaluation, researchers and practitioners have proposed various economic sustainability indices that integrate multiple economic performance indicators into a unified metric. These indices often consider parameters such as construction cost efficiency, operational cost savings, material reuse and recyclability, energy cost reduction, and return on investment. These indices are designed to assist decision-makers by providing quantifiable and comparable metrics for evaluating alternative building designs or materials based on their long-term economic impact.

Moreover, economic sustainability is closely linked with affordability and marketability, particularly in the case of residential and commercial developments. A building that integrates sustainable features but exceeds market price expectations may struggle with economic sustainability despite strong environmental performance.

Therefore, achieving balance between cost-effectiveness and sustainability goals is essential. In summary, the economic sustainability of buildings is a multi-faceted concept that extends beyond mere cost-cutting. It requires the integration of financial planning with sustainable design strategies to ensure that buildings remain operationally viable, affordable, and competitive in the long run. The integration of comprehensive economic sustainability indices enhances the decision-making capacity of developers, policymakers, and investors by facilitating choices that balance economic viability with environmental responsibility [81]. This research seeks to advance the current literature by developing methodological frameworks for selecting the most appropriate retrofit design solutions that promote both energy efficiency and sustainable outcomes. The paper introduces an integrated methodology designed to assist various stakeholders, such as architects, builders, developers, and public authorities, in making informed decisions during the retrofit planning process. This methodology combines two established evaluation frameworks: Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) collectively offer a comprehensive evaluation of the environmental and economic impacts associated with retrofit options. The outcomes derived from the LCA and LCC analyses are subsequently employed within the Strategic Choice Approach (SCA), which functions as a foundational framework for decision-making. The SCA facilitates the integration and systematic organization of interdisciplinary knowledge across three principal domains: Materials Science and Technology, Environmental Technology, and Real Estate Market Evaluation.

By facilitating structured knowledge-sharing, this approach enhances transparency and strengthens stakeholder collaboration. The proposed methodology's effectiveness is demonstrated through its application to a case study conducted in Turin, Northern Italy. The chosen reference building exemplifies common construction typologies in the region that are in critical need of retrofitting to reduce energy consumption, thereby contributing to both building-level and urban-scale sustainability goals [82]. At present, there is no universally recognized methodology for assessing and ensuring building sustainability. Addressing this gap, an ongoing research initiative aims to develop a design

support tool to improve sustainability outcomes during the early stages of building design. This paper presents the preliminary phase of the research, which concentrates on formulating a methodology to assess the impact of social and economic indicators on sustainable building construction and evaluation practices. Understanding how these factors are addressed during the early design phases, and how they ultimately impact the overall sustainability evaluation, is essential for achieving effective outcomes. The proposed methodology represents a preliminary step toward the development of the intended tool and provides valuable insights into current design practices, including the challenges and barriers associated with integrating sustainability principles from the outset of the project lifecycle[83].

2.5.3 Social Sustainability in Building Construction Projects

Sustainability had gained widespread recognition in the global building industry; however, despite growing attention to environmental and economic aspects, the social dimension remained significantly underrepresented in most assessment frameworks. This lack of emphasis resulted in limited analytical support for incorporating social considerations into sustainable decision-making, especially in developing countries[84]. In response to this gap, the study proposed a framework to assess social sustainability in residential building construction, specifically tailored to the context of Iran. Using a multi-criteria decision-making (MCDM) approach and expert input, the study identified and prioritized key social indicators. Results indicated that safety was considered the most critical factor, while site considerations and equipment were ranked as least important, with performance and flexibility emerging as the third-highest priority. These findings highlighted the need for context-sensitive assessment tools and demonstrated that establishing a localized social sustainability framework could play a pivotal role in promoting balanced, inclusive, and effective sustainability evaluation practices in developing nations[85]. The construction industry exerts significant influence on society across environmental, economic, and social dimensions. While sustainability has become a central concern for both academia and industry, the majority of existing research in the construction sector has predominantly focused on environmental and economic aspects, with comparatively limited attention given to social sustainability. To address this gap, the present study employed a qualitative approach to investigate social sustainability issues within the construction industry. The research specifically examined

the perspectives of industry professionals regarding the social impacts of construction activities and the methods used to assess social performance in construction projects. Findings revealed a considerable willingness among practitioners to incorporate social considerations into their project planning and execution.

Additionally, the study identified 26 key criteria that can be used to evaluate social sustainability performance in the construction context. These criteria serve as a foundational framework for assessing the social dimension of sustainability within construction-related enterprises. The study also acknowledged its limitations, which provide direction for future research[86]. Drawing on input from 25 experts spanning academia, industry, and government sectors, the study utilized multidimensional scaling and hierarchical cluster analysis to organize their insights into six principal dimensions characterizing social sustainability in construction projects: stakeholder engagement, user considerations, team formation, management practices, impact assessment, and place context. While previous research had acknowledged social sustainability as a collection of discrete processes, this study represents the first effort to consolidate these components into a comprehensive and structured framework. The resulting framework offers practical value to industry practitioners by enhancing existing sustainability assessment methods and addressing the persistent challenge of achieving truly sustainable construction outcomes.

Furthermore, it provides academics with a valuable pedagogical tool for introducing students to the principles of social sustainability within the construction project context[87]. Theoretical models of social sustainability were critically examined in relation to their practical application by stakeholders within the building industry. A central question explored in the study concerned whether, and to what extent, social sustainability can be measured, evaluated, and certified in the context of housing construction or neighborhood renewal initiatives. Beyond conventional physical and functional metrics, the study proposed that certification systems, such as the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), should also incorporate and reward social sustainability initiatives. In support of this objective, a framework consisting of 12 indicators was developed, organized under three overarching themes: social cohesion, participatory processes, and accessibility to living opportunities. A collaborative case study was subsequently undertaken within two Danish social housing neighborhoods explored the integration of these social sustainability indicators into existing certification systems like the DGNB. The study further investigated whether incorporating social and organizational dimensions

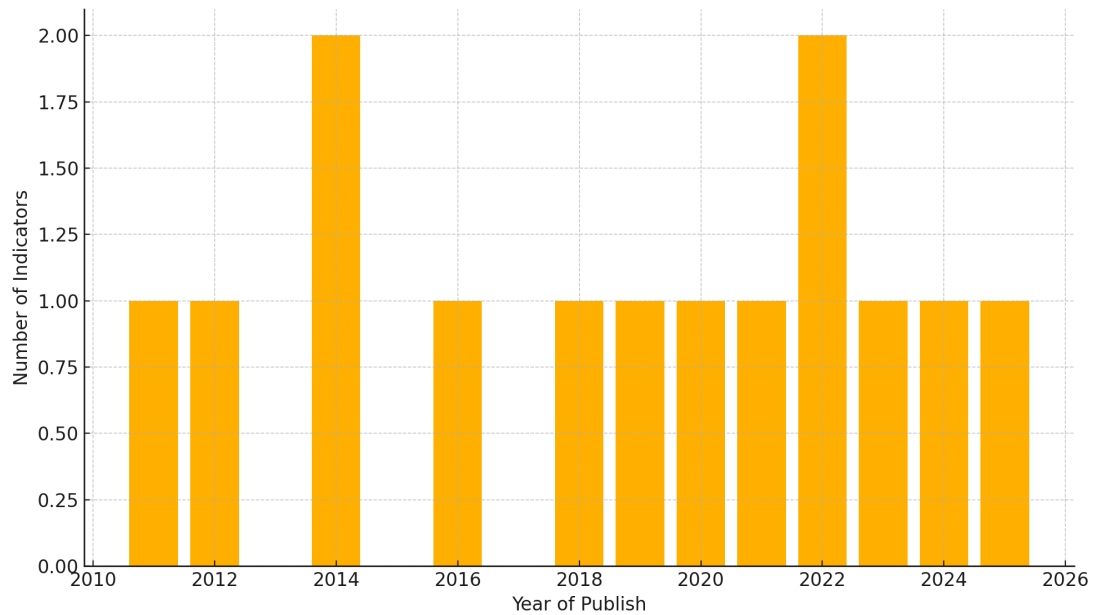


FIGURE 2.3: Published sustainability indicators from 2011-2025

could enhance the comprehensiveness of current certification criteria, which primarily focus on physical and functional design. Findings indicated that effective certification must consider the relationship of housing complexes and neighborhoods with the broader urban context, including their capacity to adapt over time and respond flexibly to evolving future needs[88].

2.6 Sustainability Indicators in Building Construction Projects

The bar chart in Fig 2.3 illustrates the temporal distribution of sustainability indicators published in academic research between 2011 and 2025. The data is categorized by year of publication and reflects the number of distinct sustainability indicators reported across various studies related to building and construction. The graph reveals a fluctuating but generally upward trend in the publication of sustainability indicators over the observed period. Initial years, such as 2011 and 2012, show relatively low reporting activity, with one to two indicators identified. Beginning in 2014, a notable rise is apparent, reflecting the intensified focus of both academia and industry on implementing sustainable development practices within the built environment. Peaks in the number of indicators occur in the years 2014, 2022, and 2025, suggesting heightened research

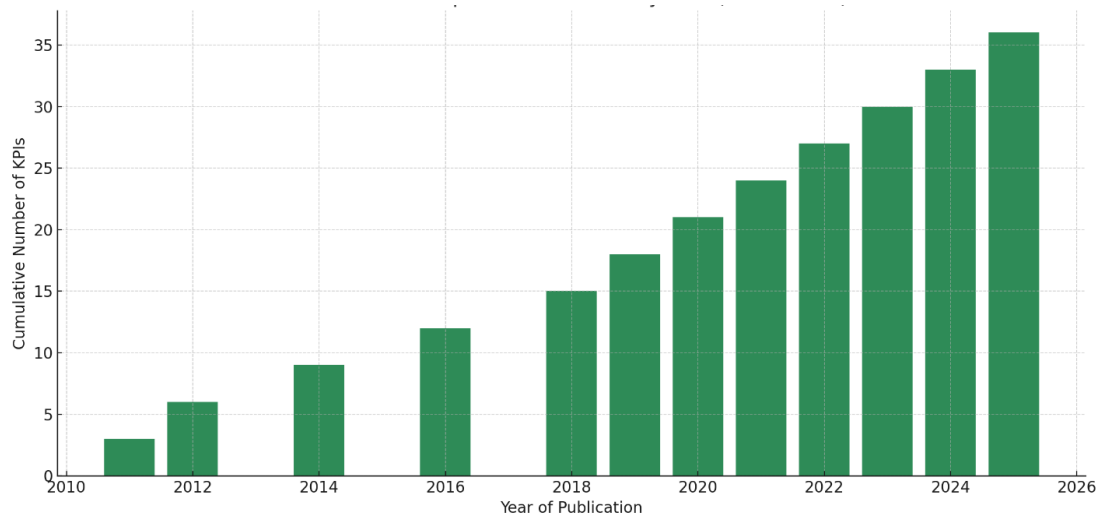


FIGURE 2.4: Published cumulative sustainability key performance indicators from 2011-2025

interest and comprehensive sustainability evaluations during these periods. The 2022 peak notably aligns with studies integrating social sustainability metrics, such as those derived from the Global Reporting Initiative (GRI), reflecting a shift toward more inclusive assessment frameworks. Similarly, the expected rise in 2025 underscores a projected increase in publications addressing emerging dimensions of sustainability, particularly affordability and localized socioeconomic impacts. Overall, the chart underscores the evolving nature of sustainability discourse in the construction sector, demonstrating a gradual progression from predominantly environmental and economic concerns toward more holistic frameworks that also incorporate social and institutional dimensions. Figure 2.2 illustrates the cumulative number of proposed sustainability Key Performance Indicators (KPIs) published in academic literature related to construction projects from 2011 to 2025. Each bar on the chart represents the running total of KPIs identified up to and including that year, thereby reflecting the expanding body of knowledge and academic focus on sustainability assessment in the built environment. The visualization reveals a consistent upward trend, indicating a progressive increase in the volume of sustainability-related research over the years. Early years, such as 2011 to 2014, show a relatively modest cumulative count, which gradually accelerates in later years.

This growth is particularly evident from 2016 onward, suggesting a shift in academic and industry priorities toward the integration of sustainability metrics in construction practices. The chart underscores the broadening scope of sustainability indicators, moving from primarily environmental concerns in earlier studies to the inclusion of social and

economic dimensions in more recent work. The cumulative increase not only demonstrates rising scholarly engagement but also highlights the expanding complexity and interdisciplinary nature of sustainability in construction. This trend supports the thesis objective of developing a holistic sustainability assessment framework that encompasses diverse performance indicators across environmental, social, and economic themes.

An extensive review of scholarly publications between 2011 and 2025 reveals a broad spectrum of sustainability indicators proposed for evaluating construction projects. These indicators have been developed to address the growing need for integrated performance assessment frameworks that align with the three fundamental pillars of sustainability: Environmental, Social, and Economic. Their emergence in literature reflects a collective response to increasing regulatory, environmental, and societal pressures facing the global construction industry. Environmental indicators have been the most widely studied, particularly in the earlier part of the review period. These include metrics such as energy consumption reduction, carbon emissions per square meter, use of recycled and locally sourced materials, construction waste reduction, rainwater harvesting systems, and integration of renewable energy technologies. The literature emphasizes these indicators as critical tools for minimizing ecological footprints and improving energy efficiency across the project lifecycle [89, 90]. Social indicators, though less frequently explored in earlier studies, have gained prominence in recent years, particularly after 2016. The reviewed literature identifies indicators such as workplace safety (injury rates), employee training and development, community engagement, public consultation mechanisms, equitable access to infrastructure, universal design practices, and compensation policies for displacement. These metrics reflect a shift toward more inclusive and people-centered sustainability frameworks, aligning with the growing recognition of social justice, health, and well-being within construction discourse [91, 92]. Economic indicators have been consistently addressed throughout the literature. Key metrics include life cycle cost analysis (LCC), net present value (NPV), return on investment (ROI), payback period, cost per unit area, and housing affordability ratios. These indicators support strategic planning and investment decisions by offering insights into both immediate and long-term financial performance [93, 94]. Despite the growing body of research, the literature reveals persistent gaps. Many studies continue to prioritize environmental and economic indicators, with social dimensions often underrepresented or superficially addressed. Moreover, most frameworks are context-specific and lack adaptability across diverse geographic and socio-economic settings, particularly in developing countries. The

absence of a standardized set of sustainability Key Performance Indicators (KPIs) further complicates benchmarking and comparative analyses. This review underscores the need for a comprehensive, context-sensitive framework that integrates environmental, social, and economic indicators. The proposed research aims to fill this gap by developing an integrated set of sustainability KPIs tailored to construction stakeholders and aligned with international best practices.

2.7 Summary

This research addresses the critical need for a comprehensive and balanced framework to assess sustainability in construction projects. Through an extensive literature review spanning 2011 to 2025, a total of 49 key performance indicators (KPIs) were identified and categorized under the three core dimensions of sustainability: economic, environmental and social. Economic indicators emphasize life cycle cost analysis, return on investment, and the affordability of housing. Environmental indicators include metrics such as energy consumption reduction, carbon emissions, and the use of recycled and locally sourced materials. Social indicators encompass workplace safety, labor rights, stakeholder engagement, and universal design practices. The findings indicate that, although environmental and economic aspects are well-represented in current research, social sustainability continues to receive limited attention, particularly in the context of developing nations. Based on these insights, this research proposes a holistic and context-sensitive sustainability assessment framework tailored for application in construction. The proposed framework is intended to facilitate informed decision-making among stakeholders and to advance more equitable, efficient, and sustainable development practices within the built environment. Within the context of Pakistan's developed urban centers, a major barrier to the adoption of sustainable building construction practices is identified as the limited knowledge and awareness among key stakeholders, particularly consultants and project managers. This highlights an urgent need for the development of a comprehensive framework to guide sustainable construction practices in cities such as Rawalpindi and Islamabad.

Chapter 3

Research Approach

3.1 Background

This chapter describes the research methodology, outlining the methods and techniques employed to achieve the study's objectives. The methodology centers on the identification of sustainability indicators and the formulation of a framework that embeds sustainability principles. The research commenced with a thorough literature review, utilizing leading databases including ScienceDirect, Web of Science (WOS), Google Scholar, and SpringerLink, which are broadly acknowledged for their extensive coverage of scholarly work, to extract critical sustainability indicators pertinent to construction projects. Subsequently, relevant sustainability indicators were gathered through an online survey administered to engineers engaged in different building construction projects (BCPs) and registered with the Pakistan Engineering Council. The study's design aimed to highlight the sustainability indicators that influence building construction projects in developed cities of Pakistan, thereby contributing to the objectives of sustainability guidelines for building construction projects (BCPs). The survey questions were validated through a pilot study, ensuring clarity and relevance to the research objectives. A combination of descriptive and inferential statistical tools was used to explore relationships between variables and prioritize indicators. Ethical considerations, including informed consent and respondent anonymity, were strictly observed throughout the data collection phase. The Statistical Package for the Social Sciences (SPSS) was employed to perform the data analysis. The methodology adopted for this research is illustrated in Figure 3.1.

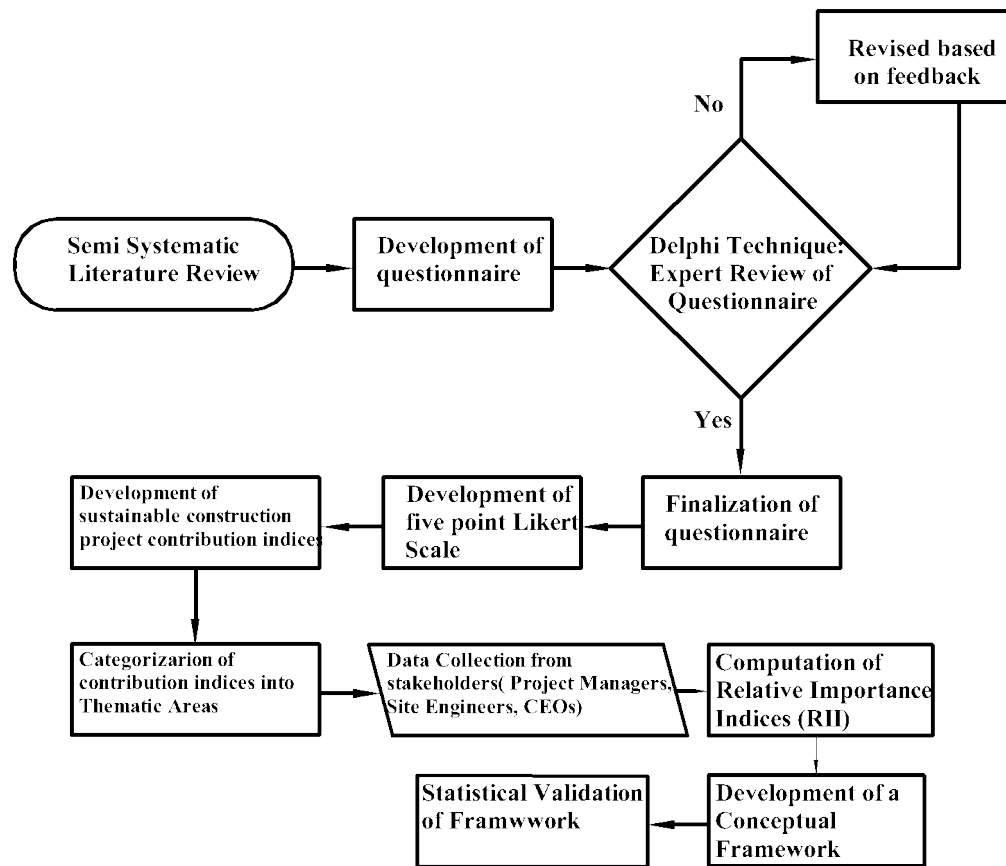


FIGURE 3.1: Diagrammatic overview of the research methodology

3.2 Selection and Prioritization of Sustainability Indicators

An extensive review of the literature was steered to identify and extract valuable sustainability indicators that can be effectively assessed and monitored within construction projects. The selection process focused on indicators deemed most relevant for assessing sustainability within the context of the construction and building sector. While numerous sustainability indicators have been proposed across various domains and dimensions of sustainability, this study specifically shortlisted those applicable to construction and building-related activities to ensure contextual relevance and practical applicability.

