Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Government Buildings in Addis Ababa

Sena Kedir Lugo

A Thesis Submitted to the department of Construction Engineering and Management

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Construction Engineering and Management

Office of Graduate Studies

Adama Science and Technology University

November, 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled **"Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Government Buildings in Addis Ababa"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Sena Kedir Lugo ________________________ ____________________

Name of the student Signature Date

RECOMMENDATION OF ADVISORS/ SUPERVISORS

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Government Buildings in Addis Ababa**" prepared under my guidance by Sena Kedir Lugo submitted in partial fulfillment of the requirements for the degree of Master of in Construction Engineering and Management. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedures

Bahiru Bewket (Ph.D.)	______________________	_______________
Major Advisor/Supervisor	Signature	Date

APPROVAL PAGE FOR THESIS

I hereby certify that the recommendation and suggestion given by the Thesis review the committees are appropriately incorporated into the final thesis entitled **"Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Government Buildings in Addis Ababa"** by **Sena Kedir Lugo**.

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We, the undersigned, members of the Board of Reviewers of the thesis open defense by Sena Kedir Lugo have read and evaluated the thesis paper entitled **“Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Selected Government buildings in Addis Ababa”** and assessed the understanding of the candidate about the proposed research. This is, therefore, to certify that the thesis for partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and Management.

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ESI…………………....Environmental Sustainability Indicators

PQM…………………….Project Quality Management

GB………………..Green Building

LEED………………Leadership in Energy and Environmental Design

BREEM................ Building Research Establishment Environmental Assessment Method

CASBEE…......Comprehensive Assessment System for Building Environmental Efficiency

GBC……………….….…Green Building Certificate

SDG……………………. Sustainable Development Goals

GBT……………………..Green Building Tools

SPSS…………………….Statistical Package for the Social Science

IAQ……………………..Indoor air quality

GSRS……………………Green Star rating system

CO2……………………… Carbon dioxide

ABSTRACT

There is an increasing focus on infrastructure development in Ethiopia hence why the construction sector is on the forefront of the country's priority. However there is a high tendency to overlook the impact this construction industry has on the environment and the surrounding communities. By integrating sustainability practices the industry can minimize its negative impacts and contribute to environmental conservation efforts. The research focuses on the role of Environmental sustainability indicators such as energy efficiency, water conservation, waste management, and the use of sustainable materials in enhancing project quality and environmental performance., Through a mixed-method approach, data were collected from government officials, project managers, engineers, and architects using questionnaires and interviews. The analysis, conducted using SPSS, reveals a moderate to high level of familiarity with PQM practices, though awareness and implementation of ESIs remain inconsistent. Key barriers to integration, such as lack of knowledge, increased costs, and insufficient policies, were identified. The study found a positive correlation between ESI integration and improved project performance, including enhanced quality, reduced operational costs, and compliance with environmental regulations. The findings underscore the need for stronger policies, training, and financial incentives to encourage sustainable practices in government construction projects. This research provides valuable insights for policymakers and project managers aiming to improve sustainability outcomes in public building projects.

Keywords: environmental sustainability indicator; construction; project quality management Energy Efficiency, Water Conservation, Waste Management, Sustainable Materials.

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

The construction industry is one of the largest sectors worldwide, contributing significantly to economic development but also to environmental degradation. Buildings are major consumers of natural resources, using significant amounts of energy, water, and raw materials, while producing substantial waste and greenhouse gas emissions. In response to the growing global awareness of environmental challenges such as climate change, resource depletion, and pollution, there has been an increasing focus on integrating environmental sustainability practices into construction projects. The concept of sustainable development has become essential in ensuring that present needs are met without compromising the ability of future generations to meet their own needs. (Fathalizadeh, Hosseini et al. 2021)

Environmental sustainability indicators (ESIs) — such as energy efficiency, water conservation, waste management, and the use of sustainable materials — are critical tools for assessing and reducing the environmental impact of construction projects. By integrating these indicators into construction processes, projects can contribute to reducing their ecological footprint, promoting resource efficiency, and ensuring long-term sustainability.(Chan, Darko et al. 2017)

In the context of Addis Ababa, Ethiopia's capital and largest city, rapid urbanization has led to an increase in the construction of government buildings, which play a crucial role in housing public institutions and serving the growing population. However, as the city expands, there is growing concern about the environmental impact of these construction activities. Government buildings, being high-visibility projects funded by public resources, have the potential to set an example by incorporating sustainable construction practices. (Assefa, Lee et al. 2022)

Project Quality Management (PQM) in construction traditionally focuses on ensuring that projects meet technical specifications, cost, and time requirements. However, integrating environmental sustainability into PQM is necessary to ensure that quality encompasses not only structural integrity and functionality but also environmental responsibility. The inclusion of ESIs into PQM can lead to enhanced building performance, reduced operational costs, and alignment with global sustainability standards.

Despite the global emphasis on sustainable construction, there is limited research on the extent to which environmental sustainability indicators are integrated into the project quality management of government buildings in Addis Ababa. This study aims to bridge that gap by assessing how these indicators are currently implemented, identifying challenges, and providing recommendations for future improvements. By examining selected government building projects, this research will contribute to the ongoing discussion on sustainable urban development and environmental responsibility in Ethiopia.

1.2. Statement of the Problem

The rapid urbanization and expansion of Addis Ababa have led to an increasing number of government building projects, reflecting the city's growing need for infrastructure and public services. However, while these projects contribute to the city’s development, they also have significant environmental impacts, including high energy consumption, water usage, waste generation, and greenhouse gas emissions. In the face of these challenges, it is critical to ensure that construction practices align with global sustainability standards to mitigate negative environmental effects.

Environmental sustainability indicators (ESIs) — such as energy efficiency, water conservation, waste management, and the use of sustainable materials — have been identified as crucial tools for reducing the environmental footprint of construction projects. Despite global awareness of sustainable building practices, the integration of these indicators into government building projects in Addis Ababa remains unclear and under-researched. More specifically, the extent to which these sustainability measures are incorporated into the Project Quality Management (PQM) process in these government projects has not been thoroughly examined.

Project Quality Management traditionally focuses on ensuring that projects meet specific standards related to cost, time, and technical performance. However, there is a growing need to expand PQM to include environmental sustainability as a key dimension of quality. The failure to integrate ESIs into PQM could result in buildings that meet technical specifications but are unsustainable, costly to operate, and environmentally damaging in the long run.

In Addis Ababa, there are several challenges that may hinder the integration of sustainability indicators into PQM. These include a lack of awareness among stakeholders, limited regulatory frameworks enforcing sustainable construction practices, and perceived cost increases associated with green building methods. Furthermore, there is little evidence on whether government building projects in the city are incorporating global best practices in sustainable construction, or whether local challenges such as resource constraints and expertise gaps are limiting progress.

The problem this study seeks to address is the lack of integration of environmental sustainability indicators into the project quality management of government building projects in Addis Ababa. Without a clear understanding of how these indicators are being used (or not used), and the challenges preventing their integration, it is difficult to develop strategies to improve the environmental performance of these critical public projects. This study will assess the current state of sustainability practices in government building projects, identify the barriers to effective integration of ESIs into PQM, and provide recommendations for enhancing sustainability in future construction efforts.

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1.3. Objectives

1.3.1. General objective

To assess the integration of environmental sustainability indicators into project quality management practices in the construction and management of government buildings in Addis Ababa.

1.3.2. Specific objectives

- To identify and categorize key environmental sustainability indicators relevant to project quality management for government building projects.
- To assess the current level of integration of these sustainability indicators within existing project quality management frameworks.
- To analyze the roles and contributions of various stakeholders in enhancing the integration of environmental sustainability within project quality management.
- To propose practical recommendations for improving project quality management practices by incorporating environmental sustainability indicators effectively.

1.4. Research Questions

- To what extent are environmental sustainability indicators integrated into project quality management practices in the construction of government buildings in Addis Ababa?
- What are the key environmental sustainability indicators commonly used in government building projects, and how are they applied?
- What are the major challenges and barriers to integrating environmental sustainability indicators into project quality management for government buildings?
- How does the integration of environmental sustainability impact the overall quality management of government building projects?
- What strategies or best practices can enhance the integration of environmental sustainability indicators into project quality management in government construction projects?

1.5. Significance of the Study

The significance of this study lies in its potential to contribute to the growing body of knowledge on sustainable construction practices, particularly in the context of government building projects in Addis Ababa. As global and local awareness of environmental challenges continues to rise, integrating environmental sustainability into project management processes becomes increasingly important. By assessing how sustainability indicators—such as energy efficiency, waste management, and resource conservation—are integrated into project quality management, this research provides valuable insights for policy-makers, project managers, and contractors in Ethiopia.

Furthermore, this study addresses the pressing need for sustainable urban development in Addis Ababa, a rapidly growing city facing environmental degradation, resource scarcity, and infrastructure challenges. Government buildings, which consume significant resources during their construction and operation, can serve as exemplars of sustainable practices. The findings from this research could inform the development of more robust policies and frameworks for integrating sustainability into government projects, helping the city meet its sustainability goals while improving the quality of public infrastructure.

The study has practical implications for enhancing project quality management. By identifying gaps and challenges in the current approach to sustainability, the research can offer solutions and strategies for better aligning environmental sustainability with the goals of project management. This, in turn, can lead to more efficient use of resources, cost savings, and improved long-term performance of government buildings. Ultimately, the study aims to support the transition toward greener, more sustainable urban development practices in Ethiopia.

1.6. Scope of the Study

Thematic Scope

The thematic scope of this study focuses on the integration of environmental sustainability indicators into project quality management in the construction and maintenance of selected government buildings in Addis Ababa. The research examines key sustainability indicators such as energy efficiency, waste management, water conservation, and the use of sustainable building materials. It also explores the role of project quality management processes planning, monitoring, execution, and control—in embedding these sustainability principles into government projects. This study aims to identify how sustainability considerations are incorporated into the project lifecycle and evaluate their impact on the quality and long-term sustainability of public buildings.

Spatial Scope

The spatial scope is limited to selected government buildings in Addis Ababa, Ethiopia's capital city and its largest urban center. The buildings under review include major public administration offices, institutional buildings, and facilities managed by the Ministry of Urban Development and Infrastructure. This geographical focus allows for an in-depth examination of the environmental sustainability practices in public projects that are located in a fast-growing urban area with significant construction activity and infrastructure development needs. The findings may, however, provide insights that could be applied to other urban areas in Ethiopia.