3.2.1 Identification of Sustainability Indicators for BCPs

A comparative analysis of the case studies yields three key conclusions. The identification and compilation of sustainability indicators serve not only to generate essential data

for informed decision-making but also to promote community engagement and empowerment—elements frequently neglected in traditional development approaches. Secondly, multi-stakeholder processes must be systematically embedded within decision-making platforms; otherwise, they risk being marginalized or overlooked by policymakers and other stakeholders. Third, given that ecological boundaries seldom align with political ones, decision-making and monitoring efforts must adopt a flexible, landscape-based approach. This necessitates an understanding of broader environmental linkages, recognizing that distant areas may be interconnected through complex ecological pathways[95]. Enhancing the sustainability performance of construction projects is vital for achieving regional, national, and global sustainability goals. Key Performance Indicators (KPIs) serve as critical tools in promoting sustainable construction practices. Although extensive research exists on sustainability indicators, a significant gap remains in identifying practical KPIs specifically applicable during the execution phase of construction projects from the building construction perspective. This thesis aims to identify and evaluate key performance indicators (KPIs) capable of effectively monitoring and assessing the sustainability performance of construction activities during this critical phase[19].

The sustainability indicators have been reclassified into three primary dimensions, Economic (ECN), Environmental (ENVR), and Social (SCL), to enhance thematic structure and maintain a level of distinction and novelty in the study. These acronyms were purposefully adapted from the conventional ECO, ENV, and SCO to avoid overlap with existing indicator coding systems and to ensure clarity within the context of this research. The classification is grounded in a comprehensive review of scholarly literature and global sustainability assessment frameworks. The sources consulted include [4–6, 9, 11–13, 15, 16, 20, 28, 46].

3.2.2 Foremost Sustainability Indicators for BCPs

This pertains to the frequency with which sustainability indicators appear in published research. Some indicators are derived from factors such as energy consumption and the life cycle of building construction projects. Regulatory sustainability indicators, on the other hand, are based on carefully selected variables aimed at supporting the success of the construction industry, predominantly in building construction projects. In certain instances, a contractor's success is measured by the degree of advancement toward strategic goals[5]. Although it is the most commonly defined as the consistent,

periodic achievement of specific operational goals (e.g., zero defects, perfect customer satisfaction), the literature reveals that numerous researchers have proposed various dimensions and sub-dimensions to measure sustainability performance. A consolidated list of the most frequently cited dimensions and sub-dimensions has been compiled from existing studies. Furthermore, several new sustainability indicators have recently been identified and analyzed. Based on a frequency analysis of previously published data, approximately 61 key indicators were found to be predominant. The table 3.1 presents a comprehensive classification of sustainability indicators relevant to the construction sector, categorized into environmental, social, economic, technical, institutional, governance, health and safety, waste management, energy performance, water efficiency, and innovation domains. Each category outlines key aspects, such as energy efficiency, community impact, life cycle cost, structural durability, regulatory compliance, and adoption of emerging technologies, that contribute to the overall sustainability performance of construction projects. The table is supported by multiple peer-reviewed references for each indicator type, reflecting the breadth and repetition of scholarly focus across diverse sustainability dimensions.

TABLE 3.1: Sustainability Indicators in the Construction Sector with Key References

Indicator	Cate- gory	Description	Key References
Environmental Indicators	In-	Energy efficiency, carbon footprint, material sustainability, waste reduction	[96–98]
Social Indicators		Community impact, worker health & safety, user comfort, stakeholder engagement	[99–101]
Economic Indicators	Indica-	Life cycle cost, ROI, operational savings, budget performance	[102–104]
Technical Indicators	Indica-	Structural durability, maintainability, adaptability, construction quality	[105–107]

Continued on next page

Indicator Category	Description	Key References
Institutional Indicators	Policy framework, regulatory compliance, procurement methods, transparency	[108–110]
Governance Indicators	Anti-corruption policies, accountability, public participation, legal enforcement	[108–110]
Health and Safety	Occupational health standards, safety training, emergency procedures	[99–101]
Waste Management	Construction and demolition waste, recycling rates, disposal systems	[96–98]
Energy Performance	Use of renewables, energy audits, energy-saving materials	[97, 98, 103]
Water Efficiency	Rainwater harvesting, greywater recycling, low-flow systems	[96, 97, 104]
Innovation Indicators	New materials, smart construction tech, digital tools (BIM, IoT)	[105–107]

3.3 Development and Finalization of the Questionnaire

To appropriately assign weight to sustainability indicators before developing the sustainability indicator framework, a structured questionnaire survey was designed and developed. The Delphi technique was initially utilized to identify key sustainability indicators and to develop the questionnaire. Originally conceived as a forecasting method, the Delphi approach serves as a structured communication process that draws upon the

insights of a panel comprising professionals, researchers, and subject matter experts. It is widely used in scientific research and business decision-making due to its structured and effective nature, often incorporating expert feedback through iterative rounds and focus group discussions [111]. In this study, the Delphi technique was implemented across three rounds. In the first round, seven experts participated and refined the list of sustainability indicators down to 85. In the second round, six experts further reviewed the indicators and reduced the number to 60. Finally, in the third round, six experts finalized a compilation of 49 sustainability indicators for incorporation into the questionnaire survey. This field study engaged a diverse group of industry professionals, whose insights and feedback were pivotal in refining the final version of the questionnaire. The list of sustainability indicators was refined through comprehensive discussions with experts and feedback from industry professionals. These finalized indicators formed the basis for the questionnaire included in appendix.

The purpose of this questionnaire was to appropriately assign weight to each indicator and rank them according to their perceived importance, based on expert opinions. This tool proves particularly effective in capturing respondent behavior, preferences, intentions, and perspectives. The questionnaire was organized into two main sections; the first section outlined the survey's objectives, incorporated a consent form, and collected profile information, including the respondent's occupation, contact details, years of experience, and type of organization. The second section required participants to rate the importance of each sustainability indicator in accordance with their level of expertise. Respondents were carefully selected from the construction industry, specifically targeting professionals involved in building construction projects within the developed cities of Pakistan. A total of 50 respondents were selected to evaluate all 49 sustainability indicators spanning economic (ECN), social (SCL), and environmental (ENVR) dimensions. This sample size, while modest, is methodologically justifiable and supported by existing literature. According to Hair et al., a minimum of 5 respondents per variable is generally acceptable for exploratory factor analysis (EFA), implying that 245 responses are needed for 49 indicators [112]. In our case, each of the 50 respondents assessed all 49 indicators, resulting in 2,450 usable data points, which satisfies this ratio. Moreover, MacCallum et al. emphasized that sample adequacy should be evaluated in context, particularly where variables have high communalities and factors are well defined [113]. In such cases, reliable factor structures can be obtained with smaller samples, especially in focused domains like sustainable construction. Additionally, similar sample sizes have

been employed in peer-reviewed studies. Ametepey et al. conducted a sustainability barriers assessment in the Ghanaian construction industry using 50 respondents, validating the relevance and sufficiency of expert-based sample sets in this field [37]. Thus, based on precedent, theoretical guidelines, and the richness of indicator-level data, the sample size of 50 is appropriate for the purpose of this research.

TABLE 3.2: Likert Scale Response Categories

Sr. No.	Description	Score
1	Not important	1
2	Less important	2
3	Neutral	3
4	Important	4
5	Very important	5

3.4 Conduct of Study

The significance of key sustainability indicators was assessed through an online platform. A structured questionnaire was designed and administered to professional engineers involved in building construction, with a particular focus on those registered in Rawalpindi and Islamabad, as illustrated in Figure 3.2. Altogether, 50 responses were obtained exclusively from professional engineers engaged in building construction. Construction professionals' responses were recorded using a 5-point Likert scale, spanning from 'not important' to 'very important,' with a score of 1 representing the lowest level of perceived significance, suggesting that the indicator would have little or no impact on the sustainability comparison between two construction approaches—whereas a rating of 5 reflected high importance, implying that the indicator significantly varies between techniques. To ensure clarity, each question was supported with concise definitions and context-specific examples, enabling respondents to make informed evaluations. The questionnaire was piloted with a small group before large-scale circulation to verify its At the end of the questionnaire, respondents were also invited to suggest additional sustainability indicators not previously listed. For data collection, both direct and indirect methods of outreach were employed. Indirectly, relevant construction industry organizations were approached to help disseminate the questionnaire among their members, particularly building construction firms. A contact list of professionals and experts engaged in construction processes was compiled to facilitate direct communication. The



FIGURE 3.2: Map of Rawalpindi Islamabad

questionnaire was distributed to these individuals electronically through email and social media platforms. Two follow-up reminders were dispatched after the initial distribution to maximize the response rate

3.5 Procedure for Analysis

After collecting all the completed questionnaires, the next critical step involved analyzing the data. The process began with a reliability analysis to assess the consistency of the questionnaire. As multiple items (i.e. sustainability indicators or SIs) were utilized to assess the same construct, Cronbach's alpha, a measure of internal consistency, was applied to evaluate the reliability of the scale. Cronbach's alpha values range between 0 and 1, with higher values reflecting greater internal reliability among the indicators. According to Nunnally (1978), values above 0.70 are considered acceptable [114]. SPSS version 21 was utilized to compute Cronbach's alpha for this analysis. Following the reliability check, a ranking approach was applied to assess the importance of each sustainability indicator. A 5-point ordinal Likert scale was employed to assess the perceived significance of each indicator. Since the scale is ordinal, it indicates the order of importance but does not quantify the exact difference between scale points. For instance, a rating of 4 is more significant than 3, but the magnitude of that difference is not defined.

As recommended in the literature[115], non-parametric methods are more suitable than parametric ones for analyzing ordinal data. Accordingly, the Relative Importance Index (RII) was applied to rank the indicators according to their perceived significance[116]. The analysis began with frequency calculations to determine the percentage responses for each indicator using SPSS. These valid percentages were then used to calculate the RII in Microsoft Excel. All sustainability indicators were ranked based on their RII values, both across all 49 indicators and within their respective categories, namely environmental, economic, and social dimensions. Based on these rankings, a significance level was assigned to each indicator using the RII scale. Indicators classified as having "very high," "high," or "important" relevance were considered key sustainability indicators. According to the study participants, these indicators were perceived to exert a significant influence on the sustainability performance of construction practices relative to conventional methods.

3.5.1 Reliability Test

The reliability test is a fundamental approach for assessing the consistency and dependability of a study's findings. It evaluates the stability and precision of the statistical analyses conducted. Cronbach's alpha is widely recognized as a principal measure for determining the internal consistency and reliability of data obtained through a given instrument[117]. Specifically, Cronbach's alpha assesses the reliability of the data, with established benchmarks in the literature indicating a range from low to high reliability. A Cronbach's alpha value exceeding 0.7 is generally regarded as acceptable and suitable for research purposes, implying that the collected data is sufficiently reliable for further analysis and interpretation[118]. In statistical analyses, Cronbach's alpha is commonly employed to evaluate the reliability of datasets [119].

As illustrated in Table 3.2, the reliability scale ranges from unacceptable to excellent [120]. The Cronbach's Alpha value confirms a high degree of internal consistency among the selected items, indicating that the questionnaire was reliable for assessing sustainability indicators. This level of reliability supports the robustness of the data collected and enhances confidence in the subsequent statistical analysis. The results affirm that the instrument was well-structured and effectively captured the intended constructs. Furthermore, this statistical reliability reinforces the credibility of the respondents' evaluations across various sustainability dimensions. The consistency observed validates the

integration of these indicators in broader sustainability frameworks and decision-making tools.

TABLE 3.3: Cronbach's Alpha Value Ranges for Internal Consistency

Internal Consistency	Cronbach's Alpha Value
Excellent	$\alpha \geq 0.90$
Good	$0.80 \leq \alpha < 0.90$
Acceptable	$0.70 \leq \alpha < 0.80$
Questionable	$0.60 \leq \alpha < 0.70$
Poor	$0.50 \leq \alpha < 0.60$
Unacceptable	$\alpha < 0.50$

3.5.2 Normality Test

The Shapiro-Wilk test, introduced by Wilk in 1965, is a widely recognized and reliable method for assessing the normality of a data set. Often referred to as the normality test, this assessment determines whether the collected data conforms to a normal distribution. A significance level (p-value) greater than 0.05 indicates that the data is normally distributed (parametric). Conversely, a p-value less than 0.05 suggests that the data deviates from normality and is classified as non-parametric[121].

3.5.2.1 Assessment of Parametric and Non-Parametric Characteristics

In statistical analysis, the selection between parametric and non-parametric tests is contingent upon whether the data satisfy the assumptions underlying the test hypothesis. Parametric tests are appropriate when the data exhibit a normal distribution, maintain homogeneity of variance across groups, and demonstrate linear relationships. Conversely, non-parametric tests are applied when the data are measured on ordinal or ranked scales, deviate from any specific distribution, or display non-linear characteristics [122]. Parametric tests imply that the data conform to a normal distribution, whereas non-parametric tests indicate a departure from normality. Kim and Park [85] emphasized that non-parametric methods are suitable when the data fail to meet the assumption of normality. The normality assumption is rejected if the p-value is less than or equal

to 0.05. The hypotheses for assessing normality are articulated as follows: the null hypothesis (H_0) posits that the data follow a normal distribution if the p-value exceeds the alpha level, while the alternative hypothesis (H_1) asserts that the data do not follow a normal distribution if the p-value is less than the alpha level.

3.5.3 Demographic Analysis

The demographic and professional attributes of the survey respondents were analyzed, with a primary focus on their educational attainment, relevant professional experience, and engagement within various sectors of the construction industry. All data were collected exclusively from recognized industry experts. This ensured that the insights derived from the survey were both credible and grounded in practical field experience. The respondents represented a balanced mix of public and private sector professionals, including consultants, contractors, and regulatory authorities.

3.5.4 Relative Importance Index

The methodology employed in this study encompassed the identification and evaluation of the intensity levels associated with outcomes related to accidents and hazards, unsafe behaviors, hazardous environments, management practices, social groups, and natural factors. The significance of each factor was determined by calculating the mean of the values reported by respondents. These intensity levels were subsequently utilized to compute the Relative Significance Index (RSI) for each factor. This process ensured a data-driven basis for comparing multiple risk elements within the construction context. By capturing the perceived severity and frequency of each factor, the study aimed to provide actionable insights for improving safety and sustainability in project environments. Furthermore, to quantify the ranking of all elements, the 1-to-5 rating scale was converted into a Relative Importance Index (RII), as presented in Equation (1) [123].

$$RII = W / (A \times N) \quad (1)$$

where:

W Denotes the total weight attributed to each factor by respondents, based on a Likert scale ranging from 1 to 5;

A denotes the maximum possible rating on the Likert scale (which is 5);

N represents the total number of respondents.

3.5.5 Co-relation Analysis

In this analysis, the relationships among various variables are examined, which may be positive, negative, or reciprocal in nature.

3.5.6 Frequency Analysis

Frequency analysis constitutes a descriptive statistical technique used to present the number of times each response option is selected by respondents, helping to interpret patterns and draw conclusions. It provides insight into respondent perceptions and highlights trends observed in the survey. This technique allows for a detailed understanding of response distributions by examining cumulative percentages across variables, which represent both individual percentage values and the sum of preceding percentages. In this study, frequency analysis was applied to selected sustainability indicators by measuring the frequency of each response. Indicators were chosen based on their mean score values, which were calculated using SPSS. The indicators were then ranked in descending order based on their means, and representative factors from the upper, middle, and lower segments of the list were selected for subsequent analysis. This categorization enabled the identification of critical focus areas for sustainability performance improvement. The segmentation also facilitated comparative analysis among varying priority levels of indicators. Furthermore, by anchoring the analysis in empirical response data, the framework ensures alignment with actual stakeholder perspectives. This approach enhances the objectivity and relevance of the results. The selected indicators subsequently informed the structure of the proposed integration construction framework.

3.6 Framework Development Using SPSS

This study proposes a structured framework to support the integration of building projects by identifying various attributes based on their relative significance. The framework serves as a valuable tool for construction professionals to optimize resource utilization and achieve more cohesive project delivery. While the research highlights key

integration traits such as coordination, collaboration, leadership, information sharing, and trust, it does not fully address other critical aspects like change management and the integration of uncertainties. As a result, there is a need for a dedicated framework of sustainability indicators that can comprehensively capture the diverse factors influencing the construction industry. The construction sector, marked by its dynamic, fragmented, and complex nature, poses greater challenges than other industries owing to the involvement of multiple stakeholders and the critical need for effective process management. This complexity requires the implementation of well-defined plans and procedures to effectively manage risks and uncertainties. Variations in cost and schedule can lead to unintended outcomes that negatively impact client satisfaction. Therefore, identifying and addressing core criteria is vital when project success is a priority. Numerous studies emphasize that safety and timely completion are among the most critical indicators of project success. In the majority of cases, construction projects are deemed successful when they achieve client satisfaction and adhere to budgetary constraints, highlighting the critical role of these factors in project outcomes [124].

3.7 Summary

This thesis is grounded in an extensive review of literature that explores the challenges faced by the Pakistani construction industry, with a particular focus on building construction projects (BCPs). The principal objective of this research is to identify the sustainability factors impacting such projects and to align them with established sustainability criteria for building construction. A survey method was adopted to collect data through questionnaires distributed to Project managers, site managers, construction professionals, and on-site workers. Descriptive research was employed to assess the implementation of sustainability practices. The Delphi technique was utilized to determine the key sustainability parameters and to develop the questionnaire accordingly. A statistical methodology was subsequently employed to analyze the collected data, facilitating the development of the study's findings and conclusions.

Chapter 4

Research Findings and Critical Discussion

4.1 Background

Based on the questionnaire distributed among building construction projects in Pakistan's capital region, this chapter presents a synthesis of the collected responses, highlighting the main findings and their implications. The dataset was subjected to analysis using SPSS, thereby enabling the extraction of meaningful inferences from the results. This chapter incorporates graphs and tables to substantiate the findings. The principal aim of this study is to identify and compile sustainability indicators specifically pertinent to the management of building construction projects in Pakistan. These findings are based on evaluations provided by respondents from private construction companies in Islamabad and Rawalpindi. Additionally, a framework of sustainability indicators has been developed, along with practical recommendations tailored for engineers and contractors.