Temporal Scope

The temporal scope covers government building projects completed or under construction within the last decade (2013-2023). This period is chosen because of the increasing global emphasis on sustainability and the Ethiopian government's recent efforts to promote greener urban development. By focusing on projects from this time frame, the study captures how modern sustainability practices are being integrated into relatively recent projects, while also considering the long-term implications of these practices in managing public infrastructure. The research will also consider any ongoing projects where data on sustainability and quality management can be obtained.

1.7. Limitation of the Study

This study faces several specific limitations notably the restricted scope of data collection, as it was limited to government buildings in Addis Ababa, which may not fully represent the broader national or international context as well as access to detailed data on project quality management and sustainability practices may be restricted due to confidentiality or bureaucratic challenges, limiting the depth of the analysis. Additionally, the relatively small sample size of respondents could limit the generalizability of the findings. The reliance on self-reported data also posed the risk of bias, as respondents may have provided socially desirable answers rather than accurate reflections of their practices.

These limitations were addressed by triangulating data through a mixed-method approach, combining qualitative interviews with quantitative questionnaires to validate responses. Moreover, the study employed statistical methods, such as regression analysis and correlation tests, to ensure robust analysis despite the smaller sample size, thus strengthening the reliability of the findings.

1.8. Organization of the Study

This thesis is categorized into five chapters. Each chapter systematically and effectively examines the content and data of the study accordingly. The fundamentals of each chapter in the paper are further demonstrated as follows.

Chapter One: Introduction: Introduction to the study introduce the thesis by emphasizing the main topic of the study, statement of problems, objectives, research questions, significance and the scope in detail..

Chapter Two: Literature Review: This chapter presents a comprehensive review of relevant literature on environmental sustainability, project quality management, and their integration into construction projects. It explores theories, frameworks, and previous studies on sustainability indicators and project management practices, providing the conceptual foundation for the research.

Chapter Three: Research Methodology: This chapter describes the research design, methods, and tools used to conduct the study. It details the data collection process, including sampling techniques, data sources, and instruments. The chapter also explains the data analysis methods and how the study's validity and reliability are ensured.

Chapter Four: Result and Discussion: This is the section where the data is analyzed and discussed in detail with the aim of summarizing major findings. in relation to the research questions, and patterns or gaps .

Chapter Five: Conclusion and Recommendations: The final chapter summarizes the key findings of the study and provides conclusions based on the research objectives. It also offers practical recommendations based on the finding outcomes.

CHAPTER TWO: LITERATURE RIVIEW

2.1 Sustainability in Construction

The idea behind sustainable development is the need to balance and integrate environmental protection, social progress, and economic growth. Long-term progress necessitates taking into account the interdependencies between these three dimensions, which are acknowledged to be interconnected. With the 1987 release of the Brundtland Report, which defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," the idea gained popularity. While making sure that opportunities and resources are available for future generations, it demands that the needs of the current generation be met. (Rogers, Jalal et al. 2012)

The goal of sustainable development is to improve people's quality of life so they can live in a healthy environment and to improve the social, economic, and environmental conditions for both the current and future generations.(Ortiz, Castells et al. 2009) To maintain long-term well-being and guarantee the preservation of natural resources and ecosystems, it entails striking a balance between environmental, social, and economic factors. Reducing the harm that human activity causes to the environment is the main goal of environmental sustainability. It includes encouraging the use of renewable energy sources, cutting down on waste and pollution, and conserving resources. Along with preventing climate change, maintaining ecosystems, and safeguarding biodiversity are also included. (Harris 2003)

The integration of the economic, environmental, and social goals is referred to as the triple bottom line perspective or the three pillars of sustainability. (Chawla, Chanda et al. 2018) claims that the economic pillar is generally regarded as more important than the other two pillars. The three pillars are interrelated. Therefore, gaining in one dimension is beneficial to the other two dimensions. For instance, social wellbeing and the wise use of environmental resources have positive economic effects. The economic pillar is particularly significant since it protects and sustains the project investors’ capital, which promotes the need to maximize profit; reduce costs; increase revenue, profitability, and quality; and seek a return on investment.

To achieve sustainable development, international cooperation, partnerships, and collaboration among governments, businesses, civil society, and individuals are essential. It requires the integration of sustainable practices into various sectors, including energy, transportation, agriculture, industry, and urban development. Additionally, sustainable development necessitates the adoption of sustainable consumption and production patterns, education and awareness, and the promotion of responsible citizenship.(Elliott 2012)

The concept of sustainability has been expanding to all areas of economic activity, including construction engineering. Construction engineering is a complex discipline that involves designing, planning, constructing and managing infrastructures.(Zavadskas, Šaparauskas et al. 2018) The improving social, economic and environmental indicators of sustainable development are drawing attention to the construction industry, which is a globally emerging sector, and a highly active industry in both developed and developing countries.
(Ortiz, Castells et al. 2009)

In developing nations particularly, the construction industry is one of the major drivers of socioeconomic growth. The sector is diverse, distinct, and complex by nature, and it frequently deals with long-term issues like waste production (roughly 10% of material cost), cost overruns (which account for 70% of projects), and schedule delays (14% of contract cost on average). Furthermore, it is thought to be among the biggest environmental polluters. The carbon emission issue and other unprecedented challenges are beyond the control of traditional construction process and management techniques. These difficulties highlight how important it is for professionals to reconsider and advance technology and the building process. This demonstrates that through addressing issues of an economic, social, and environmental nature, the construction industry has a significant potential to advance sustainable development. By using sustainable building practices, one can minimize waste, conserve water resources, improve water quality, lessen the likelihood of flooding, reduce overall energy use, maximize the potential for renewable energy sources, reduce polluting emissions to air, water, soil, and reduce noise and light pollution.
(Hussin, Rahman et al. 2013)

Growing at a rapid pace, the construction industry is essential to a nation's economic expansion. It contributes to raising the standard of living of its people by supplying the essential socioeconomic infrastructure, including schools, hospitals, and other basic and improved facilities. On the other hand, it also has an impact on the nation's social and environmental aspects. As a result of the majority of projects' traditional design, which disregards energy and environmental effects as well as the preservation of natural resources, there has been waste that compromises the integrity of our ecosystem. (Hussin, Rahman et al. 2013)

The construction industry produces wastes and pollution as a result of its excessive resource consumption and life cycle. The world's extreme weather patterns and global warming were caused in part by buildings' CO2 emissions. The building industry is responsible for about 40% of global resource and energy consumption. The green building approach, which is more sustainable than current practices, can address these issues. Throughout a building's life cycle, green building practices are resource- and environmentally conscious. The methods are related to sustainable development because they encourage the use of water and energy-efficient building techniques while protecting open spaces. (Hussin, Rahman et al. 2013)

The importance of researching sustainability in the civil construction industry is clear given that businesses are realizing that maintaining a competitive edge requires more than just satisfying customers with low prices or high-quality offerings. Consumers anticipate ethical behavior, social responsibility, and environmental respect from businesses. (Lima, Trindade et al. 2021)

Sustainability practices can be introduced at any stage in construction, from design to deconstruction. Ideally, the impact of the built environment should be addressed on a life cycle basis, from the origins of the building material, through the manufacture and installation of these materials, to their eventual demolition of the building. Also, considering that construction waste comprises a significant portion of landfill material, sustainable principles are a good starting point, by guiding builders to realize the kinds of waste that are generated during the construction stage and how to reduce them (Hussin, Rahman et al. 2013)

Through reuse, recycling, creative design, and a reduction in waste and pollution, sustainability in the construction sector can help meet the needs of both the present and the

future generations. It can also help conserve energy and water. Proactive steps are made to minimize or reverse the damaging effects that construction operations have on the environment in order to achieve this goal. (Lima, Trindade et al. 2021)
Projects are carried out in order to accomplish specific goals and objectives. Businesses are becoming more and more concerned with a project's overall value and advantages in addition to the iron triangle goals of scope, time, and cost. A project's strategic value can be evaluated in light of the different social, ecological, and economic aspects of sustainability.(Kivilä, Martinsuo et al. 2017) Project management is now seen differently by academics and the corporate community due to the growing emphasis on sustainable business operations. These days, maintaining natural and environmental resources and business operations are of utmost importance. This has had a profound effect on project management activities, including their conception, planning, scheduling, and execution (Chawla, Chanda et al. 2018)

By incorporating sustainability principles into project management, measurement, and reporting processes, organizations can ultimately increase business success. Even though many organizations have started to focus on sustainability, many of them continue to manage their projects with traditional project management techniques, which prevent them from reaching their goals as planned. (Chofreh, Goni et al. 2019)

By integrating sustainability into project management processes, organizations can contribute to positive environmental and social outcomes while achieving project goals and delivering value. Sustainable project management aligns with the principles of sustainable development, supports responsible business practices, and helps create a more sustainable future.

The last few years have seen a steady increase in the significance of sustainable project management techniques. One way to guide contemporary projects toward sustainability is through the use of pertinent indicators. Therefore, it's essential to determine a set of sustainability indicators that have an impact on the building process.(Stanitsas and Kirytopoulos 2023)

2.2. Overview of Environmental Sustainability in Construction

One of the key aspects of environmental sustainability in construction is the use of sustainable building materials. These materials reduce the environmental impact of construction projects by lowering energy use, minimizing waste, and promoting the reuse or recycling of resources. Researchers like Asif et al. (2007) emphasize that the choice of materials in construction greatly influences the carbon footprint of buildings. Studies have also focused on the development and promotion of alternative, eco-friendly materials such as recycled concrete, bamboo, and fly ash-based cement, as well as the benefits of using locally sourced materials to reduce transportation emissions (Cabeza et al., 2014)

Sustainability indicators reduce the amount of harmful materials released into the environment over the course of its life and blends in with the local environment, customs, and climate. These indicators have the power to preserve and enhance human life while preserving the ecosystem's ability to function both locally and globally. The utilization of building resources more efficiently, considerable operational savings, and higher workplace productivity are just a few advantages of green buildings. (Hussin, Rahman et al. 2013)