4.2 Demographic Analysis

Out of a total of 65 distributed questionnaires, 50 were completed and returned, resulting in a response rate of 77%. This is considered a strong response rate for generating reliable research findings. In cases where the total population size is unknown, a sample size

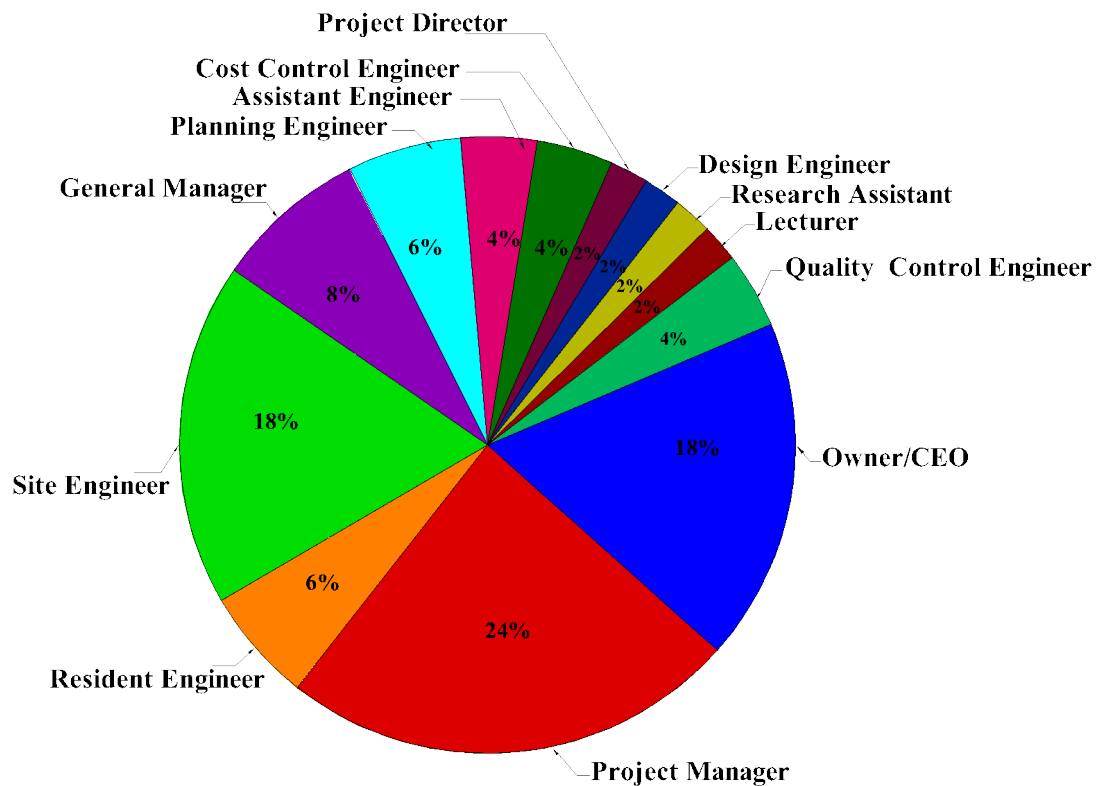


FIGURE 4.1: Designation of Respondents

exceeding 50% is generally regarded as both adequate and sufficient for analysis [89]. As noted by Ashley and Boyd [90], a 50% response rate is acceptable, 60% is considered good, and 70% or higher is deemed excellent. Therefore, the 65% response rate achieved in this study is good and supports the credibility of the data collected. Furthermore, as illustrated in Figure 4.1, the majority of responses came from individuals with direct experience in the construction industry, indicating a strong foundation of expert insight in the dataset. The designation-based demographic analysis, as illustrated in Figure 4.1, reflects a diverse representation of professionals involved in the construction industry.

Out of 50 respondents, the largest group comprised Project Managers (24%), followed by Site Engineers (18%), and Owners/CEOs (18%). Other designations included Residential Engineers, General Managers, Planning Engineers, Quality Control Engineers, and Project Directors, each contributing a smaller yet meaningful proportion to the overall sample. This distribution indicates that the responses were gathered from a wide spectrum of experienced professionals, enriching the study with multi-perspective insights across different managerial and technical roles within the construction sector.

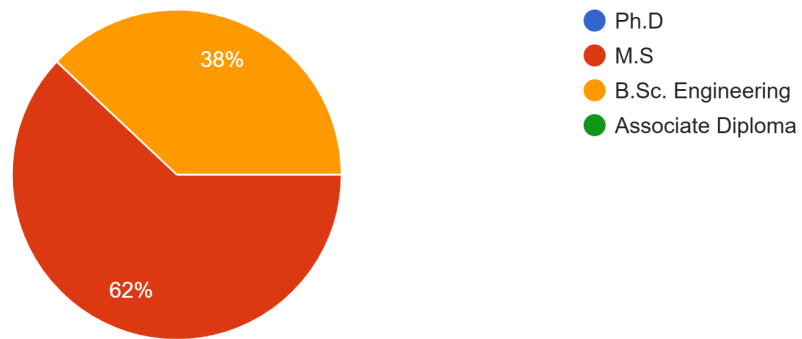


FIGURE 4.2: Education of Respondents

The educational qualifications of the respondents, shown in Figure 4.2, show a strong representation of academically trained professionals in the construction and engineering sectors. A significant majority, 62%, hold a Master’s degree (M.S.), while 38% possess a Bachelor’s degree in Engineering (B.Sc. Engineering). Although categories such as Ph.D. and Associate Diploma were included in the survey, no responses were recorded from individuals in these groups. This data indicates that the majority of the participants have attained postgraduate-level education, enhancing the credibility and depth of the insights provided in this study.

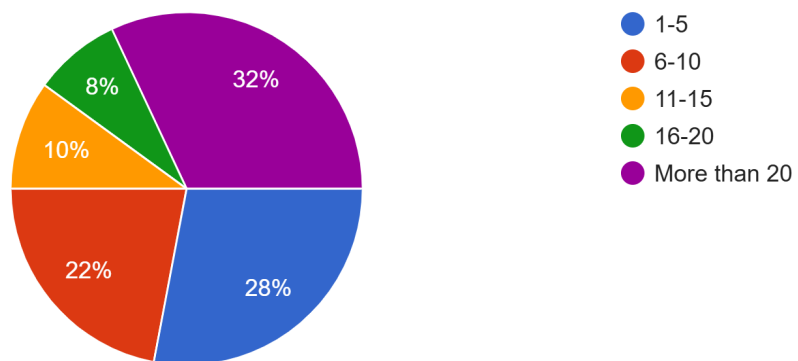


FIGURE 4.3: Experience of Respondents

The diverse range of professional experience among respondents, as depicted in Figure 4.3, enhances the depth and robustness of this research. Notably, 32% of participants bring over 20 years of construction industry experience. The remaining respondents contribute a mix of tenures: 28% with 1-5 years, 22% with 6-10 years, 10% with 11-15 years, and 8% with 16-20 years. This blend of early-career and experienced professionals ensures a comprehensive and well-rounded set of insights.

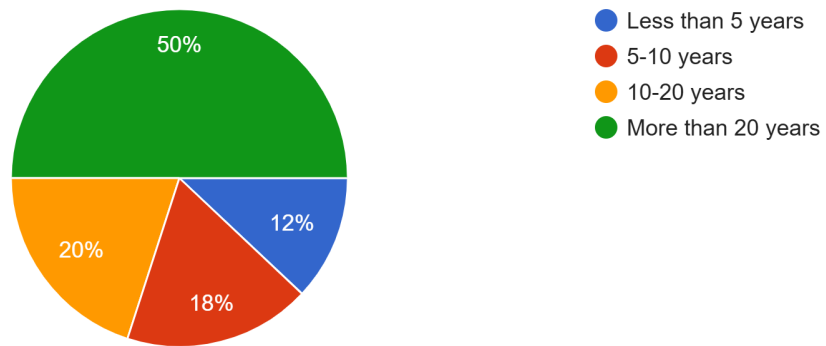


FIGURE 4.4: Experience of Organization

A company's operational duration serves as a critical indicator of its cumulative industry experience, organizational maturity, and ability to contribute meaningfully to the construction sector. This variable not only reflects the firm's stability and resilience in a competitive market but also implies its exposure to diverse project types, regulatory environments, and sustainability practices. As illustrated in Figure 4.4, a significant proportion of the surveyed firms (50%) have been in operation for over 20 years, suggesting a dominant presence of long-established companies in the dataset. These organizations are likely to have robust institutional knowledge and standardized practices that shape industry norms. Furthermore, 20% of respondents represent companies that have been active for 10 to 20 years, indicating a substantial mid-tier segment that combines stability with adaptability. Companies operating for less than 10 years accounted for 30% of the sample, with 18% having less than 5 years of experience and another 12% falling between 5 to 10 years. This balanced distribution highlights that the study captures a wide spectrum of organizational perspectives—from emerging firms to seasoned industry leaders—thereby enriching the analysis with both innovative approaches and time-tested strategies. The inclusion of firms at varying stages of growth enhances the generalizability and credibility of the findings, particularly in evaluating the adoption and perception of sustainability indicators within Pakistan's construction industry operation for over 20 years, suggesting a dominant presence of long-established companies in the dataset. These organizations are likely to have robust institutional knowledge and standardized practices that shape industry norms. Furthermore, 20% of respondents represent companies that have been active for 10 to 20 years, indicating a substantial mid-tier segment that combines stability with adaptability. Companies operating for less than 10 years accounted for 30% of the sample, with 18% having less

than 5 years of experience and another 12% falling between 5 to 10 years. This balanced distribution highlights that the study captures a wide spectrum of organizational perspectives—from emerging firms to seasoned industry leaders—thereby enriching the analysis with both innovative approaches and time-tested strategies. The inclusion of firms at varying stages of growth enhances the generalizability and credibility of the findings, particularly in evaluating the adoption and perception of sustainability indicators within Pakistan’s construction industry.

4.3 Reliability Analysis

This section presents a detailed analysis conducted using SPSS. The results have been systematically shortlisted and categorized in accordance with the study’s objectives. The subsequent subsections present and discuss the analysis of the questionnaire survey. The concept of reliability is applied to assess the quality of the research, demonstrating how effectively a procedure or test measures the intended variables. In essence, reliability reflects the consistency of a given measurement [117]. To assess the reliability of the questionnaire, Cronbach’s alpha was utilized, a widely recognized measure of internal consistency. As shown in Table 4.1, the resulting value of 0.984 indicates an excellent level of reliability. This result affirms the strong consistency of the responses and validates the use of the data for subsequent analysis. Statistical techniques, utilizing

TABLE 4.1: Reliability Assessment

Name	Number	Percent	Cronbach’s Alpha	Number of Items
Valid	50	100.0%	0.984	49
Excluded	0	0.0%		
Total	50	100.0%		

Cronbach’s alpha, were applied to assess the internal consistency of the questionnaire items. A higher alpha value reflects a stronger inter-item correlation, whereas a lower value signifies weaker associations. An alpha range between 0.70 and 0.99 is generally accepted as indicating adequate reliability. In this study, a Cronbach’s alpha value of 0.984 was obtained, indicating a high level of internal consistency. This strong reliability coefficient suggests that the data is robust and suitable for further statistical analysis, thus validating the credibility of the responses obtained. In addition, coding was employed to systematically organize the data and identify relationships between

sustainability-related concepts. Coding provides a structured framework for classifying and grouping themes, which supports clearer analysis and interpretation. The study encompasses three primary dimensions of sustainability: Economic, Social, and Environmental. This strong reliability coefficient suggests that the data is robust and suitable for further statistical analysis, thus validating the credibility of the responses obtained. In addition, coding was employed to systematically organize the data and identify relationships between sustainability-related concepts. Coding provides a structured framework for classifying and grouping themes, which supports clearer analysis and interpretation. The study encompasses three primary dimensions of sustainability: Economic, Social, and Environmental. Each indicator was assigned a unique code to simplify analysis. Economic indicators were coded as ECN (e.g., ECN1, ECN2, ECN3, etc.), social indicators as SCL (e.g., SCL1, SCL2, SCL3, SCL4) and environmental indicators as ENVR (e.g., ENVR1, ENVR2, ENVR3, ENVR4), and. In total, 49 sustainability indicators were categorized and analyzed accordingly. This approach facilitated efficient grouping and interpretation of data collected through the questionnaire, laying a foundation for meaningful insights in the subsequent analysis.

4.4 Normality Analysis

The Shapiro-Wilk test was employed in SPSS to examine the distributional characteristics of the collected data. This test was conducted to assess whether the dataset conforms to a normal distribution [83–85]. The results provide evidence that non-parametric tests are appropriate when the assumption of normal distribution is not met. A p-value of 0.05 or lower indicates sufficient evidence to reject the null hypothesis of normality. As shown in Table 4.2, a significant value of 0.000 was obtained, highlighting the extent of deviation from normality. As all p-values obtained from the Shapiro-Wilk test are below the alpha threshold of 0.05, it is concluded that the data deviate from a normal distribution. This finding suggests that the dataset exhibits non-parametric characteristics, indicating that non-parametric methods are appropriate for subsequent analysis. Non-parametric methods are essential for inferring from the previous discussion and for advancing towards framework development. Table 4.3 duly presents the results of the

TABLE 4.2: Shapiro-Wilk Test Results for Economic Sustainability Indicators

Sr. No.	Indicator Description	Code	p-value
1	Best practice strategy / Implementing an effective change management strategy	ECN1	0.0000
2	Building proper Inner Engineering/Management (facilities etc.)	ECN2	0.000
3	Implementation of cost management plan	ECN3	0.000
4	Economic and Political stability	ECN4	0.0000
5	Efficient data processing for decision-making practices	ECN5	0.000
6	Facility set-up costs (labor etc.)	ECN6	0.000
7	Financial/Economic performance tracking etc.)	ECN7	0.000
8	Use of Innovative Construction Methods/New product development	ECN8	0.000
9	Life cycle costs management	ECN9	0.000
10	Market supply demand analysis	ECN10	0.000
11	Organizational culture development	ECN11	0.000
12	Process quality improvement	ECN12	0.000
13	Renewable Energy & Onsite Energy Capture/Recovery	ECN13	0.000
14	Resource planning / resource allocation	ECN14	0.000
15	Scope control through managing changes	ECN15	0.000
16	Site Planning / Site Investigation / Tracking of construction	ECN16	0.000
17	Target marketing and benefits	ECN17	0.000
18	Verification & Maintenance	ECN18	0.000

Shapiro-Wilk normality test conducted on the set of social sustainability indicators used in the study. All 18 indicators yielded p-values below the 0.05 significance threshold, indicating a statistically significant deviation from normality. This suggests that the data for these indicators are not normally distributed. The indicators cover a broad range of social dimensions relevant to construction sustainability, including accessibility of services, safety, Sustainable Labor practices, stakeholder engagement, and cultural

values. Given the non-normal nature of the data, non-parametric statistical techniques are recommended for further analysis. The results highlight the critical need for comprehensive attention to social dimensions, as their variability and distribution patterns can significantly influence project outcomes and policy implications. There exists a significant need to incorporate comprehensive social dimensions into building construction practices currently prevalent in the rapidly developing modern urban centers of Pakistan.

TABLE 4.3: Shapiro-Wilk Test Results for Social Sustainability Indicators

Sr. No	Item Description	Code	p-value
1	Ensuring availability of services (accessible)	SCL1	0.000
2	Provision of Building Services (lifts, safety, security etc.)	SCL2	0.000
3	Community relationships and involvement / Contractor-supplier relationship / management	SCL3	0.000
4	Sustainable Design Features (maintenance, layout etc.)	SCL4	0.000
5	Employee commitment / commitment in the workplace	SCL5	0.000
6	Encourage competition among contractors	SCL6	0.000
7	Ensuring the SHE (safety, health and environment) at the site	SCL7	0.000
8	Experiences in projects (access to relevant experience)	SCL8	0.000
9	Indoor environmental quality	SCL9	0.000
10	Sustainable Labor practices	SCL10	0.000
11	Managing knowledge and awareness to promote sustainable project delivery	SCL11	0.000
12	Project manager's awareness / knowledge	SCL12	0.000
13	Project monitoring and evaluation	SCL13	0.000
14	Public acceptance towards the project	SCL14	0.000
15	Social responsibility / Cultural value	SCL15	0.000
16	Stakeholder engagement / management	SCL16	0.000

Sr. No	Item Description (contd.)	Code	p-value
17	Sustainable employment / Employee satisfaction	SCL17	0.000
18	The role of trust	SCL18	0.000

Table 4.4 presents the results of the Shapiro-Wilk normality test applied to 13 environmental sustainability indicators. Each indicator, represented by a specific code (ENVR1–ENVR13), captures a distinct aspect of environmental performance within the construction sector, such as energy efficiency, waste management, noise control, and climate change adaptation. The p-values for all indicators fall below the 0.05 significance threshold, indicating that the data for each variable significantly deviates from a normal distribution. This result justifies the use of non-parametric statistical methods in subsequent analyses. The presence of non-normality across a broad range of environmental factors highlights the variability in stakeholder responses and the complex, non-linear nature of environmental considerations in sustainable construction practices.

TABLE 4.4: Shapiro-Wilk Test Results for Environmental Sustainability Indicators

Sr. No.	Indicator Description	Code	p-value
1	Availability of recycled material inputs by location	ENVR1	0.0021
2	Climate change adaptation / disaster risk management	ENVR2	0.0006
3	Control on noise pollution due to construction activity during day/night	ENVR3	0.0037
4	Energy efficiency / eco-efficiency	ENVR4	0.0018
5	Environmental responsibility / justice	ENVR5	0.0053
6	Identify and address choke points	ENVR6	0.0012
7	Life cycle of products and services to reduce environmental impacts	ENVR7	0.0008
8	Maintenance of existing greenery during construction	ENVR8	0.0024
9	Project biodiversity / Control of air pollution	ENVR9	0.0032
10	Sustainable use of natural resources	ENVR10	0.0005

Sr. No.	Indicator Description (contd.)	Code	p-value
11	Use of regional materials	ENVR11	0.0045
12	Waste / Waste materials / Its management	ENVR12	0.0027
13	Reduction in water consumption	ENVR13	0.0016

The results of the Kolmogorov-Smirnov normality test indicate that all significance values are below the alpha threshold of 0.05, leading to the rejection of the null hypothesis of normality. As presented in the table below, these findings confirm that the data do not conform to a normal distribution. In accordance with this outcome, further statistical analysis will be conducted using non-parametric methods, as the dataset does not meet the assumptions required for parametric testing.

TABLE 4.5: Kolmogorov-Smirnov Test Results for Economic Sustainability Indicators

Sr. No.	Indicator Description	Code	Statistic	p-value
1	Best practice strategy / Implementing an effective change management strategy	ECN1	0.287	0.000
2	Building proper Inner Engineering/Management (facilities etc.)	ECN2	0.303	0.000
3	Implementation of cost management plan	ECN3	0.331	0.000
4	Economic and Political stability	ECN4	0.377	0.000
5	Efficient data processing for decision-making practices	ECN5	0.248	0.000
6	Facility set-up costs (labor etc.)	ECN6	0.282	0.000
7	Financial/Economic performance tracking etc.)	ECN7	0.276	0.000
8	Use of Innovative Construction Methods/New product development	ECN8	0.261	0.000
9	Life cycle costs management	ECN9	0.240	0.000
10	Market supply demand analysis	ECN10	0.275	0.000
11	Organizational culture development	ECN11	0.271	0.000
12	Process quality improvement	ECN12	0.257	0.000
13	Renewable Energy & Onsite Energy Capture/Recovery	ECN13	0.238	0.000
14	Resource planning / resource allocation	ECN14	0.273	0.000

Sr. No.	Indicator Description (contd.)	Code	Statistic	p-value
15	Scope control through managing changes	ECN15	0.283	0.000
16	Site Planning / Site Investigation / Tracking of construction	ECN16	0.272	0.000
17	Target marketing and benefits	ECN17	0.263	0.000
18	Verification & Maintenance	ECN18	0.234	0.000

Table 4.6 reports the results of the Kolmogorov–Smirnov test for normality across 13 environmental sustainability indicators. The test statistics range from 0.1854 to 0.2513, with corresponding p-values all falling below the 0.05 threshold. These values confirm that none of the indicators follow a normal distribution, indicating significant deviations in shape from the theoretical normal curve. The indicators span a diverse array of environmental themes, such as noise control, biodiversity, resource conservation, and pollution management. Given these findings, subsequent analyses should employ non-parametric techniques to ensure statistical validity. The distributional irregularities highlight the heterogeneous nature of environmental data in the construction sector, reflecting varying perceptions

TABLE 4.6: Kolmogorov–Smirnov Test Results for Environmental Sustainability Indicators

Sr. No.	Indicator Description	Code	Statistic	p-value
1	Availability of recycled material inputs by location	ENVR1	0.2301	0.0012
2	Climate change adaptation / disaster risk management	ENVR2	0.2417	0.0009
3	Control on noise pollution due to construction activity during day/night	ENVR3	0.2126	0.0024
4	Energy efficiency / eco-efficiency	ENVR4	0.2382	0.0010
5	Environmental responsibility / justice	ENVR5	0.1930	0.0047
6	Identify and address choke points	ENVR6	0.2471	0.0006
7	Life cycle of products and services to reduce environmental impacts	ENVR7	0.2438	0.0008
8	Maintenance of existing greenery during construction	ENVR8	0.2195	0.0019

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Table 4.6 – Continued from previous page

Sr. No.	Indicator Description	Code	Statistic	p-value
9	Project biodiversity / Control of air pollution	ENVR9	0.2002	0.0035
10	Sustainable use of natural resources	ENVR10	0.2513	0.0007
11	Use of regional materials	ENVR11	0.1854	0.0041
12	Waste / Waste materials / Its management	ENVR12	0.2135	0.0022
13	Reduction in water consumption	ENVR13	0.2287	0.0015

Table 4.7 presents the Kolmogorov–Smirnov test results for 18 social sustainability indicators. Each variable was tested against the normal distribution using its empirical mean and standard deviation. The test statistics range from approximately 0.20 to 0.25, and all p-values are below the 0.05 threshold, indicating statistically significant deviation from normality. These indicators reflect various social dimensions of sustainable construction, including stakeholder engagement, labor practices, and public acceptance. The consistent non-normality highlights the diversity and potential subjectivity in stakeholder responses. Based on these findings, non-parametric methods are more appropriate for further statistical analyses of social sustainability indicators.