In order to effectively assess and measure sustainability development practices, a number of green certificates, rating systems, and labeling programs have been introduced as a result of the rise of green building. Some examples of these include the Building Research Establishment Environmental Assessment Method (BREEAM) of the UK, Leadership in Energy and Environmental Design (LEED) of the US, Green Star of Australia, and Green Mark Scheme of Singapore. The literature generally agrees that these rating systems and labeling programs play a significant role in promoting the use of environmental indicators and practices. Researchers have also contended that financial and regulatory incentive schemes play a critical role in the successful adoption sustainable practices. They have further claimed that one of the most important things that can be done to promote green building is to educate clients about the advantages of green buildings. Strengthening publicity and education has also been seen as an effective way to increase public awareness of environmental sustainability and customers' willingness to pay for green buildings, as consumer and public behaviors and attitudes have a significant impact on the promotion of green buildings. (Chan, Darko et al. 2017)

2.3. Environmental Sustainability Indicators (ESIs)

Sustainability indicators are tools used to measure and assess progress towards sustainable development goals. They provide quantitative or qualitative data that help track and evaluate the environmental, social, and economic dimensions of sustainability. (Bell and Morse 2012) It is necessary to measure the events that indicate such progress in order to gauge the direction of development—whether sustainable or unsustainable. Indicators are used for this. Measuring economic development, for example, might be done with basic indicators like GDP per capita, or more sophisticated one.(Verma and Raghubanshi 2018)

Sustainability indicators in construction project management are used to measure and assess the environmental, social, and economic impacts of construction projects. These indicators help evaluate the sustainability performance of construction activities and guide decision-making towards more sustainable practices. (Stanitsas and Kirytopoulos 2023)

Environmental indicators include measuring carbon emissions, water footprint, renewable energy share, air quality, and land use change. Social indicators encompass poverty rates, education attainment, income inequality, health indicators, and gender equality. Economic indicators involve measuring GDP, employment rates, economic inequality, resource productivity, and investment in sustainable businesses. Governance indicators assess corruption perception, government transparency, rule of law, and public participation. These indicators enable organizations and stakeholders to monitor progress, identify areas for improvement, and make informed decisions to advance sustainable development goals. (Wu and Wu 2012)

Carbon footprint: Measures the greenhouse gas emissions associated with an activity, organization, or product. Water consumption: Tracks the amount of water used and helps identify opportunities for conservation. Waste generation: Measures the amount of waste produced and encourages waste reduction and recycling efforts. Biodiversity index: Assesses the health and diversity of ecosystems and the impact of human activities on biodiversity. Air quality: Measures air pollutants, such as particulate matter and ozone, to evaluate air pollution levels. (Moldan, Janoušková et al. 2012)

These indicators provide a framework for monitoring progress, setting targets, and evaluating the effectiveness of sustainability initiatives. They allow policymakers, businesses, and organizations to identify areas for improvement, track trends over time, and make informed decisions that promote sustainable development. It's important to select indicators that are relevant to specific contexts and goals, ensuring they align with local priorities and global sustainability frameworks such as the United Nations Sustainable Development Goals (SDGs). (Valentin and Spangenberg 2000) (Hák, Moldan et al. 2012)

Here are some common environmental sustainability indicators

2.3.1 Energy Efficiency:

Energy efficiency has become a central focus in both academic research and practical applications, particularly in sectors such as construction, manufacturing, and urban development. The concept of energy efficiency refers to using less energy to achieve the same level of energy service, such as heating, lighting, or manufacturing. In the context of construction, energy efficiency emphasizes designing, constructing, and operating buildings in ways that reduce energy consumption without compromising comfort or functionality. This has far-reaching implications for environmental sustainability, as it directly addresses issues like resource conservation, carbon emissions, and long-term energy costs. The literature on energy efficiency highlights its importance for reducing the environmental footprint of buildings while simultaneously cutting operational costs.

Historically, energy efficiency has been driven by concerns about energy supply and security, particularly during periods of energy crises. However, in more recent decades, its role in combating climate change has become a key focus. The building sector, which accounts for a significant percentage of global energy consumption and greenhouse gas emissions, has been identified as a primary target for energy efficiency improvements. Studies, such as those by (WBCSD, 2019), suggest that improving energy efficiency in buildings could reduce global carbon emissions by up to 30% by 2030. Energy-efficient buildings are often designed to minimize heat loss, maximize the use of natural light, and employ energy-saving technologies such as insulation, advanced HVAC systems, and energy-efficient windows.

One of the most influential frameworks in the energy efficiency literature is the concept of "Passive House" design, which emphasizes ultra-low energy buildings. Developed in Germany in the early 1990s, Passive House principles focus on building envelopes that are highly insulated and airtight, thus requiring minimal energy for heating and cooling. Studies on Passive House construction show that these buildings can reduce energy consumption for heating by up to 90% compared to standard buildings. This design philosophy is now internationally recognized and has been adapted to various climates, proving that energy efficiency can be achieved in diverse geographical contexts.

Moreover, research on energy efficiency retrofits of existing buildings has also grown. Many buildings constructed before energy codes were established are significant energy wasters, but they represent an enormous opportunity for energy savings. Retrofitting older buildings with modern, energy-efficient technologies such as LED lighting, smart thermostats, and improved insulation can drastically reduce their energy consumption. According to (Janda, 2018), retrofitting the existing building stock could contribute as much to energy savings as constructing new energy-efficient buildings, as a large proportion of global buildings were built decades ago and have not yet been updated to modern energy standards.