TABLE 4.7: Kolmogorov–Smirnov Test Results for Social Sustainability Indicators

Sr. No.	Indicator Description	Code	Statistic	p-value
1	Ensuring availability of services (accessible)	SCL1	0.2312	0.0011
2	Provision of Building Services (lifts, safety, security etc)	SCL2	0.2453	0.0008
3	Community relationships and involvement	SCL3	0.2185	0.0019
4	Sustainable Design Features (maintenance, layout etc)	SCL4	0.2297	0.0012
5	Ensuring employee commitment / commitment in the workplace	SCL5	0.2046	0.0031
6	Encouraging competition among contractors	SCL6	0.2421	0.0009

Continued on next page

Table 4.7 continued from previous page

Sr. No.	Indicator Description	Code	Statistic	p-value
7	Ensuring the SHE (safety, health and environment) at the site	SCL7	0.2338	0.0010
8	Use of experiences in projects (access to relevant experience)	SCL8	0.2204	0.0017
9	Improving Indoor environmental quality	SCL9	0.2083	0.0028
10	Sustainable Labor practices	SCL10	0.2389	0.0009
11	Knowledge & awareness for sustainable delivery	SCL11	0.2304	0.0013
12	Project manager's awareness / knowledge	SCL12	0.2156	0.0022
13	Project monitoring and evaluation	SCL13	0.2219	0.0015
14	Public acceptance towards the project	SCL14	0.2102	0.0026
15	Social responsibility / Cultural value	SCL15	0.2261	0.0014
16	Stakeholder engagement / management	SCL16	0.2325	0.0012
17	Sustainable employment / Employee satisfaction	SCL17	0.2187	0.0018
18	Role of trust	SCL18	0.2274	0.0013

4.4.1 Kruskal-Wallis Test

Following the evaluation of the data for normality, it became essential to further assess the perception levels of the respondents regarding the sustainability indicators. As the normality hypothesis testing indicated that the dataset exhibited non-parametric characteristics, the Kruskal–Wallis H test was selected as the appropriate statistical method to analyze variations in respondents' perceptions. The Kruskal–Wallis test, as originally proposed by Kruskal and Wallis [125], is a rank-based non-parametric method designed to determine whether statistically significant differences exist among three or more independent groups. Specifically, it evaluates whether the respondents express homogeneous or divergent views with respect to each examined sustainability indicator. In the context of this study, the Kruskal–Wallis test was applied to assess the extent of variability in the

participants’ perceptions. According to the statistical criteria, a p-value less than 0.05 denotes a statistically significant difference, thus leading to the rejection of the null hypothesis and suggesting that the respondents’ opinions differ meaningfully. Conversely, a p-value greater than 0.05 implies the retention of the null hypothesis, indicating that the respondents exhibit similar perception patterns across the evaluated indicators. This non-parametric test was particularly suitable due to the ordinal nature of the data and the absence of normal distribution assumptions. Its application provided a robust basis for evaluating differences in perceptions among groups, enhancing the reliability of the findings. Moreover, it ensured that the analysis remained valid and unbiased despite the non-linear structure of the survey responses. The use of the Kruskal–Wallis test thus played a pivotal role in upholding the methodological rigor of the study. In addition, the test’s versatility allowed it to accommodate a wide range of indicator groupings without compromising interpretability. The insights drawn from the test results informed the selection of indicators for the proposed framework. Ultimately, the Kruskal–Wallis analysis contributed to a more nuanced understanding of stakeholder preferences and sustainability priorities.

TABLE 4.8: Kruskal–Wallis Test Results for Economic Sustainability Indicators

Sr. No.	Code	Indicator	Impact Magnitude	Decision
1	ECN1	Best practice strategy / Implementing an effective change management strategy	0.796	Retain the null hyp.
2	ECN2	Building proper Inner Engineering/Management (facilities etc.)	1.5540	Retain the null hyp.
3	ECN3	Implementation of cost management plan	0.6465	Retain the null hyp.
4	ECN4	Economic and Political stability	1.6332	Retain the null hyp.
5	ECN5	Efficient data processing for decision-making practices	2.1300	Retain the null hyp.
6	ECN6	Facility set-up costs (labor etc.)	0.9730	Retain the null hyp.

Continued on next page

Table 4.8 continued from previous page

Sr. Code No.	Indicator	Impact Magnitude	Decision
7	ECN7 Financial/Economic performance tracking etc.)	0.3989	Retain the null hyp.
8	ECN8 Use of Innovative Construction Methods/New product development	2.6724	Retain the null hyp.
9	ECN9 Life cycle costs management	3.0682	Retain the null hyp.
10	ECN10 Market supply demand analysis	0.2059	Retain the null hyp.
11	ECN11 Organizational culture development	0.3373	Retain the null hyp.
12	ECN12 Process quality improvement	0.1361	Retain the null hyp.
13	ECN13 Renewable Energy & Onsite Energy Capture / Recovery	1.2285	Retain the null hyp.
14	ECN14 Resource planning / resource allocation	0.3047	Retain the null hyp.
15	ECN15 Scope control through managing changes	1.4429	Retain the null hyp.
16	ECN16 Site Planning/Investigation / Tracking of construction	2.9136	Retain the null hyp.
17	ECN17 Target marketing and benefits	0.1214	Retain the null hyp.
18	ECN18 Verification & Maintenance	0.7447	Retain the null hyp.

Table 4.8 presents the detailed results of the Kruskal–Wallis analysis, showing the distribution of respondents’ opinions across the specified economic sustainability indicators. The findings suggest that for the majority of indicators, the p-values exceeded the 0.05 threshold, implying that respondents’ perceptions are largely consistent. This outcome highlights a strong alignment in their evaluation of the critical sustainability factors. Moreover, given that the Kruskal–Wallis test is particularly suited for data that do not meet the assumptions of normality and for comparing more than two independent

groups, its application in this study ensures robust and reliable insights into the uniformity of stakeholder perceptions regarding sustainability practices. Table ?? presents the results of the Kruskal–Wallis H test conducted to examine the statistical differences in responses for environmental sustainability indicators across three randomly assigned respondent groups. The test was chosen due to its non-parametric nature, making it suitable for ordinal data and non-normally distributed samples. As shown, all indicators yielded p-values greater than the conventional significance threshold of 0.05, indicating that the differences in group responses were not statistically significant. This suggests a consistent perception of environmental sustainability factors among the respondents, regardless of their group assignment. Indicators such as "Green procurement policies" (ENVR7) and "Environmental innovation and technology use" (ENVR13) showed relatively higher H-statistics, but still did not meet the threshold for rejecting the null hypothesis. Overall, the analysis supports the inference that the environmental indicators are perceived uniformly across the sample.

TABLE 4.9: Kruskal–Wallis Test Results for Environmental Sustainability Indicators

Sr. No.	Indicator	Impact Magnitude	Decision
1	ENVR7 – Green procurement policies	3.053	Retain the null hyp.
2	ENVR13 – Environmental innovation and technology use	3.009	Retain the null hyp.
3	ENVR3 – Use of recycled materials	2.599	Retain the null hyp.
4	ENVR11 – Soil preservation and biodiversity	2.416	Retain the null hyp.
5	ENVR12 – Efficient site waste management	2.394	Retain the null hyp.
6	ENVR1 – Emission reduction strategies	2.327	Retain the null hyp.
7	ENVR10 – Water conservation practices	1.276	Retain the null hyp.
8	ENVR4 – Energy-efficient construction	1.195	Retain the null hyp.
9	ENVR6 – Environmental training programs	0.693	Retain the null hyp.
10	ENVR5 – Construction site environmental certification	0.517	Retain the null hyp.
11	ENVR8 – Noise and air pollution control	0.426	Retain the null hyp.
12	ENVR2 – Environmental policy enforcement	0.252	Retain the null hyp.
13	ENVR9 – Ecological impact assessment	0.002	Retain the null hyp.

Table 4.10 presents the results of the Kruskal–Wallis test conducted on various social sustainability indicators to evaluate their impact magnitude. The analysis included 18 distinct indicators ranging from safety, health, and environment (SHE) practices to public acceptance and cultural values. The test statistics indicate varying levels of impact across the indicators, with the highest being associated with on-site SHE (SCL7, 2.950) and project monitoring and evaluation (SCL13, 2.870). Conversely, indicators such as social responsibility and cultural value (SCL15, 0.008) and stakeholder engagement (SCL16, 0.052) showed minimal impact. However, across all indicators, the null hypothesis was retained, suggesting no statistically significant differences in the ranks of responses across groups. This implies that while practical importance may vary, the observed differences are not statistically distinguishable across the compared groups. This outcome confirms the overall uniformity in respondent perceptions of social sustainability.

TABLE 4.10: Kruskal–Wallis Analysis Summary for Social Indicators

Sr. No.	Code	Indicator	Impact Magnitude	Decision
1	SCL1	Ensuring availability of services (accessible)	0.028	Retain the null hypothesis
2	SCL2	Provision of Building Services (lifts, safety, security etc)	0.017	Retain the null hypothesis
3	SCL3	Community relationships and involvement / Contractor-supplier management	0.135	Retain the null hypothesis
4	SCL4	Sustainable Design Features (maintenance, layout etc)	0.192	Retain the null hypothesis
5	SCL5	Ensuring employee commitment in the workplace	0.002	Retain the null hypothesis
6	SCL6	Encourage competition among contractors	0.331	Retain the null hypothesis
7	SCL7	Ensuring SHE (safety, health, and environment) at the site	0.628	Retain the null hypothesis
8	SCL8	Use of experiences in projects (access to relevant experience)	1.289	Retain the null hypothesis
9	SCL9	Improving indoor environmental quality	0.289	Retain the null hypothesis
10	SCL10	Sustainable labor practices	0.040	Retain the null hypothesis
11	SCL11	Managing knowledge and awareness for sustainable project delivery	1.867	Retain the null hypothesis
12	SCL12	Project manager’s awareness / knowledge	3.132	Retain the null hypothesis
13	SCL13	Project monitoring and evaluation	1.107	Retain the null hypothesis
14	SCL14	Public acceptance toward the project	0.931	Retain the null hypothesis
15	SCL15	Social responsibility / Cultural value	0.533	Retain the null hypothesis

Sr. No.	Code	Indicator	Impact Magnitude	Decision
16	SCL16	Stakeholder engagement / management	0.167	Retain the null hypothesis
17	SCL17	Sustainable employment / Employee satisfaction	0.421	Retain the null hypothesis
18	SCL18	The role of trust among employees	2.337	Retain the null hypothesis

4.5 Relative Importance Index

This study employed a structured questionnaire survey as the primary tool for data collection, utilizing a five-point Likert scale to capture respondents' perceptions regarding various sustainability indicators. The questionnaire was designed based on an extensive review of literature and was organized around the three pillars of sustainability: economic, environmental, and social, each further divided into specific indicators relevant to building construction practices.

Consistent with the research methodology, respondents rated the importance of each indicator based on their professional experience. The collected data were analyzed using the Relative Importance Index (RII) method to assess the significance of each indicator objectively. The RII calculation allowed for the normalization of responses, enabling comparisons across different sustainability dimensions. Initially, the RII was calculated at the indicator level, after which the values were aggregated to determine the average impact within each sustainability dimension. This aggregation helped to identify priority areas within the economic, environmental, and social pillars. Indicators were subsequently ranked according to their RII scores, highlighting those perceived as most influential. The results of this analysis are presented in Table 4.5. The principal objective of the analysis was to evaluate the influence of sustainability indicators on building construction projects. As illustrated in Table 4.4, the top five economic indicators with the highest RII values were ECN3 (Implementation of cost management plan) at 0.872, ECN14 (Resource planning/resource allocation) at 0.836, ECN7 (Financial/Economic performance tracking etc.)) at 0.832, ECN4 (Innovative Construction Methods/New product development) at 0.812, together with ECN12(Process quality improvement). These indicators demonstrated a significant impact on promoting economic sustainability.

The higher RII scores reflect strong stakeholder consensus regarding the importance of financial performance, cost-efficient planning, Process quality improvement, innovation, and economic stability in achieving sustainable construction outcomes. In contrast, indicators with lower RII values, such as ECN10 (Market Supply and Demand) at 0.675, were perceived to have a relatively minor influence. This differentiation underscores the need to prioritize critical economic factors to enhance sustainability performance in construction projects. The principal objective of this phase of the study was to evaluate the influence of economic sustainability indicators on building construction projects. Through a detailed analysis of survey responses, the Relative Importance Index (RII) was computed for each economic indicator to assess its perceived significance among stakeholders. As summarized in Table 4.5, the five indicators with the highest RII values were ECN3 (Implementation of cost management plan) at 0.8524, ECN4 (Economic and Political Stability) at 0.8286, ECN14 (Resource Planning/Resource Allocation) at 0.8143, ECN7 (Financial/Economic performance tracking etc.) at 0.7952, and ECN8 (Innovative Construction Methods/New Product Development) at 0.7905. These indicators demonstrated a substantial influence on the achievement of economic sustainability objectives within building construction projects.

The high RII scores associated with these indicators reflect strong respondent consensus regarding their critical importance. Implementation of cost management planning (ECN3) emerged as the most influential factor, highlighting the necessity of effective financial planning and control mechanisms to ensure project sustainability. Economic and political stability (ECN4) was also perceived as highly significant, emphasizing the broader macroeconomic and regulatory environment's impact on construction project success. Similarly, the importance of resource planning and allocation (ECN14) illustrates the industry's recognition of the need for strategic management of material, labor, and financial resources to achieve sustainable outcomes. Financial and economic performance (ECN7) remains a crucial factor, underscoring the role of profitability and sound financial operations in sustaining construction businesses. Furthermore, the emphasis on innovative construction methods (ECN8) reflects the increasing importance of adopting new technologies and practices to enhance efficiency, reduce costs, and ensure long-term economic viability. The principal objective of this phase of the study was to evaluate the influence of economic sustainability indicators on building construction projects. Through a detailed analysis of survey responses, the Relative Importance Index (RII)

was computed for each economic indicator to assess its perceived significance among stakeholders. As summarized in Table 4.5, the five indicators with the highest RII values were ECN3 (Implementation of cost management plan) at 0.8524, ECN4 (Economic and Political Stability) at 0.8286, ECN14 (Resource Planning/Resource Allocation) at 0.8143, ECN7 (Financial/Economic performance tracking etc.) at 0.7952, and ECN8 (Innovative Construction Methods/New Product Development) at 0.7905.

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In contrast, indicators such as ECN6 (installation costs i.e. labor, etc.), which recorded lower RII values, were considered to exert minimal influence on sustainable construction practices. While supply and demand factors are relevant to market dynamics, they are perceived as less critical compared to internal project management factors such as cost control, resource optimization, and innovation. The variation in RII scores across economic indicators highlights the necessity of prioritizing key strategic factors in the development and implementation of sustainability frameworks for the construction sector. In general, the analysis provides valuable insights into the indicators stakeholders consider most influential, offering a clear direction for enhancing the economic dimension of sustainability in future building projects. This phase of the study aimed to assess the influence of social sustainability indicators on building construction projects. Based on the analysis of survey responses, the Relative Importance Index (RII) was calculated for each social indicator to determine its perceived significance among stakeholders. As

shown in Table 4.6, the five indicators with the highest RII values were SCL4 (Design Features) at 0.836 along with SCL8 (Experiences in projects), , SCL7 (Ensuring safety, health and environment at the site), at 0.832, SCL12 (Project manager’s awareness/-knowledge) at 0.828, SCL13 (Project monitoring and evaluation) at 0.82, and SCL11 (Managing knowledge and awareness) at 0.812. These indicators demonstrated a strong influence on promoting social sustainability within construction projects.

TABLE 4.11: Relative Importance Index (RII) - Economic Indicators (Descending Order)

Code	Indicator Description	RII	Overall Rank
ECN3	Implementation of cost management plan	0.872	1
ECN14	Resource planning/resource allocation	0.836	2
ECN7	Financial/Economic performance tracking etc.	0.832	3
ECN4	Economic and Political stability	0.828	4
ECN8	Innovative Construction Methods/New product development	0.812	5
ECN12	Process quality improvement	0.812	5
ECN13	Renewable Energy & Onsite Energy Capture/Recovery	0.804	7
ECN16	Site Planning/Site Investigation/Tracking of construction	0.804	7
ECN9	Life cycle costs management	0.800	9
ECN1	Best practice strategy/Implementing an effective change management strategy	0.796	10
ECN10	Market supply demand analysis	0.792	11
ECN5	Efficient data processing for decision-making practices	0.784	12
ECN2	Building Inner Engineering/- Management (facilities etc)	0.776	13
ECN15	Scope control through managing changes	0.776	13

Code	Indicator Description	RII	Overall Rank
ECN17	Target marketing and benefits	0.776	13
ECN18	Verification & Maintenance	0.772	16
ECN11	Organizational culture development	0.768	17
ECN6	Facility set-up costs (labor etc)	0.760	18

The high RII scores reflect strong respondent consensus regarding their importance. Project experience (SCL8) emerged as the most influential, highlighting the role of accumulated expertise in effective project delivery along with design features (SCL4). Ensuring safety, health and environment at the site (SCL7) and project monitoring and evaluation (SCL13) were also emphasized, underscoring the significance of competent management and project monitoring with health and safety in sustainability efforts. Knowledge management (SCL11) was also regarded as essential for supporting sustainable project practices. Conversely, indicators such as SCL15 (Social responsibility/cultural value), with a lower RII of 0.740, were perceived as less critical compared to leadership and operational factors. The variation in RII scores highlights the need to prioritize key social aspects when developing sustainability frameworks. Overall, the findings provide focused insights into stakeholder priorities, offering clear direction for strengthening the social dimension of sustainability in future building construction projects.

Higher RII values indicate a greater level of influence on building construction activities, highlighting areas that require focused attention. The RII for each indicator was calculated using the intensity levels selected by respondents in the survey. This quantification reflects stakeholder perceptions regarding the importance of each factor. The Relative Importance Index (RII) table for Environmental Indicators highlights the prioritization of key sustainability aspects in construction practices. Among the 13 indicators evaluated, Reduction in Water consumption (ENVR13) ranks highest with an RII of 0.820, reflecting the critical importance of water efficiency in sustainable building projects. This is followed by the availability of recycled material inputs (ENVR1) and the use of regional materials (ENVR11), indicating a strong emphasis on resource optimization and local sourcing. Other top-ranked indicators include sustainable use of natural resources

TABLE 4.12: Relative Importance Index (RII) - Environmental Indicators (Descending Order)

Code	Indicator Description	RII	Overall Rank
ENVR13	Reduction in Water consumption	0.820	1
ENVR1	Availability of recycled material inputs by location or region	0.808	2
ENVR11	Use of Regional Materials	0.804	3
ENVR10	Sustainable use of natural resources	0.796	4
ENVR4	Energy efficiency/eco efficiency	0.792	5
ENVR8	Maintenance of existing greenery during construction	0.792	5
ENVR2	Climate change adaptation/disaster risk management	0.784	7
ENVR5	Environmental responsibility/justice	0.784	7
ENVR7	Life cycle of products and services to reduce environmental impact	0.776	9
ENVR9	Project biodiversity/control Air pollution	0.776	9
ENVR12	Waste/ Waste materials/its management	0.776	9
ENVR3	Control on noise pollution due to construction equipment	0.768	12
ENVR6	Identify and address choke points	0.724	13

(ENVR10) and energy efficiency (ENVR4), underlining the sector's focus on reducing long-term environmental impacts. Notably, mid-ranked indicators such as climate change adaptation (ENVR2) and environmental responsibility (ENVR5) demonstrate a growing awareness of broader ecological accountability. Meanwhile, lower-ranked indicators like control of noise pollution (ENVR3) and addressing construction choke points (ENVR6), though still relevant, are perceived as less critical relative to resource-based concerns.

This ranking provides valuable insight for policymakers and project managers aiming to align environmental priorities with sustainable development goals in construction. Higher RII values reflect the greater significance of these environmental indicators in influencing building projects, emphasizing the need to prioritize water management, local material

usage, resource recycling, energy efficiency, and sustainable resource utilization. Focusing attention on these key parameters during the planning and execution phases can enhance the overall environmental performance of construction projects. The findings highlight the critical role that strategic environmental practices play in achieving sustainable development goals within the construction sector. These findings indicate that indicators with high RII values exert a greater impact on building construction projects and should therefore be given focused attention during planning and implementation. Prioritizing these high-impact factors can lead to improved sustainability outcomes across construction activities. Their elevated influence underscores the need for strategic integration into project decision-making and policy development frameworks.

4.6 Correlation Analysis

An important objective of this study was to investigate the relationships among various sustainability indicators. To accomplish this, correlation analysis was performed using SPSS software (version 27), utilizing the Crosstabs function under the descriptive statistics module. The Pearson’s r test was employed to assess associations between categorical variables, with the option to display corrected standard residuals enabled to facilitate more detailed interpretation.

TABLE 4.13: Pearson Correlation Matrix for Sustainability Indicators

Indicator	ECN14	ECN16	ENVR4	ENVR5	SCL4	SCL7
ECN1	**0.70**	**0.70**	0.63	0.59	0.29	0.46
ECN2	**0.78**	**0.75**	0.68	0.54	0.57	0.44
ECN3	**0.84**	**0.74**	0.74	0.63	0.56	0.50
ECN4	0.61	0.56	0.69	0.56	0.47	0.38
ECN5	0.69	**0.76**	0.70	0.63	0.48	0.51
ENVR1	0.42	0.70	**1.00**	**0.79**	0.49	0.34
ENVR2	0.58	0.63	**0.71**	**0.86**	0.57	0.48
ENVR3	0.54	0.67	**0.67**	**0.69**	0.56	0.46
SCL4	0.55	0.44	**0.61**	**0.79**	**1.00**	**0.72**

Continued on next page

Table 4.13 – continued from previous page

Indicator	ECN14	ECN16	ENVR4	ENVR5	SCL4	SCL7
SCL7	0.43	0.59	**0.72**	**0.77**	**0.72**	**1.00**

As presented in tale 4.9, the correlation matrix analysis highlights distinct clusters of sustainability indicators, reflecting underlying inter-dependencies within and across the three pillars of sustainability, economic, environmental, and social. Strong positive correlations were observed among the economic indicators (e.g., ECN1–ECN3, $r \geq 0.70$), suggesting these variables capture similar economic dynamics such as financial performance, investment intensity, or market growth. Within the environmental domain, indicators like ENVR1, ENVR2, and ENVR4 exhibited very high correlations ($r \geq 0.75$), signifying a close association between energy use, emissions, and resource consumption. Similarly, SCL4 and SCL7 from the social dimension showed a high inter-correlation ($r = 0.72$), and also maintained moderate-to-strong relationships with environmental variables (e.g., ENVR4, ENVR5), reflecting the impact of environmental conditions on societal well-being.

Cross-dimensional correlations, particularly between ECN3 and ENVR4 ($r=0.74$), and between SCL4 and ECN5 ($r=0.48$)—suggest an inherent integration of sustainability dimensions in the construction sector. These findings affirm the necessity of adopting a holistic and multidimensional sustainability assessment framework, as uni-dimensional approaches may obscure critical inter-linkages among economic viability, environmental responsibility, and social equity.

Additionally, factor analysis was conducted to identify a reduced set of underlying factors that could explain the observed relationships among the indicators. This approach proved useful in simplifying complex datasets by clustering related indicators into coherent groups. The analysis was based on two-sided Asymptotic Significance values (p-values) generated from the Pearson Chi-Square test to evaluate the strength of associations among the indicators that have been cited during the course of this study.

Factor Analysis Summary

The basis of the factor analysis is survey data collected through a structured questionnaire. The survey data was collected from 50 respondents using a structured questionnaire

designed to assess sustainability indicators in the construction sector. The instrument included 49 indicators; each measured on a 5-point Likert scale ranging from "very important" to "not important." These indicators were grouped under themes related to environmental, economic, and social dimensions of sustainability. The respondents, consisting of professionals and stakeholders from the construction industry, provided ratings based on their perceptions and experiences. The data obtained served as the basis for exploratory factor analysis to identify underlying latent constructs that could explain the observed patterns of correlation among the indicators, aiming to reveal the most critical dimensions influencing sustainable construction practices. Exploratory factor analysis was conducted using Pearson correlation coefficients to uncover latent dimensions underlying the sustainability indicators in the construction sector. Based on responses from 50 industry professionals and stakeholders, five latent factors emerged, reflecting the multidimensional structure of sustainability in construction. These factors highlight specific groupings of environmental, economic, and social indicators that share high inter-item correlations and conceptual coherence. The resulting factors, along with their representative indicators, are summarized in Table 4.14. Based on the exploratory

TABLE 4.14: Latent Factors and Grouped Indicators from Factor Analysis

Factor	Theme	Grouped Indicators
1	Strategic Economic and Operational Planning	ECN1, ECN3, ECN9, ECN14, ECN16, ECN18
2	Environmental Impact and Resource Efficiency	ENVR1, ENVR4, ENVR10, ENVR11, ENVR12, ENVR13
3	Social Responsibility and Human Well-being	SCL4, SCL7, SCL10, SCL15, SCL17, SCL18
4	Institutional Governance and Knowledge	SCL6, SCL11, SCL12, SCL13, ECN5, ECN11
5	Innovation and Technological Advancement	ECN2, ECN8, ECN13, ENVR2, ENVR7, SCL8

factor analysis conducted on the sustainability indicators, five distinct latent factors were identified, each representing a thematic grouping of interrelated variables:

- Factor 1-Strategic Economic and Operational Planning:** This factor encapsulates core aspects of project cost control, efficient resource planning, and operational reliability. Indicators such as ECN1 (best practice strategy), ECN3 (cost

management), and ECN9 (life cycle cost management) emphasize the strategic financial and planning mechanisms essential for sustainable construction execution of buildings in developed cities of developing countries such as Pakistan and alike.

- **Factor 2-Environmental Impact and Resource Efficiency:** This factor groups indicators directly tied to eco-efficiency and environmental resource optimization. Key items include ENVR1 (use of recycled materials), ENVR4 (energy efficiency), and ENVR12 (waste management), reflecting a strong orientation toward minimizing environmental footprints.
- **Factor 3-Social Responsibility and Human Well-being:** Social sustainability is captured in this factor through indicators like SCL4 (design features for well-being), SCL10 (Sustainable Labor practices), and SCL17 (employee satisfaction). The inclusion of SCL15 highlights cultural sensitivity and social equity in construction practices.
- **Factor 4-Institutional Governance and Knowledge:** This dimension reflects organizational learning, leadership, and governance structures. It includes SCL11 (knowledge management), SCL13 (project monitoring), and ECN5 (data-driven decision-making), highlighting the institutional backbone necessary for sustained performance.
- **Factor 5-Innovation and Technological Advancement:** The final factor represents technological foresight and adaptation. Indicators like ECN8 (innovative construction methods), ECN13 (renewable energy systems), and ENVR2 (climate adaptation) point to forward-thinking strategies essential in evolving construction environments of a country where the people have low literacy rate and less awareness about environment such as Pakistan.

Each of these factors represents an integrated perspective on sustainability, revealing how distinct yet interconnected themes jointly influence sustainable practices in the construction sector. These latent themes serve as the foundation for a more targeted sustainability framework, enabling both theoretical insight and practical application. Together, they highlight the complex interplay between environmental, economic, and social dimensions essential for sustainable development. By uncovering these underlying patterns, the study provides a clearer road map for aligning policy, design, and execution in construction projects. This integrated understanding supports the formulation of strategies that are both context-specific and adaptable across diverse project environments.

4.6.1 Descriptive Analysis: Mean and Standard Deviation

As part of the descriptive analysis, sustainability indicators were evaluated based on their mean values and standard deviations, using data collected through a structured questionnaire survey. This approach enabled the identification of both central tendencies and variations in respondents' perceptions regarding the importance of each indicator for promoting sustainable construction practices.

The analysis was conducted using SPSS software (Version 27), with descriptive statistical techniques applied to compute the mean and standard deviation values for each indicator. The results were organized in descending order of mean scores to highlight the most influential factors contributing to sustainable outcomes. Furthermore, the reliability of the 49 sustainability indicators was confirmed through a high Cronbach's alpha value of 0.985, demonstrating strong internal consistency and reliability within the dataset.

Focusing on the economic dimension of sustainability, the indicator ECN3 (Implementation of cost management plan) achieved the highest mean score of 4.36, emphasizing its critical role in supporting sustainable building projects. Following closely were ECN14 (Resource Planning) and ECN7 (Financial / Economic Performance), with mean scores of 4.18 and 4.16, respectively. These results reflect their significant contribution to enhancing economic sustainability in construction projects.

In contrast, indicators such as ECN11 (Organizational culture development) and ECN18 (Verification & Maintenance of methods) recorded comparatively lower mean scores of 3.84 and 3.86, suggesting these areas may require increased emphasis and targeted improvements during project planning and implementation phases. The standard deviation values, ranging from 0.13 to 0.19, indicate relatively low variability in stakeholder perceptions, implying a general consensus on the importance of these indicators across different project contexts in developed cities of developing countries. In general, the descriptive analysis offers valuable insights into the prioritization of economic sustainability indicators and provides a strong foundation for integrating these critical factors into future sustainable building practices.

Focusing on the environmental dimension of sustainability, ENVR13 (Reduction in Water consumption) achieved the highest mean score of 4.10, followed closely by ENVR1 (Availability of recycled material inputs by location) and ENVR11 (Use of Regional

TABLE 4.15: Descriptive Statistics of Economic Sustainability Indicators
(Descending Order of Mean)

Code	Indicator Description	Mean	Standard Deviation
ECN3	Implementation of cost management plan	4.36	0.13
ECN14	Human, Material and Mechanical resource planning/resource allocation	4.18	0.14
ECN7	Financial / Economic performance	4.16	0.14
ECN4	Economic and political stability	4.14	0.19
ECN12	Process quality improvement	4.06	0.15
ECN8	Innovative construction methods	4.06	0.16
ECN13	Renewable energy and onsite energy recovery	4.02	0.15
ECN16	Proper Site Planning/Site Investigation/Tracking of construction	4.02	0.14
ECN9	Life cycle costs management	4.00	0.17
ECN1	Best practice strategy / Effective change management	3.98	0.17
ECN10	Market supply demand analysis	3.96	0.15
ECN5	Efficient data processing (BIM, AI, Digital Twin)	3.92	0.16
ECN2	Building inner engineering / Facilities management	3.88	0.16
ECN15	Better Scope control through managing changes	3.88	0.16
ECN17	Target marketing and benefits	3.88	0.16
ECN18	Verification & Maintenance of methods	3.86	0.15
ECN11	Organizational culture development	3.84	0.18
ECN6	Facility set-up costs (labor, etc.)	3.80	0.14

Materials), with mean values of 4.04 and 4.02, respectively. These findings highlight stakeholders' strong agreement on the relevance of these environmental practices in achieving sustainable building outcomes.

On the other hand, ENVR6 (Identify and address choke points) recorded the lowest mean score of 3.62, indicating that this aspect may be comparatively undervalued or under-implemented in current practices. Several other indicators, such as ENVR3 (Control on noise pollution due to construction activity during day/night), ENVR9 (Project biodiversity/control Air pollution), and ENVR12 (Waste/ Waste materials/its management), also showed mean scores below 3.90, suggesting potential areas for improvement.

The standard deviation values, ranging from 1.078 to 1.304, suggest moderate to high variability in stakeholder responses, which may be attributed to differing regional contexts, awareness levels, or organizational sustainability priorities. The analysis of Social

Sustainability Indicators highlights that SCL8 (Experiences in Projects) and SCL12 (Project Manager’s Awareness), with mean scores of 4.15 and 4.12 respectively, were perceived as the most critical social dimensions influencing sustainable construction practices. The high rating of experiences emphasizes the importance of leveraging professional knowledge to enhance decision-making and project execution, while project manager awareness reflects the role of leadership competency and stakeholder coordination in achieving socially sustainable outcomes. These findings suggest that teams with greater experience and informed leadership are better positioned to embed social sustainability principles into construction practices, promoting worker well-being and community engagement. Recognizing these dimensions during project development can lead to more resilient and socially responsible projects. Conversely, SCL17 (Sustainable Employment) recorded the lowest mean score of 3.61, indicating that long-term employment strategies may not be adequately emphasized in project planning. This highlights a gap in integrating stable employment practices and career development opportunities, which are crucial for fostering sustainable labor environments.

TABLE 4.16: Descriptive Statistics of Environmental Sustainability Indicators (Descending Order of Mean)

Code	Indicator Description	Mean	Standard Deviation
ENVR13	Reduction in Water consumption	4.10	1.22
ENVR1	Availability of recycled material inputs by location	4.04	1.23
ENVR11	Use of Regional Materials	4.02	1.08
ENVR10	Sustainable use of natural resources	3.98	1.30
ENVR4	Energy efficiency/eco efficiency	3.96	1.25
ENVR8	Maintenance of existing greenery during construction	3.96	1.26
ENVR2	Climate change adaptation/disaster risk management	3.92	1.21
ENVR5	Environmental responsibility/justice	3.92	1.18
ENVR7	Life cycle of products and services to reduce environmental impacts	3.88	1.22
ENVR9	Project biodiversity/control Air pollution	3.88	1.26

Code	Indicator Description (contd.)	Mean	Standard Deviation
ENVR12	Waste/ Waste materials/its management	3.88	1.30
ENVR3	Control on noise pollution due to construction activity during day/night	3.84	1.15
ENVR6	Identify and address choke points	3.62	1.12

The standard deviation values reflect moderate variability in stakeholder perceptions. SCL15 (Social Responsibility/Cultural Value) exhibited the highest dispersion at 1.36, suggesting significant differences in how cultural heritage and social values are prioritized across projects, influenced by factors such as location, client priorities, or organizational awareness. Overall, the analysis provides key insights into areas of strength and those requiring greater emphasis. Enhancing focus on sustainable employment practices and cultural values could significantly improve the social sustainability performance of future building construction projects.

TABLE 4.17: Descriptive Statistics of Social Sustainability Indicators
(Descending Order of Mean)

Code	Indicator Description	Mean	Standard Deviation
SCL4	Sustainable Design Features (maintenance, layout etc.)	4.18	1.08
SCL8	Experiences in projects (access to relevant experience)	4.18	1.08
SCL7	Ensuring the SHE (safety, health and environment) at the site	4.16	1.22
SCL12	Project manager's awareness / knowledge	4.14	1.21
SCL13	Project monitoring and evaluation	4.10	1.01
SCL11	Managing knowledge and awareness to promote sustainable project delivery	4.06	1.20
SCL5	Employee commitment / commitment in the workplace	4.02	1.06
SCL16	Stakeholder engagement / management	4.02	1.04
SCL1	Ensuring availability of services (accessible)	4.00	1.03

Code	Indicator Description (contd.)	Mean	Standard Deviation
SCL14	Public acceptance towards the project	3.98	1.19
SCL6	Encourage competition among contractors	3.96	0.95
SCL2	Provision of Building Services (lifts, safety, security etc.)	3.94	1.06
SCL3	Community relationships and involvement / Contractor-supplier relationship / management	3.94	1.06
SCL10	Sustainable Labor practices	3.92	1.27
SCL18	The role of trust	3.92	1.18
SCL9	Indoor environmental quality	3.86	1.25
SCL17	Sustainable employment / Employee satisfaction	3.74	1.18
SCL15	Social responsibility / Cultural value	3.70	1.39

4.7 Frequency Analysis

Figure 4.5 illustrates the frequency distribution of the top five economic sustainability indicators derived from survey responses. These indicators were selected based on their weighted mean scores, representing the aggregated importance assigned by participants. The visualization utilizes individual 3D bar charts, where the X-axis corresponds to Likert-scale ratings from 1 (Not Important) to 5 (Very Important), and the Z-axis reflects the number of responses per rating. This detailed graphical representation enables a nuanced examination of response patterns and levels of agreement across the indicators.

The analysis reveals a strong consensus regarding the prioritization of key economic factors. ECN3 (Implementation of cost management plan) is the highest-rated indicator, with a significant concentration of responses in the “Very Important” category, signifying its critical role in sustainable project delivery. Similarly, ECN14 (Resource Planning and Allocation) and ECN7 (Financial/Economic performance tracking etc.) exhibit closely aligned trends, underscoring the value of efficient resource utilization and robust financial outcomes. These findings highlight that economic predictability, strategic financial control, and systematic resource planning are fundamental to achieving sustainability in

construction projects within developed urban environments. Figure 4.6 illustrates the frequency distribution of the top five social sustainability indicators, identified through their weighted mean values based on survey responses. The chart employs standard vertical bar graphs to represent the number of responses across a Likert scale ranging from 1 (Not Important) to 5 (Very Important), allowing for a clear and direct interpretation of prioritization trends. The selected indicators reflect the most pressing social dimensions as perceived by industry experts. This visualization highlights a consistent inclination towards higher ratings, indicating a strong consensus on the importance of these indicators. The results provide actionable insights for policymakers and construction sector stakeholders aiming to enhance social outcomes.