The literature also emphasizes the role of building automation and smart technologies in enhancing energy efficiency. The use of smart meters, sensors, and automated energy management systems can optimize energy use in real-time, responding to changes in occupancy, outdoor temperature, and energy prices. A study by (Oluwaseun and Akinola 2020) on smart buildings found that these technologies could reduce energy consumption by up to 40%, primarily by eliminating energy waste and optimizing energy use based on actual demand. The integration of smart technologies into energy efficiency strategies aligns with the broader trend of digitization in the built environment, where data-driven insights are used to make buildings more responsive and efficient.

Another important strand is on policy and regulation as drivers of energy efficiency in buildings. Many governments have adopted stringent building codes and energy standards to enforce energy efficiency in new constructions and renovations. In the European Union, for instance, the Energy Performance of Buildings Directive (EPBD) sets requirements for energy performance certificates and aims for all new buildings to be nearly zero-energy by

2021. Similar standards exist in other regions, with initiatives like the U.S. Energy Star program and China's Green Building Standard. These policies have catalyzed significant improvements in building energy performance by ensuring that energy efficiency is a mandatory part of the design and construction process, rather than an optional add-on.

In addition to policies, the literature emphasizes the role of financial incentives and market mechanisms in promoting energy efficiency. Programs such as tax credits, subsidies, and low-interest loans have been used to encourage building owners and developers to invest in energy-efficient technologies and construction methods. Studies like (Zheng and Kahn, 2013) highlight the economic benefits of energy-efficient buildings, noting that while initial costs for energy-efficient technologies can be higher, the long-term savings in operational costs often outweigh these upfront investments. In many cases, energy-efficient buildings also have higher market values and can command higher rental or sale prices, creating a financial incentive for developers and building owners.

Energy efficiency highlights the importance of user engagement in achieving energy-saving goals. Even the most energy-efficient building can fall short of its potential if the occupants are not mindful of energy use. Research by (Darby,2006) found that providing real-time energy feedback to building occupants could lead to energy savings of between 5% and 15%, simply by making users more aware of their energy consumption. This suggests that energy efficiency is not only a matter of design and technology but also of fostering energy-conscious behaviors among building users.
Energy consumption: Measures the amount of energy used during construction and operation phases. Energy performance: Evaluates the efficiency of building systems and equipment. Greenhouse Gas Emissions: Carbon footprint: Measures the amount of greenhouse gas emissions associated with construction activities, including materials production, transportation, and on-site operations.(Stanitsas and Kirytopoulos 2023)

Energy efficiency underscores its critical role in both environmental sustainability and cost reduction, particularly in the construction sector. From the design of new buildings based on Passive House principles to the retrofitting of older structures and the use of smart technologies, energy efficiency is a multifaceted concept that touches on many aspects of the built environment. Policies, regulations, financial incentives, and user behavior all play significant roles in promoting energy efficiency. As global energy consumption continues to rise, and the need to reduce carbon emissions becomes more urgent, energy efficiency remains one of the most effective strategies for achieving both economic and environmental goals in the construction and operation of buildings.

2.3.2 Waste Management:

Construction waste generation: Tracks the amount of waste generated during construction and demolition activities. Waste diversion rate: Measures the percentage of waste that is recycled, reused, or diverted from landfill. (Valentin and Spangenberg 2000)

Waste management is a critical component of environmental sustainability, especially in industries such as construction, which generate significant volumes of waste. Waste management indicators are used to measure the effectiveness of waste management practices and help assess the environmental impact of waste generation, treatment, and disposal. These indicators are essential for tracking progress toward waste reduction, resource recovery, and pollution control. In recent years, waste management has garnered increased attention in both academic research and policy discussions as the global waste problem continues to escalate. Effective waste management not only minimizes the adverse effects of waste on human health and the environment but also plays a crucial role in resource conservation and the circular economy.

In the construction sector, which is among the largest producers of solid waste, the application of waste management indicators is particularly relevant. Construction activities generate a variety of waste materials, including concrete, wood, metal, glass, and hazardous substances. According to (Wang et al.2020), construction and demolition waste (CDW) can account for up to 30% of total solid waste in developed countries. Given the magnitude of waste generated, indicators are necessary to measure how well construction projects manage, recycle, or dispose of their waste. Common indicators in this context include waste generation per square meter of construction, recycling rate of construction materials, and percentage of hazardous waste treated.

One widely recognized set of waste management indicators comes from the European Commission’s Waste Framework Directive, which sets targets for recycling and reusing materials, particularly from construction and demolition waste. This policy has led to the development of indicators such as the recycling rate of non-hazardous construction waste, which is aimed at promoting the recovery of materials rather than landfill disposal. Studies, such as those by (Villoria-Sáez et al 2016), show that these indicators have been effective in reducing the amount of construction waste sent to landfills in the European Union, where recycling rates of over 70% have been achieved in some countries.