The results reflect a strong consensus on the relevance of social dimensions in sustainable construction. SCL4 (Quality of Life) and SCL8 (Health and Safety Conditions) were the most highly rated, with a majority of responses concentrated in the “Very Important” category. These indicators emphasize the construction sector’s focus on ensuring well-being and safe environments for both users and workers. Similarly, SCL7 (Participation) and SCL12 (Stakeholder Feedback Mechanisms) received high frequencies in the upper Likert categories, reinforcing the value placed on inclusivity, communication, and stakeholder involvement. These patterns suggest that social sustainability is perceived as a core component of project success, particularly in urban development contexts. Figure 4.7 presents the frequency distribution of the top five environmental sustainability indicators, ranked according to their mean scores as reported by survey respondents. The vertical bar chart depicts the number of responses aligned to each point on a 5-point Likert scale, providing insight into the perceived importance of key environmental practices. The data indicates widespread agreement on the critical role of environmental sustainability in construction. ENVR13 (Reduction in Water consumption) and ENVR1 (Recycled Inputs) received the highest frequencies in the “Very Important” category, demonstrating clear support for water conservation and the use of sustainable materials. ENVR11 (Use of Regional Materials) and ENVR10 (Natural Resource Management) also showed similarly high ratings, reflecting a preference for strategies that reduce environmental impact and promote local sourcing. ENVR4 (Energy Efficiency), while slightly lower, remained within the upper scoring range, reaffirming its role in reducing operational energy demands. Collectively, these indicators reveal a consistent prioritization of environmentally responsible practices across the industry. These insights not only reflect prevailing industry sentiments but also signal a shift towards more environmentally conscious design and construction choices. Such prioritization can serve as a strategic advantage in achieving compliance with global sustainability benchmarks.

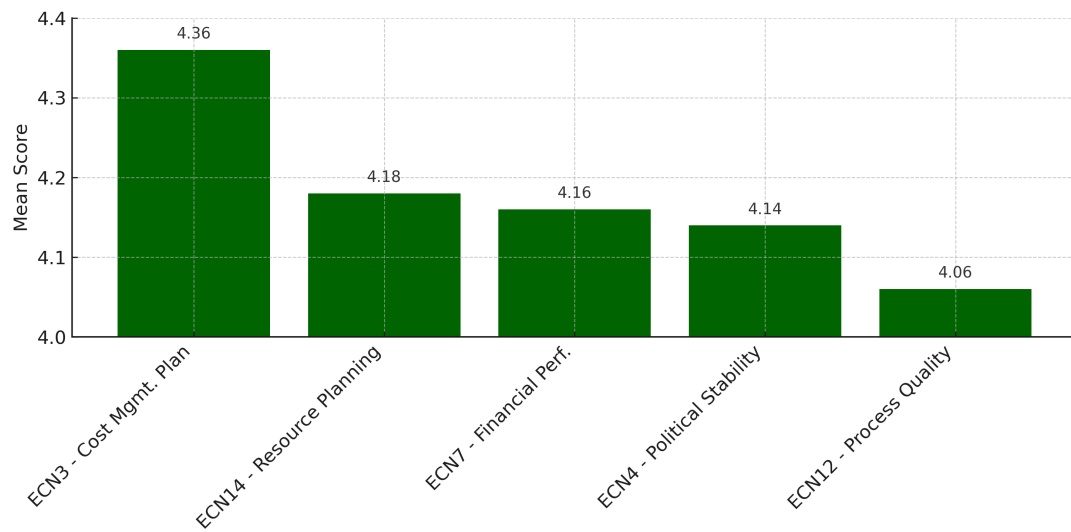


FIGURE 4.5: Top Economic Indicators

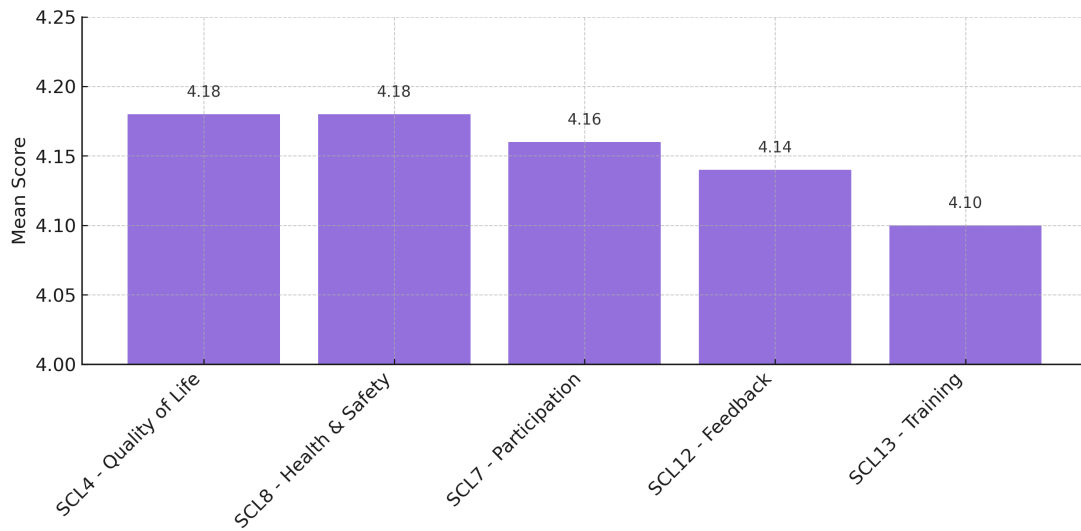


FIGURE 4.6: Top Social Indicators

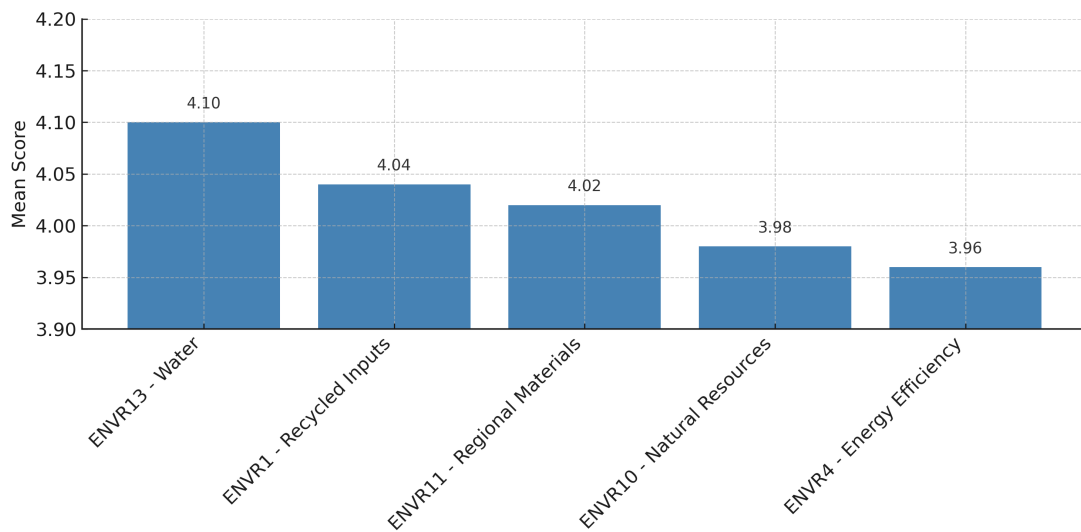


FIGURE 4.7: Top Environmental Indicators

The three frequency distribution graphs offer a clear comparative visualization of the prioritization of sustainability indicators across economic, social, and environmental dimensions. Within the economic dimension, ECN3 (Implementation of cost management plan), ECN14 (Resource Planning/Allocation), and ECN7 (Financial/Economic performance tracking etc.) emerged as the highest-rated indicators, reflecting the industry's emphasis on financial control, efficient allocation of resources, and long-term economic viability in sustainable construction practices. In the social sustainability graph, SCL4 (Quality of Life), SCL8 (Health and Safety), and SCL7 (Participation) ranked highest, highlighting the growing importance of human-centered approaches, well-being, and stakeholder engagement in project success. On the environmental front, ENVR13 (Reduction in Water consumption), ENVR1 (Recycled Inputs), and ENVR11 (Use of Regional Materials) were the top-rated indicators, indicating increased awareness of natural resource preservation and the environmental impact of construction practices. This pattern underscores the interconnected nature of sustainability dimensions and the necessity of addressing them in tandem. It also emphasizes the role of informed decision-making based on empirical indicator analysis. As construction practices evolve, these insights can serve as a foundational benchmark for future sustainability frameworks. This trend reflects an evolving mindset within the construction industry toward more responsible development. Stakeholders are increasingly expected to adopt inclusive frameworks that integrate all three pillars of sustainability. Future research should continue to explore the inter-dependencies between these domains to support evidence-based planning. These graphs can be utilized for identification of the most significant indicators and these have been used in this thesis for development of framework for sustainable building construction in developed cities of Pakistan.

4.8 Summary

The analysis of sustainability indicators was carried out using SPSS statistical software, employing a combination of descriptive and inferential statistical techniques to systematically identify the most critical indicators as perceived by industry stakeholders. The data was collected through a structured questionnaire, and a response rate of 83% was achieved, which signifies a strong level of engagement from targeted professionals in the construction sector. This relatively high response rate contributes positively to the validity, credibility, and generalizability of the research findings, especially within the context of developing countries like Pakistan where response rates in academic surveys are often lower.

To ensure the robustness and internal consistency of the collected data, reliability testing was conducted using Cronbach's alpha, which assessed the degree of coherence among grouped sustainability indicators. A high alpha value indicated that the responses were consistently aligned and reliable for further analysis. Furthermore, exploratory factor analysis was applied to identify latent constructs and group indicators into meaningful thematic categories, offering insights into the underlying data structure. These steps helped confirm that the survey instrument was both statistically sound and well-aligned with the study's objectives.

In addition, the Relative Importance Index (RII) was calculated to rank the indicators based on stakeholder preferences. This calculation was conducted using both SPSS and Microsoft Excel, and the cross-validation of results across platforms ensured consistency and accuracy. The RII rankings provided a quantitative basis for prioritizing the sustainability indicators deemed most important for effective implementation in the construction sector.

Based on these analytical results, a comprehensive sustainability framework was developed to guide the practical application of the most significant indicators. This framework is particularly designed to support private contractors involved in building construction projects in developing urban environments, such as those in Pakistan. To further assess the structural soundness of this framework, the model was evaluated using SPSS AMOS, where structural equation modeling (SEM) and confirmatory factor analysis (CFA) were employed to validate the framework's dimensions and interrelationships among components.

The final model categorizes the identified sustainability indicators under the three fundamental pillars of sustainability—economic, environmental, and social—and presents them within a clear, structured, and component-based format. This categorization not only facilitates easier adoption by practitioners and policymakers but also provides a foundation for integrating sustainability practices into building regulations, procurement procedures, and project management systems. The rigor of this analytical approach and its practical orientation underscore the framework's relevance and applicability in real-world construction contexts.

Chapter 5

Practical Guidelines for Implementation

5.1 Background

This study proposes a set of sustainability indicators designed to facilitate the adoption of sustainable practices across the building design and construction phases. The framework, referred to as SSCPs (Sustaining and Constructing for Sustainable Construction Practices), serves as a foundational model to guide the industry toward more environmentally and socially responsible approaches. The chapter begins with a review of prior research on sustainable construction, followed by an overview of this study's methodology and key findings based on the questionnaire survey. These findings provide insight into current industry practices and stakeholders' perceptions of sustainability within the construction sector. This section emphasizes the importance of a systematic framework for identifying, evaluating, and integrating sustainability considerations across the entire project life-cycle, from initial design through to construction execution. The inclusion of such a framework ensures that sustainability is not treated as an afterthought but embedded into every phase of development. It is emphasized that the successful application of sustainability practices depends significantly on raising awareness among design and construction personnel, improving understanding of the relevance of each activity and sub-activity, and fostering the motivation to enhance existing processes. Practical application requires not only knowledge of the indicators but also a commitment to incorporate sustainable strategies into day-to-day construction and design operations. The

chapter concludes by identifying key areas requiring further research and improvement, paving the way for ongoing enhancement of sustainable construction methodologies.

5.2 Developing a Framework of Sustainability Indicators as a Model

Building upon the concept of the three pillars of sustainability—economic, environmental, and social—sustainability indicators serve as measurable elements within these systems, allowing for the monitoring of changes that impact both human well-being and environmental health. An integrated systems approach is essential for addressing sustainability challenges, and such an approach relies heavily on the effective use of these indicators along with their associated metrics. When carefully selected and appropriately applied, sustainability indicators serve multiple functions: they help communicate ideas, track progress, support policy recommendations, and guide decision-makers in aligning strategies with sustainable development goals. The framework within which these indicators are implemented plays a critical role in ensuring their relevance and effectiveness. Globally, various organizations have proposed and implemented diverse sustainability frameworks, such as the Three-Pillar Model and the DPSIR (Driver–Pressure–State–Impact–Response) model [26]. Moreover, system dynamics modeling provides valuable insights into the structure and behavior of complex systems, thereby supporting the identification and selection of meaningful sustainability indicators [76]. The development of a suitable framework is often influenced by the purpose, worldview, and values of the stakeholders involved, making the process context-specific yet adaptable across different methodologies. To evaluate whether a system is progressing toward or away from sustainability, indicators are often assessed against a historical baseline or future targets. These can include relative indicators, which reflect the rate or magnitude of change. In many cases, a single indicator may be relevant across multiple domains. For example, Occupational safety practices highlight both environmental risks and human health concerns, Trends in green construction employment reflect the dual goals of natural resource conservation and economic development, Charitable donations per year serve as indicators of both economic health and quality of life and Per capita floor area in residential buildings simultaneously reflects energy use, living standards, and resource consumption. Once indicators and their corresponding metrics are identified, appropriate data collection methodologies, such as Life Cycle Assessment (LCA), must be implemented to gather relevant information for evaluation [93]. These tools

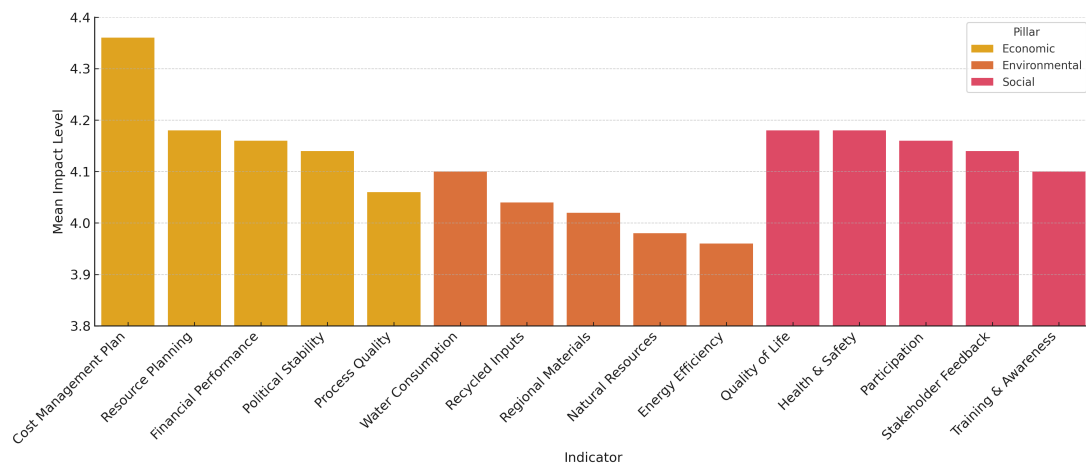


FIGURE 5.1: Top 5 sustainability indicators from each pillar

form the backbone of sustainability based decision-making. Organizing Sustainability Indicators As defined earlier, sustainability indicators are quantifiable components of social, economic, or environmental systems. For effective application, these indicators must be organized into clearly defined categories and subcategories, commonly referred to as a taxonomy. A well-structured taxonomy simplifies indicator selection, ensures consistent application, and enhances comparability across studies. For the purposes of this research, various existing taxonomies were reviewed to identify suitable classifications. These taxonomies are especially valuable for organizations like the EPA in designing programs and monitoring performance. Within each of the three pillars, indicators must be prioritized based on their relevance and impact in the decision-making process. This prioritization reflects the values and strategic goals of the stakeholders involved. Furthermore, conducting a system-level analysis can help determine which indicators most effectively represent key dynamics influencing sustainability—either positively or negatively. This deeper insight enhances the strategic selection of indicators and supports the development of models that are both actionable and aligned with sustainable development objectives. A comprehensive evaluation of sustainability indicators across Economic, Environmental, and Social pillars was conducted to identify those most impactful for

sustainable building construction. Figure 5.1 presents a comparative matrix of the top sustainability indicators across the three pillars—economic, environmental, and social—based on their respective mean impact scores. This visual framework provides a structured summary of stakeholder priorities in sustainable construction.

From the Economic pillar, indicators such as Cost Management Plan, Resource Planning, Financial Performance, Political Stability, and Process Quality achieved the highest

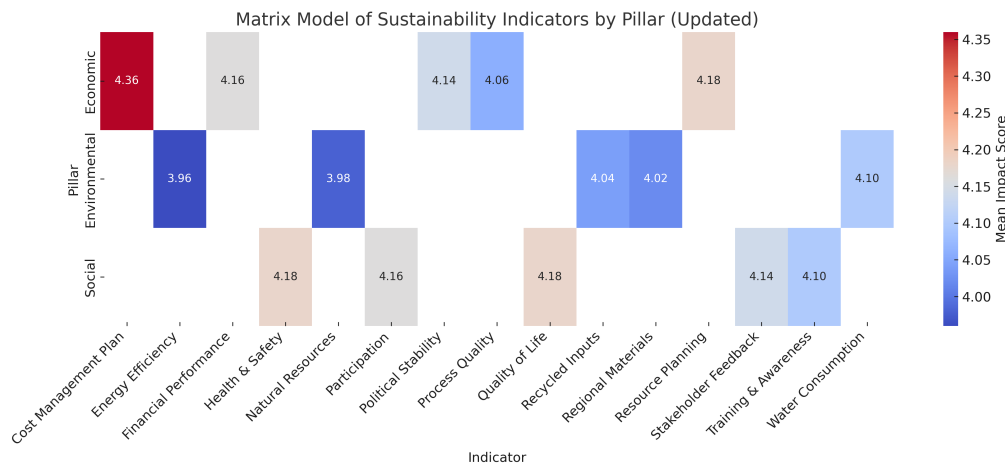


FIGURE 5.2: Matrix Model for Sustainability Indicators

scores. These findings underscore the sector’s continued emphasis on financial control, efficient resource utilization, and macroeconomic stability—fundamental components that ensure project viability and long-term success.

Within the Environmental pillar, indicators including Water Consumption, Recycled Inputs, Use of Regional Materials, Natural Resource Management, and Energy Efficiency were prioritized. These results reflect a growing awareness of ecological sustainability, particularly the need to conserve resources, minimize environmental impact, and adopt circular material practices within the construction lifecycle.

In the Social pillar, Quality of Life, Health and Safety, Participation, Stakeholder Feedback, and Training and Awareness ranked as the most influential indicators. This highlights the importance of human-centric strategies, emphasizing well-being, inclusive decision-making, and the development of human capital. These elements are increasingly recognized as essential for achieving socially sustainable outcomes and enhancing public trust in urban development initiatives.

Figure 5.2 presents a comparative visualization of the top five sustainability indicators from each of the three core pillars—economic, environmental, and social. This graphic offers a clear and integrated representation of the relative significance of each indicator, as determined by their mean impact scores derived from stakeholder responses. By aligning indicators from different sustainability dimensions within a unified visual framework, the figure enables stakeholders to discern both intra-pillar priorities and cross-pillar balance. This holistic representation enhances understanding of how financial performance, environmental responsibility, and social well-being intersect within the context of sustainable construction. The visualization serves not only as a tool for prioritization

but also as an analytical basis for the development of strategic sustainability frameworks. Specifically, it supports evidence-based decision-making in urban development projects situated in rapidly expanding and environmentally sensitive regions such as Islamabad and Rawalpindi. Through this approach, key indicators can be systematically integrated into planning, policy formulation, and performance monitoring, thereby promoting more resilient, equitable, and resource-efficient urban environments. It encourages planners and developers to move beyond traditional cost-centered approaches toward inclusive, long-term value creation. By embedding these indicators into project life-cycles, stakeholders can proactively address risks and opportunities associated with sustainability. Such integration also fosters transparency and accountability in the development process. Ultimately, this leads to built environments that are not only technically sound but also socially inclusive and ecologically balanced.

5.3 Development of Policy Guidelines

To promote sustainable building construction in the rapidly urbanizing regions of Rawalpindi and Islamabad, the development of a cohesive, well-integrated policy framework is essential. Drawing on the top-ranked sustainability indicators, this framework must prioritize economic stability, environmental responsibility, and social inclusiveness.

From the economic pillar, indicators such as ECN3 (Cost Management Plan), ECN14 (Resource Planning), and ECN7 (Financial/Economic Performance) emerged as top priorities. Projects should adopt life-cycle costing models, rigorous budgeting frameworks, and real-time financial monitoring systems to ensure long-term viability. Financial feasibility should be evaluated throughout all project stages, with incentives like green financing, tax benefits, and subsidies introduced to encourage sustainable investments. Moreover, ECN12 (Process Quality) must be institutionalized through standardized construction protocols and regulatory oversight to reduce inefficiencies, minimize material wastage, and enhance output quality. Feasibility assessments based on ECN10 (Market Demand) should be mandated to ensure infrastructure development aligns with real economic needs and urban growth projections.

Environmental considerations must be embedded into the development approval process. Projects should conform to internationally recognized green rating systems and be evaluated against national benchmarks that integrate indicators such as ENVR13, ENVR1, and ENVR11. The consistent application of ENVR10 and ENVR4 will further reinforce

ecological resilience. Additionally, proactive planning in terms of site selection, biodiversity preservation, and waste reduction should be prioritized. Environmental impact assessments (EIAs) must be conducted comprehensively and made publicly accessible to ensure transparency and foster accountability throughout the project lifecycle.

In the social domain, a human-centric approach must be adopted. Key indicators such as SCL4, SCL8, and SCL7 emphasize the importance of public welfare and inclusive governance in construction practices. Local authorities should institutionalize community consultation mechanisms, enforce labor safety regulations through periodic audits, and penalize non-compliance. Equally critical is the promotion of SCL12 and SCL13, which call for inclusive capacity-building efforts to bridge the skills gap and ensure that engineers, contractors, and laborers are trained in sustainable construction practices, emerging technologies, and environmental stewardship.

The Pakistan Engineering Council (PEC) plays a vital role in embedding sustainability into national construction practices. Building upon the Building Code of Pakistan (Energy Provisions 2011), PEC must enforce compliance with energy efficiency and sustainability benchmarks. Moreover, PEC should update engineering curricula to reflect sustainability priorities and require certification in sustainable construction as a prerequisite for professional licensing and project approvals.

Local authorities such as the Capital Development Authority (CDA) and Rawalpindi Development Authority (RDA) must also take a more active stance in localizing and enforcing sustainability regulations. While initiatives like the Islamabad Building and Zoning Regulations (2020) have introduced land-use efficiency and energy compliance codes, implementation gaps persist. Enhanced inter-agency coordination, stronger compliance tracking, and collaboration with academic institutions and private sector innovators will be necessary to mainstream sustainability at the urban scale.

These efforts should be directly aligned with Pakistan's obligations under the United Nations Sustainable Development Goals (SDGs), specifically SDG 11, SDG 9, and SDG 13. Achieving these targets will require localized policy enforcement, multi-stakeholder engagement, and regulatory reforms.

By institutionalizing these indicator-driven guidelines and empowering regulatory bodies, Rawalpindi and Islamabad can emerge as national leaders in the transition toward a resilient, inclusive, and sustainable urban future. This transformation requires a consistent commitment to implementation, cross-sector collaboration, and capacity building within municipal systems. Such an approach not only enhances urban livability but also sets a precedent for other developing cities aiming to achieve long-term sustainability.

5.4 Framework Implementation

For the advancement of sustainable building construction in the urban contexts of Rawalpindi and Islamabad, it is imperative to establish a coherent and integrated set of policy guidelines. Based on the prioritized indicators identified in this study, project-level decisions must strategically emphasize economic viability, environmental responsibility, and social inclusiveness.

From the economic perspective, indicators such as Cost Management Plan (ECN3), Resource Planning (ECN14), and Financial Performance (ECN7) should form the foundation of project planning. These can be operationalized through lifecycle costing models, detailed financial forecasting, and the integration of real-time budget monitoring systems. To strengthen financial sustainability, local governments should introduce mechanisms such as tax rebates, subsidies, and access to green financing for compliant projects. Moreover, institutionalizing Process Quality (ECN12) through regulatory oversight and quality assurance protocols will help mitigate construction delays and material inefficiencies. The inclusion of Market Demand (ECN10) assessments as a prerequisite for project approval will ensure alignment with real urban needs and investment feasibility.

From the environmental pillar, key indicators such as Water Consumption (ENVR13), Recycled Inputs (ENVR1), and Use of Regional Materials (ENVR11) must be incorporated into the core of building approval criteria. All urban development projects should be mandated to align with internationally recognized green rating systems, while national guidelines must embed standards for Energy Efficiency (ENVR4) and Natural Resource Management (ENVR10). Additionally, environmental impact assessments must be mandatory and publicly available prior to project approvals, ensuring transparency and accountability. Proactive site planning, conservation of local ecosystems, and strategies for climate resilience should also be integrated through the planning process.

Social sustainability should be operationalized through participatory frameworks and human-centered development protocols. Indicators such as Quality of Life (SCL4), Health and Safety (SCL8), and Stakeholder Engagement (SCL12) demand regulatory attention. Local governments should mandate structured community consultations during the design phase and enforce labor safety standards through audits and penalties for non-compliance. Promoting Training and Awareness (SCL13) is vital for capacity building, particularly for contractors, site engineers, and workers involved in sustainable practices and modern construction technologies.

Resource planning in construction involves the systematic estimation, allocation, and management of essential inputs such as labor, materials, equipment, time, and finances to ensure timely and cost-effective project completion. It includes forecasting resource needs, scheduling their use, coordinating procurement, and monitoring utilization to minimize waste and downtime. Effective resource planning enhances productivity, reduces delays and cost overruns, and ensures optimal use of available assets, making it a critical component of successful construction project management. Institutions such as the Pakistan Engineering Council (PEC) must take a leadership role by embedding sustainability metrics within the Building Code of Pakistan (Energy Provisions 2011) and requiring project-specific sustainability compliance for professional licensing and building approvals. PEC should also update engineering curricula and introduce continuing professional development (CPD) modules focused on sustainable construction, energy efficiency, and environmental stewardship. Similarly, local authorities such as the Capital Development Authority (CDA) and Rawalpindi Development Authority (RDA) must strengthen their enforcement of sustainability guidelines. Although initiatives like the Islamabad Building and Zoning Regulations (2020) have introduced important reforms—including energy efficiency standards and land-use optimization—there remain gaps in enforcement. These agencies must enhance their monitoring capacity, collaborate with research institutions, and incentivize innovation through public-private partnerships.

All these efforts must be aligned with Pakistan’s obligations to the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). Effective progress toward these goals will require cross-sector collaboration, institutional reform, and robust policy enforcement at both municipal and national levels.

5.5 Institutionalizing Urban Sustainability

Pilot implementations within CDA and RDA jurisdictions can serve as demonstration projects, showcasing feasibility and enabling refinements prior to broader application. Furthermore, the creation of a digital sustainability dashboard would allow real-time tracking of project compliance, directly supporting SDG reporting and policy evaluation. Public outreach, stakeholder engagement, and knowledge dissemination are critical to drive cultural change. In the long term, the framework must be reviewed periodically

to incorporate technological advances, emerging urban needs, and evolving global best practices.

By institutionalizing this framework and embedding sustainability across planning, regulation, and practice, Rawalpindi and Islamabad can serve as national exemplars for sustainable urban development in Pakistan.

Chapter 6

Conclusion and Future Work

6.1 Key Conclusions

This study concentrated on prioritizing sustainability indicators relevant to building construction projects by developing and applying a structured qualitative assessment framework. The study successfully identified key sustainability indicators, designed a Likert-scale-based questionnaire, gathered expert feedback, applied statistical analysis using SPSS, and calculated Relative Importance Index (RII) values to rank these indicators based on their significance. The proposed framework is a practical alternative to subjective evaluation and offers a clear and methodical process to support sustainable construction decision making. A simplified sustainability indicator framework was developed, which will serve as a foundation for an ongoing effort to establish a quantitative sustainability assessment model. This framework is expected to assist stakeholders in integrating sustainability principles into routine construction activities to enhance project outcomes. Summarized Conclusion are shown below:

- The demographic analysis revealed that the majority of the respondents were experienced professionals actively engaged in the construction sector. Their academic qualifications and practical exposure strengthened the credibility of the responses and enhanced the contextual relevance of the selected sustainability indicators.
- The reliability analysis confirmed high internal consistency of the questionnaire, along with a strong response rate, validating the accuracy and dependability of the collected data for assessing sustainability indicators within the context of Pakistan's urban construction sector.

- The normality test produced p-values below 0.05, indicating that the dataset was not normally distributed. Accordingly, non-parametric statistical techniques were appropriately applied for further analysis. The Kruskal-Wallis test yielded p-values greater than 0.05, suggesting no statistically significant differences among respondent groups in their perceptions of sustainability indicators. This finding reinforces a general consensus across diverse stakeholder categories on core sustainability priorities.
- Moderate correlations were observed among the three sustainability pillars—economic, environmental, and social—highlighting their interconnected influence on sustainable construction practices in Pakistan’s developed urban centers. Through mean and standard deviation analysis, priority indicators were identified within each dimension. Economically, the most critical indicators were cost management (ECN3), resource optimization (ECN14), and financial viability (ECN7). Environmentally, top-ranked indicators included water conservation (ENVR13), use of recycled materials (ENVR1), and local sourcing (ENVR11). In the social domain, key indicators emphasized quality of life (SCL4), health and safety (SCL8), and community participation (SCL7).
- To address the identified lack of awareness among stakeholders regarding sustainability indicators, a structured and context-specific framework was developed. The indicators were systematically grouped into five latent constructs derived through factor analysis including Strategic Economic and Operational Planning, encompassing effective cost management; human material and mechanical resource allocation, and life cycle financial viability, Environmental Impact and Resource Efficiency, reflecting eco-conscious practices such as recycling, energy efficiency, and waste reduction; Social Responsibility and Human Well-being, emphasizing labor practices, safety, and community welfare; Institutional Governance and Knowledge, highlighting leadership, data-driven monitoring, and organizational learning; and Innovation and Technological Advancement, capturing forward-thinking solutions including renewable systems and climate adaptation.
- This proposed framework integrates economic, environmental, and social indicators into a cohesive and context-sensitive model aimed at guiding senior management and policymakers in aligning urban construction strategies with clearly defined sustainability goals. By offering a structured approach, it enables decision-makers to consider a broad spectrum of sustainability dimensions throughout the project life-cycle, from conceptual planning to post-construction evaluation. Its

adoption in Pakistan’s rapidly developing urban centers—particularly in cities such as Islamabad, Lahore, and Karachi—can facilitate enhanced environmental stewardship through reduced ecological footprints, long-term financial efficiency by optimizing resource allocation, and improved urban living standards through better infrastructure and social equity. Furthermore, the framework serves as a practical, evidence-based decision-support tool that is applicable not only during the initial planning stages but also during the corrective or adaptive phases of sustainable building projects, ensuring flexibility in dynamic urban environments.

6.2 Future Recommendations

To build upon the findings of this research and expand the practical application of the sustainability indicators framework, the following future directions are recommended:

- Conduct detailed studies to evaluate the cost-effectiveness and long-term benefits of the proposed sustainability indicators framework in real-world projects.
- Develop tailored sustainability indicator models for other infrastructure domains, particularly for water resource and civil infrastructure projects.
- Extend the framework by developing and validating indicator sets for large-scale and mega construction projects at national and international levels to facilitate global adoption and relevance.

Bibliography

- [1] A. Khan, R. Malik, and S. Shahid, “Urban expansion and its environmental impacts in rawalpindi and islamabad,” *Sustainability*, vol. 13, no. 22, p. 12842, 2021.
- [2] M. Iqbal and S. Hussain, “Solid waste management challenges in rawalpindi city,” *Journal of Science and Technology Research*, vol. 4, no. 2, pp. 50–57, 2015.
- [3] M. Siddiqui, T. Khan, and N. Ahmed, “Occupational exposure to heavy metals among construction workers in rawalpindi,” *Environmental Health and Preventive Medicine*, 2024.
- [4] T. Poorisat, I. E. Aigwi, D. T. Doan, and A. GhaffarianHoseini, “Unlocking the potentials of sustainable building designs and practices: A systematic review,” *Building and Environment*, p. 112069, 2024.
- [5] R. Alawneh, I. Jannoud, H. Rabayah, R. Imam, and H. Almasaeid, “Development of an assessment and management framework for sustainable construction projects in jordan by incorporating the sustainable development goals,” *Infrastructures*, vol. 9, no. 7, p. 117, 2024.
- [6] C. Du Plessis, “A strategic framework for sustainable construction in developing countries,” *Construction management and economics*, vol. 25, no. 1, pp. 67–76, 2007.
- [7] M. Karamoozian and H. Zhang, “Obstacles to green building accreditation during operating phases: identifying challenges and solutions for sustainable development,” *Journal of Asian Architecture and Building Engineering*, vol. 24, no. 1, pp. 350–366, 2025.
- [8] M. M. Rahman, “Barriers of implementing modern methods of construction,” *Journal of Management in Engineering*, vol. 30, pp. 69–77, 01 2014.

- [9] A. H. Ali, A. F. Kineber, A. Elyamany, A. Hussein Ibrahim, and A. O. Daoud, “Exploring stationary and major modular construction challenges in developing countries: a case study of egypt,” *Journal of Engineering, Design and Technology*, vol. 23, no. 2, pp. 569–598, 2025.
- [10] F. Khalifa and M. Marzouk, “Integrated blockchain and digital twin framework for sustainable building energy management,” *Journal of Industrial Information Integration*, vol. 43, p. 100747, 2025.
- [11] U.S. Green Building Council, *LEED v4 for Building Design and Construction*, USGBC, Washington, DC, 2019.
- [12] Building Research Establishment, *BREEAM UK New Construction Technical Manual*, BRE Global, Watford, UK, 2022.
- [13] Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), *Sustainability Report*, DGNB, Stuttgart, Germany, 2023.
- [14] Z. O. Abdullah and T. Çelik, “Proposing an affordable real-time camera-based safety and quality management framework for construction industries in developing countries,” *Buildings*, vol. 15, 2025.
- [15] D. O. Aghimien, C. O. Aigbavboa, and W. D. Thwala, “Microscoping the challenges of sustainable construction in developing countries,” *Journal of Engineering, Design and Technology*, vol. 17, no. 6, pp. 1110–1128, 2019.
- [16] S. B. Architetti, “Bosco verticale – vertical forest,” 2015, available at: <https://www.stefanoeriarchitetti.net/en/project/vertical-forest/> [Accessed: 5-May-2025].
- [17] A. Kolte, D. Patil, A. Pawar, and A. Patil, “Assessment of barriers for small scale contractors in adopting sustainable construction practices: the perspective of indian construction industry,” *International Journal of Business and Globalisation*, vol. 39, no. 3-4, pp. 457–478, 2025.
- [18] A. Malik, P. B. K. Mbewe, N. Kavishe, and T. Mkandawire, “Sustainable construction practices: Challenges of implementation in building infrastructure projects in malawi,” *Buildings*, vol. 15, 2025.
- [19] J. Larsson and L. Larsson, “Integration, application and importance of collaboration in sustainable project management,” *Sustainability*, vol. 12, no. 2, p. 585, 2020.

- [20] P. V. Kavishe, “Sustainable construction practices: Challenges of implementation in building infrastructure projects in malawi,” *Buildings*, vol. 15, no. 4, p. 554, 2025. [Online]. Available: <https://doi.org/10.3390/buildings15040554>
- [21] D. O. Aghimien, C. O. Aigbavboa, and W. D. Thwala, “Microscoping the challenges of sustainable construction in developing countries,” *Journal of Engineering, Design and Technology*, vol. 17, no. 6, pp. 1110–1128, 2019.
- [22] H. A. Vaghefi-Rezaee, H. Sarvari, S. Khademi-Adel, D. J. Edwards, and C. J. Roberts, “A scientometric review and analysis of studies on the barriers and challenges of sustainable construction,” *Buildings*, vol. 14, no. 11, p. 3432, 2024.
- [23] R. Alawneh, I. Jannoud, H. Rabayah, R. Imam, and H. Almasaeid, “Development of an assessment and management framework for sustainable construction projects in jordan by incorporating the sustainable development goals,” *Journal of Cleaner Production*, vol. 370, p. 133554, 2022.
- [24] E. D. G. Fraser, A. J. Dougill, W. E. Mabee, M. Reed, and P. McAlpine, “Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management,” *Journal of Environmental Management*, vol. 78, no. 2, pp. 114–127, 2006.
- [25] S. Soltani, B. Abbasnejad, N. Gu, R. Yu, and D. Maxwell, “A multi-faceted analysis of enablers and barriers of industrialised building: Global insights for the australian context,” *Buildings*, vol. 15, 2025.
- [26] Y. Zhang, H. Wang, W. Gao, F. Wang, N. Zhou, D. M. Kammen, and X. Ying, “A survey of the status and challenges of green building development in various countries,” *Sustainability*, vol. 11, 2019.
- [27] S. Dalirazar and Z. Sabzi, “Barriers to sustainable development: Critical social factors influencing the sustainable building development based on swedish experts’ perspectives,” *Sustainable Development*, vol. 30, no. 6, pp. 1963–1974, 2022.
- [28] Z. O. Abdullah, T. Çelik, and T. Çelik, “Proposing an affordable real-time camera-based safety and quality management framework for construction industries in developing countries,” *Buildings*, vol. 15, no. 2, p. 156, 2025.
- [29] A. M. Ahmed, S. W., A. A., I., and Nosier, “Identifying barriers to the implementation and development of sustainable construction,” *International Journal of Construction Management*, vol. 23, no. 8, pp. 1277–1288, 2023.