Moreover, life cycle assessment (LCA) tools have become a standard approach to evaluate waste management performance in construction projects. These tools help quantify the environmental impact of waste at every stage of the building's lifecycle, from material extraction to demolition. Indicators generated through LCA models often include metrics like carbon footprint per unit of waste and energy recovery from waste, which are crucial for understanding the broader environmental consequences of waste management decisions. Research by (Ding et al. 2019) demonstrates how LCA-based indicators can help construction companies prioritize waste reduction strategies and choose materials that are more environmentally friendly throughout their lifecycle.

Waste management indicators are not limited to construction; they are also extensively used in municipal and industrial waste management. Indicators such as waste generation per capita, recycling rate, and landfill diversion rate are commonly used to measure the efficiency of municipal waste management systems. These indicators provide insights into how well a community or city is managing its waste, highlighting areas for improvement in waste segregation, recycling infrastructure, and public participation. A study by (Gupta and Arora 2017) on urban waste management in India emphasizes that using these indicators allows for better planning and policymaking, ensuring that waste is managed more sustainably and efficiently in growing urban areas.

In addition to measuring physical quantities of waste, waste management indicators also include economic and social dimensions. For instance, cost per ton of waste treated is an important economic indicator that reflects the efficiency of waste management systems. Social indicators, such as public participation in recycling programs or awareness of waste reduction practices, reflect how well communities are engaged in waste management efforts. The integration of social and economic indicators is critical in ensuring that waste management strategies are not only environmentally sustainable but also economically viable and socially acceptable.

The circular economy aims to close the loop on waste by reusing, recycling, and recovering materials at the end of their life cycle, thus minimizing the need for new raw materials and reducing environmental impact. Indicators that reflect circular economy performance include material recovery rate, recycling-to-landfill ratio, and reuse rate. Studies by (Stahel, 2016) and others emphasize that shifting from a linear economy where materials are used once and then discarded to a circular model requires robust indicators to track how effectively resources are being reused and recycled. These indicators help policymakers and businesses assess whether they are making progress toward more sustainable production and consumption patterns.

Furthermore, in developing countries, waste management indicators often reflect different priorities due to limited infrastructure and resources. In many low-income regions, the focus is on waste collection coverage and safe disposal rates. Studies by (Wilson et al, 2015) reveal that in some cities, the priority is simply to increase the proportion of waste that is collected and safely disposed of, as large percentages of waste are often left uncollected or improperly managed, leading to significant environmental and health hazards. In such contexts, waste management indicators are critical for tracking improvements in basic waste services, which are often a precursor to more advanced waste reduction and recycling initiatives.

The development of smart technologies and big data analytics has revolutionized the way waste management indicators are collected and analyzed. Smart bins, RFID technology, and GPS tracking allow for real-time monitoring of waste generation, collection, and disposal, enabling more precise and timely data collection. A study by (Song et al. (2017) discusses how these technologies can improve the accuracy of waste management indicators, such as real-time waste collection efficiency and dynamic landfill capacity utilization rates. These innovations are making waste management more data-driven, allowing cities and companies to optimize their waste management systems and make informed decisions based on up-to-date performance indicators.

Waste management indicators are indispensable for assessing the performance of waste management systems across different sectors, from construction to municipal and industrial waste management. They provide valuable insights into waste generation, treatment, recycling, and disposal processes, helping organizations and governments measure their progress toward more sustainable waste practices. The literature highlights a wide range of indicators, from those focused on physical quantities of waste to those addressing economic and social dimensions. As the global waste problem continues to grow, particularly in construction and urban areas, the use of waste management indicators will play an increasingly vital role in ensuring that waste is managed efficiently, resources are conserved, and environmental impacts are minimized. Through the use of advanced technologies and circular economy principles, waste management indicators are evolving to support a more sustainable future.

2.3.3Water Conservation:

Water conservation indicators are used to measure the efficiency and effectiveness of water use and management strategies across various sectors, including agriculture, industry, and construction. These indicators help assess the sustainability of water resources by providing metrics that quantify water usage, water efficiency, and the impacts of conservation measures. The academic literature emphasizes the need for robust water conservation indicators to support evidence-based policymaking, guide water management practices, and track progress toward sustainable water use. which measures the amount of water used during construction and operation phases. Water efficiency: Evaluates the efficiency of water use systems, such as plumbing fixtures and irrigation systems.(Valentin and Spangenberg 2000)

In the context of the construction industry, water conservation indicators have gained increasing attention due to the sector's high water demand for activities such as concrete mixing, dust suppression, and cleaning. Construction activities often rely on large volumes of water, leading to a significant impact on local water resources, especially in arid or water-scarce regions. The introduction of water-saving technologies, such as recycling wastewater on-site and using water-efficient construction practices, has led to the development of specific indicators like water use intensity and percentage of water reused or recycled on-site Research by (Alfaro et al, 2020) suggests that incorporating these indicators into project management practices can reduce water use by up to 50% in large-scale construction projects, demonstrating the potential for water savings when conservation measures are carefully monitored.

A widely used set of water conservation indicators in the construction and building sectors is derived from green building certification systems such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method). These systems include indicators like indoor water use reduction, outdoor water use reduction, and total water use reduction compared to a baseline. Such indicators help track how much water a building saves through measures like low-flow fixtures, drought-resistant landscaping, and rainwater harvesting systems. Studies, such as those by (Kamali et al, 2018), show that buildings certified under these systems typically achieve 20-30% water savings compared to conventional buildings, underscoring the role of indicators in guiding sustainable water use in construction.