- [30] A. P. C. Chan, A. Darko, A. O. Olanipekun, and E. E. Ameyaw, "Critical barriers to green building technologies adoption in developing countries: The case of ghana," *Journal of Cleaner Production*, vol. 172, pp. 1067–1079, 2018.
- [31] P. Pradhananga, M. Elzomor, and G. S. Kasabdji, "Barriers and drivers to the adoption of sustainable construction practices in developing countries: A case study of venezuela," *Journal of Architectural Engineering*, vol. 27, no. 3, p. 05021005, 2021.
- [32] H. Pham, S.-Y. Kim, and T.-V. Luu, "Managerial perceptions on barriers to sustainable construction in developing countries: Vietnam case," *Environment, Development and Sustainability*, vol. 22, no. 4, pp. 2979–3003, 2020.
- [33] I. C. Osuizugbo, O. Oyeyipo, A. Lahanmi, A. Morakinyo, and O. Olaniyi, "Barriers to the adoption of sustainable construction," *European Journal of Sustainable Development*, vol. 9, no. 2, pp. 150–150, 2020.
- [34] A. Al-Otaibi, P. A. Bowan, M. M. A. Daiem, N. Said, J. O. Ebohon, A. Alabdullatif, E. Al-Enazi, and G. Watts, "Identifying the barriers to sustainable management of construction and demolition waste in developed and developing countries," *Sustainability*, vol. 14, 2022.
- [35] S. Azeem, M. A. Naeem, A. Waheed, and M. J. Thaheem, "Examining barriers and measures to promote the adoption of green building practices in pakistan," *Smart and Sustainable Built Environment*, vol. 6, no. 3, pp. 86–100, 2017.
- [36] A. Darko, A. P. C. Chan, Y. Yang, M. Shan, B.-J. He, and Z. Gou, "Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The ghanaian case," *Journal of Cleaner Production*, vol. 200, pp. 687–703, 2018.
- [37] O. Ametepey, C. Aigbavboa, and K. Ansah, "Barriers to successful implementation of sustainable construction in the ghanaian construction industry," *Procedia Manufacturing*, vol. 3, pp. 1682–1689, 2015.
- [38] G. A. Nikyema and V. Y. Blouin, "Barriers to the adoption of green building materials and technologies in developing countries: The case of burkina faso," *IOP Conference Series: Earth and Environmental Science*, vol. 410, no. 1, p. 012079, 2020.

- [39] R. G. G. Caiado, R. S. Santos, C. A. D. Schery, L. F. Scavarda, and J. A. Garza-Reyes, “Balancing priorities: A configurational framework to achieve strategic benefits from sustainable industry 4.0 enablers in operations and supply chain,” *Business Strategy and the Environment*, 2025.
- [40] M. V. Barros, R. Salvador, G. F. do Prado, A. C. de Francisco, and C. M. Piekarski, “Circular economy as a driver to sustainable businesses,” *Cleaner Environmental Systems*, vol. 2, p. 100006, 2021. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2666789420300064>
- [41] P. Burki, U. & Ersoy, “Top management pledge, an essential component of sustainable manufacturer-customer relationships,” *Journal of Sustainable Marketing*, vol. 3, no. 2, p. 98 – 117, 2022.
- [42] N. M. Hassan, A., and Alashwal, “Developing a model for the implementation of designing out waste in construction,” *Architectural Engineering and Design Management*, vol. 21, no. 1, pp. 154–170, 2025.
- [43] K. D. Véliz, C. Pabón-Pereira, J. P. Walters, and J. Fernandez, “Applying circular business models in the chilean construction sector: A system dynamics perspective,” *Business Strategy and the Environment*, vol. 34, no. 1, pp. 1302–1319, 2025.
- [44] S. S. Sajane, V. V. Kulkarni, R. S. Sajane, and P. J. Patil, “Energy-efficient building design and green construction practices for smart cities,” in *Sustainable Smart Cities and the Future of Urban Development*, S. N. S. Al-Humairi, A. I. Hajamydeen, and A. Mahfoudh, Eds. Hershey, PA, USA: IGI Global, 2025, pp. 315–342.
- [45] A. O. Daoud, A. F. Kineber, A. H. Ali, and M. Elseknidy, “Empowering sustainable infrastructure and sustainable development goals through industry 5.0 implementation,” *Sustainable Development*, 2025.
- [46] L. B. Kulasekara, B. A. K. S. Perera, and H. A. H. P. Perera, “Impact of smart city system on the construction industry in sri lanka,” *Journal of Engineering, Design and Technology*, vol. 23, no. 2, pp. 546–568, 2025.
- [47] S. Ahmed, T. Ahmed, H. N. Ahmed, S. M. Ali, E. D. R. S. Gonzalez, and G. Kabir, “Modeling the nexus of data analytics, sustainability practices and quality management: Evidence of key enablers,” *Environment, Development and Sustainability*, vol. 27, no. 1, pp. 881–908, 2025.

- [48] N. N. Myint, M. Shafique, X. Zhou, and Z. Zheng, “Net zero carbon buildings: A review on recent advances, knowledge gaps and research directions,” *Case Studies in Construction Materials*, vol. 22, p. e04200, 2025.
- [49] T. Häkkinen, K., and Belloni, “Barriers and drivers for sustainable building,” *Building Research & Information*, vol. 39, no. 3, pp. 239–255, 2011.
- [50] L. Melchert, “The dutch sustainable building policy: A model for developing countries?” *Building and Environment*, vol. 42, no. 2, pp. 893–901, 2007.
- [51] F. C. Rios, D. Grau, and M. Bilec, “Barriers and enablers to circular building design in the us: An empirical study,” *Journal of Construction Engineering and Management*, vol. 147, no. 10, p. 04021117, 2021.
- [52] F. Shafii, Z. A. Ali, and M. Z. Othman, “Achieving sustainable construction in the developing countries of southeast asia,” *6th Asia-Pacific Structural Engineering and Construction Conference*, 2006.
- [53] M. Ghufran, K. I. Khan, F. Ullah, W. S. Alaloul, and M. A. Musarat, “Key enablers of resilient and sustainable construction supply chains: A systems thinking approach,” *Sustainability*, vol. 14, 2022.
- [54] K. Hussain, H. Zhen, A. Naveed, I. Muzaffar, S., and Nazneen, “Mapping green, lean, six sigma enablers through the lens of a construction sector: an emerging economy’s perspective,” *Journal of Environmental Planning and Management*, vol. 66, no. 4, pp. 779–812, 2023.
- [55] M. Jagannathan, R. C. Kamma, V. Renganaidu, and S. Ramalingam, “Enablers for sustainable lean construction in india,” *26th Annual Conference of the International Group for Lean Construction (IGLC)*, González, V.A. (ed.), pp. 18–22, 2018.
- [56] A. Jarkas and T. Haupt, “Major construction risk factors considered by general contractors in qatar,” *Journal of Engineering, Design and Technology*, vol. 13, pp. 165–194, 03 2015.
- [57] O. Olajiga and T. Olatunde, “Sustainable urban design: A review of eco-friendly building practices and community impact,” *Engineering Science & Technology Journal*, vol. 5, pp. 1020–1030, 03 2024.

- [58] Transportation Review. (2025, January) The role of public transit in sustainable urban development. Accessed: 6-May-2025. [Online]. Available: <https://www.transportationreview.com/news/the-role-of-public-transit-in-sustainable-urban-development-nwid-639.html>
- [59] O. Olajiga and T. Olatunde, “Sustainable urban design: A review of eco-friendly building practices and community impact,” *Engineering Science & Technology Journal*, vol. 5, pp. 1020–1030, 03/24 2024.
- [60] R. Parekh and C. Smith, “Eco-friendly urban design: An analysis of sustainable building practices and their community impact,” *World Journal of Advanced Research and Reviews*, vol. 23, pp. 2857–2864, 09/30 2024.
- [61] Green Building Initiative. (2024) Green globes incentives. Accessed: 6-May-2025. [Online]. Available: <https://thegbi.org/greenglobes/incentives>
- [62] K. Batool, A. Ghaffar, and M. Radulescu, “Sustainable construction technologies: Are construction firms ready for sustainable cities?” *Journal of Urban Technology*, vol. 32, no. 1, pp. 5–25, 01/01 2025.
- [63] V. Muerza and C. Guerlain, “Sustainable construction logistics in urban areas: A framework for assessing the suitability of the implementation of construction consolidation centres,” *Sustainability*, vol. 13, 2021.
- [64] Y. Zhang, Y. Liu, J. Zhao, and J. Wang, “Smart city construction and urban green development: empirical evidence from china,” *Scientific Reports*, vol. 13, no. 1, p. 17366, 10/13 2023.
- [65] J. M. I. Garcia, “Urban coastal development in valencian country: A paradigmatic case of non-sustainable development.”
- [66] M. Kamali, K. Hewage, and A. S. Milani, “Life cycle sustainability performance assessment framework for residential modular buildings: Aggregated sustainability indices,” *Building and Environment*, vol. 138, pp. 21–41, 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0360132318302233>
- [67] A. Czajkowska, “The role of sustainable construction in sustainable development,” *MATEC Web of Conferences*, vol. 174, p. 01027, 01/01 2018.
- [68] V. Mamilla and M. Kumar, “A review on sustainable construction,” *International Journal of Contemporary Research and Review*, vol. 11, pp. 251–258, 04/01 2024.

- [69] W.-D. Yu, W.-C. Ho, S.-T. Cheng, and H.-K. Chang, "Evaluating the sustainability of non-urban land development projects," in *The 10th International Conference on Engineering, Project, and Production Management*. Springer, 2020, pp. 3–19.
- [70] D.-G. J. Opoku, J. Ayarkwa, and K. Agyekum, "Barriers to environmental sustainability of construction projects," *Smart and Sustainable Built Environment*, vol. 8, no. 4, pp. 292–306, 2019.
- [71] S. Gusta *et al.*, "Sustainable construction in latvia—opportunities and challenges," in *15th International scientific conference "Engineering for rural development": proceedings, Jelgava, Latvia, May, 2016*, pp. 25–27.
- [72] A. Al-Otaibi, P. A. Bowan, A. Alabdullatief, M. Albaiz, and M. Salah, "Barriers to sustainable building project performance in developing countries: A case of ghana and the kingdom of saudi arabia," *Sustainability*, vol. 17, 2025.
- [73] G. T. Jinoll, L. Workalemahu, and D. Adugna, "Impact assessment of mixed land-use planning in ethiopia: The case of addis ababa," *Heliyon*, vol. 10, no. 24, p. e40814, 12 2024.
- [74] H. Unegbu, D. Yawas, B. Dan-asabe, and A. Alabi, "Development of a structural equation model for sustainable construction practices in nigeria," *Discover Civil Engineering*, vol. 2, no. 1, p. 10, 2025.
- [75] J. E. Llorente-García, D. Caparrós-Pérez, and M. D. Alba-Rodríguez, "Sustainable criteria within the construction industry," in *Life Cycle Analysis Based on Nanoparticles Applied to the Construction Industry: A Comprehensive Curriculum*. Springer, 2025, pp. 3–25.
- [76] Y. Zhong and P. Wu, "Economic sustainability, environmental sustainability and constructability indicators related to concrete- and steel-projects," *Journal of Cleaner Production*, vol. 108, pp. 748–756, 12 2015.
- [77] Y. Kajikawa, T. Inoue, and T. N. Goh, "Analysis of building environment assessment frameworks and their implications for sustainability indicators," *Sustainability Science*, vol. 6, pp. 233–246, 2011.
- [78] A. Dimoudi and C. Tompa, "Energy and environmental indicators related to construction of office buildings," *Resources, Conservation and Recycling*, vol. 53, no. 1-2, pp. 86–95, 2008.

- [79] A. Rahim and B. Reddy, “Sustainable construction: Analysis of its costs and financial benefits,” *ResearchGate*, 2023, accessed: 6-May-2025. [Online]. Available: https://www.researchgate.net/publication/312249507_Sustainable_Construction_Analysis_of_Its_Costs_and_Financial_Benefits
- [80] ESG The Report, “Life cycle cost: What it is and how to calculate it,” *ESG The Report*, 2024, accessed: 6-May-2025. [Online]. Available: <https://esgthereport.com/life-cycle-cost-what-it-is-and-how-to-calculate-it/>
- [81] D. A. Ribas and P. Cachim, “Economic sustainability of buildings,” *Engineering, Construction and Architectural Management*, vol. 26, no. 1, pp. 2–28, 2019.
- [82] E. Fregonara, G. Roberto, R. Diana, and J.-M. Tulliani, “Integrating environmental and economic sustainability in new building construction and retrofits,” *Journal of Urban Technology*, vol. 23, no. 4, pp. 3–28, 10 2016.
- [83] J. B. Andrade and L. Bragança, “Analysis of the impacts of economic and social indicators to sustainability assessment,” 2011.
- [84] J. Atanda, “Developing a social sustainability assessment framework for residential buildings,” *Journal of Cleaner Production*, vol. 206, pp. 1184–1196, 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0959652618328464>
- [85] D. Fatourehchi and E. Zarghami, “Social sustainability assessment framework for managing sustainable construction in residential buildings,” *Journal of Building Engineering*, vol. 32, p. 101761, 2020.
- [86] S. Rajabi, S. El-Sayegh, and L. Romdhane, “Identification and assessment of sustainability performance indicators for construction projects,” *Environmental and Sustainability Indicators*, vol. 15, p. 100193, 9 2022.
- [87] R. Valdes-Vasquez and E. K. Leidy, “Social sustainability considerations during planning and design: Framework of processes for construction projects,” *Journal of Construction Engineering and Management*, vol. 139, no. 1, pp. 80–89, 1 2013.
- [88] M. Stender and A. Walter, “The role of social sustainability in building assessment,” *Building Research & Information*, vol. 47, no. 5, pp. 598–610, 2019.
- [89] P. F. Smith and T. A. McDonald, *Sustainability in the built environment*. Oxford: Routledge, 2011.

- [90] Y. Chen, G. E. Okudan, and D. R. Riley, “Sustainable performance criteria for construction method selection in concrete buildings,” *Building and Environment*, vol. 45, no. 2, pp. 734–744, 2018.
- [91] V. Ahmed, Z. Aziz, and A. Tezel, “Social sustainability factors in construction projects: State-of-the-art review,” *Procedia Engineering*, vol. 145, pp. 595–602, 2016.
- [92] H. H. Ali and A. F. Kineber, “Integrated indicators for social sustainability in construction,” *Sustainability*, vol. 14, no. 10, 2022.
- [93] J. Zuo and Z. Y. Zhao, “Green building research—current status and future agenda: A review,” *Renewable and Sustainable Energy Reviews*, vol. 30, pp. 271–281, 2014.
- [94] M. Khalifa and M. Marzouk, “Evaluation of sustainable construction using economic performance indicators,” *Journal of Cleaner Production*, vol. 406, 2023.
- [95] E. D. G. Fraser, A. J. Dougill, W. E. Mabee, M. Reed, and P. McAlpine, “Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management,” *Journal of Environmental Management*, vol. 78, no. 2, pp. 114–127, 1 2006.
- [96] G. K. C. Ding, “Sustainable construction—the role of environmental assessment tools,” *Journal of Environmental Management*, vol. 86, no. 3, pp. 451–462, 2008.
- [97] C. J. Kibert, *Sustainable Construction: Green Building Design and Delivery*, 4th ed. Wiley, 2016.
- [98] J. Zuo and Z. Zhao, “Green building research—current status and future agenda,” *Building and Environment*, vol. 101, pp. 20–31, 2017.
- [99] E. W. L. Cheng and H. Li, “Social sustainability in construction: A literature review,” *Journal of Cleaner Production*, vol. 107, pp. 315–326, 2012.
- [100] J. Zuo and Z. Zhao, “Social sustainability in construction—a critical review,” *Habitat International*, vol. 36, no. 3, pp. 356–365, 2012.
- [101] L. Huang, G. Krigsvoll, and F. Johansen, “Social performance measurement of construction projects,” *Journal of Cleaner Production*, vol. 98, pp. 255–266, 2015.
- [102] E. K. Zavadskas and Z. Turskis, “Sustainable decision-making model for building renovation,” *Energy and Buildings*, vol. 47, pp. 1–9, 2012.

- [103] X. Zhang and J. Wang, “Life cycle economic analysis of green buildings,” *Building and Environment*, vol. 82, pp. 321–329, 2014.
- [104] A. Darko and A. P. C. Chan, “Critical success factors for green building technologies in developing countries,” *International Journal of Environmental Research and Public Health*, vol. 16, no. 20, p. 3843, 2019.
- [105] M. Ghanem and M. Abdel Razek, “Assessing building adaptability using performance indicators,” *Facilities*, vol. 29, no. 3/4, pp. 118–132, 2011.
- [106] M. H. Bal, “Maintaining performance of green buildings: a review,” *Energy Procedia*, vol. 57, pp. 2099–2106, 2013.
- [107] S. Azhar, W. A. Carlton, D. Olsen, and I. Ahmad, “Building performance evaluations of green buildings—a literature review,” *Automation in Construction*, vol. 22, pp. 106–116, 2011.
- [108] Y. Chen and G. Okudan, “Sustainable procurement in construction,” *Journal of Public Procurement*, vol. 10, no. 4, pp. 538–563, 2010.
- [109] S. Lopez and T. M. Froese, “Government policies on sustainable construction: A framework for evaluation,” *Environmental Policy and Governance*, vol. 24, no. 4, pp. 268–285, 2014.
- [110] H. Abdul-Rahman and C. Wang, “Influence of government regulations on sustainable construction,” *Sustainable Cities and Society*, vol. 17, pp. 35–45, 2015.
- [111] T. L. Saaty and L. G. Vargas, *Models, methods, concepts & applications of the analytic hierarchy process*. Springer Science & Business Media, 2012.
- [112] J. F. Hair, R. E. Anderson, R. L. Tatham, and W. C. Black, *Multivariate Data Analysis*, 5th ed. Upper Saddle River, NJ: Prentice Hall, 1998.
- [113] R. C. MacCallum, K. F. Widaman, S. Zhang, and S. Hong, “Sample size in factor analysis,” *Psychological Methods*, vol. 4, no. 1, pp. 84–99, 1999.
- [114] A. McNamara, “The impact (or lack thereof) of analysis choice on conclusions with likert data from the many analysts religion project,” *Religion, Brain & Behavior*, vol. 13, no. 3, pp. 324–326, 2023.
- [115] M. Lakshitha, P. R. S. Sugathadasa, K. Bandara, and A. Thibbotuwawa, “Motivation factors of engineers in private sector construction industry,” *Journal of Applied Engineering Science*, vol. 19, no. 3, pp. 794–805, 2021.

-
- [116] D. A. Abowitz and T. M. Toole, "Mixed method research: Fundamental issues of design, validity, and reliability in construction research," *Journal of Construction Engineering and Management*, vol. 136, no. 1, pp. 108–116, 2010.
- [117] A. M. Jarkas and T. C. Haupt, "Major construction risk factors considered by general contractors in qatar," *Journal of Engineering, Design and Technology*, vol. 13, no. 1, pp. 165–194, 2015.
- [118] M. M. Mohamad, N. L. Sulaiman, L. C. Sern, and K. M. Salleh, "Measuring the validity and reliability of research instruments," *Procedia-Social and Behavioral Sciences*, vol. 204, pp. 164–171, 2015.
- [119] S. Jain and V. Angural, "Use of cronbach's alpha in dental research," *Medico Research Chronicles*, vol. 4, no. 3, pp. 285–291, 2017.
- [120] B. Derrick, P. White, and D. Toher, "Parametric and non-parametric tests for the comparison of two samples which both include paired and unpaired observations," *Journal of Modern Applied Statistical Methods*, vol. 18, no. 1, p. 9, 2020.
- [121] T. K. Kim and J. H. Park, "More about the basic assumptions of t-test: normality and sample size," *Korean Journal of Anesthesiology*, vol. 72, no. 4, pp. 331–335, 2019.
- [122] A. Kamal, M. Abas, D. Khan, and R. W. Azfar, "Risk factors influencing the building projects in pakistan: from perspective of contractors, clients and consultants," *International Journal of Construction Management*, vol. 22, no. 6, pp. 1141–1157, 2022.
- [123] W. H. Kruskal and W. A. Wallis, "Use of ranks in one-criterion variance analysis," *Journal of the American Statistical Association*, vol. 47, no. 260, pp. 583–621, 1952.
- [124] C. E. Osborn, *Essentials of statistics in health information technology*. Jones & Bartlett Publishers, 2007.
- [125] P. Ashley and B. W. Boyd, "Quantitative and qualitative approaches to research in environmental management," *Australasian Journal of Environmental Management*, vol. 13, no. 2, pp. 70–78, 2006.

Appendix