In urban and municipal contexts, water conservation indicators focus on water use efficiency and water loss reduction in distribution networks. Key indicators include per capita water consumption, non-revenue water (NRW), and leakage rates. Non-revenue water, which refers to water lost before it reaches the consumer due to leaks, theft, or meter inaccuracies, is a critical indicator for assessing the efficiency of water supply systems. High NRW levels indicate inefficient water management and a need for infrastructure improvements. A study by (Kingdom et al. (2006) found that in developing countries, NRW can reach up to 50%, representing a major opportunity for conservation through improved infrastructure and management practices. Reducing NRW through the use of advanced monitoring and leak detection technologies can significantly enhance water efficiency and ensure that more water is available for consumption and ecological needs.

The use of water footprint indicators has also become prominent in the literature, particularly in industries and regions where water is a critical input. The water footprint measures the total volume of water used directly and indirectly throughout the lifecycle of a product, project, or process. It is divided into three components: blue water footprint (surface and groundwater used), green water footprint (rainwater used), and grey water footprint (water required to assimilate pollutants). In construction, the water footprint can be used to assess the water impact of building materials, construction processes, and the long-term operation of buildings. Studies by Hoekstra and Mekonnen (2012) emphasize the importance of the water footprint as an indicator for identifying areas where water use can be reduced or managed more sustainably, particularly in water-intensive processes like cement and concrete production.

Water conservation indicators are also critical in agriculture, where water is a key resource and inefficiencies are common. In this context, indicators like water use efficiency, measured as the amount of crop produced per unit of water used, are widely used to assess the sustainability of agricultural practices. WUE is an important measure for improving water productivity in regions facing water scarcity. Another key indicator is the irrigation efficiency rate, which measures the proportion of water used by crops versus the amount applied through irrigation systems. A study by (Li et al. (2018) found that improving irrigation efficiency through precision irrigation technologies can reduce water use by up to 30% while maintaining or increasing crop yields. These findings suggest that water conservation indicators are not only tools for measurement but also for guiding technological and management improvements.

The industrial sector also relies on water conservation indicators to optimize water use and reduce waste. Common indicators include water consumption per unit of production, water recycling rate, and total water withdrawal. These indicators help industries track their water use and identify opportunities for improvement through water reuse, wastewater treatment, and process optimization. In the manufacturing sector, for example, high water recycling rates are often associated with reduced costs and lower environmental impact. Research by (Chen et al., 2019) on water management in the textile industry shows that implementing water recycling systems, guided by these indicators, can lead to a 40% reduction in freshwater use, highlighting the economic and environmental benefits of water conservation in industrial processes.

Water conservation indicators are not limited to measuring direct water use they also address the impacts of water use on ecosystems and communities. Indicators like water stress index and ecosystem water balance are used to assess the sustainability of water use in relation to available water resources and environmental needs. The water stress index measures the proportion of water withdrawal to total renewable water resources in a given area. High values indicate unsustainable water use and potential water scarcity. A study by (Pfister et al. (2009) demonstrated that in regions with high water stress, even small increases in water use can have severe environmental impacts, underscoring the need for careful monitoring using these indicators. Such ecosystem-based indicators are essential for ensuring that water conservation efforts align with broader environmental sustainability goals.

The literature on water conservation indicators highlights their importance in various sectors, from construction and urban water management to agriculture and industry. These indicators provide quantitative measures that help track water use efficiency, identify areas for improvement, and support sustainable water management practices. In construction, indicators like water use intensity and water recycling rates are used to monitor and reduce the water footprint of building projects. In urban and industrial contexts, indicators such as non-revenue water and water consumption per unit of production help optimize water use and minimize losses. Meanwhile, water footprint and ecosystem-based indicators provide a broader perspective on the environmental impacts of water use. As global water resources come under increasing pressure, the role of water conservation indicators in promoting sustainable water management will only become more critical, providing a basis for effective decision-making and policy development.

2.3.4 Use of sustainable Materials and Resources:

Embodied carbon: Measures the carbon emissions associated with the production, transportation, and disposal of construction materials. Recycled content: Evaluates the percentage of recycled materials used in construction. Sustainable sourcing: Considers the use of materials that are responsibly sourced and have a lower environmental impact.(Hueting and Reijnders 2004)

The use of sustainable materials and resources is a key component of modern construction and urban development, driven by the need to minimize environmental impacts, reduce waste, and promote resource efficiency. Sustainable materials and resources indicators are used to measure how effectively materials are sourced, utilized, and managed throughout the lifecycle of a building or infrastructure project. These indicators help assess the environmental performance of construction projects, providing metrics that focus on resource conservation, material recycling, energy use, and waste generation. In the literature, the role of sustainable materials in achieving environmental sustainability is increasingly emphasized, particularly within the context of the construction industry's significant contribution to resource consumption and waste production.

In sustainable construction, the choice of materials plays a crucial role in reducing the overall environmental impact of a building. Embodied energy, one of the key sustainable material indicators, refers to the total energy consumed in the extraction, processing, manufacturing, and transportation of building materials. Studies such as those by (Moncaster and Symons,2013) highlight that high embodied energy materials, such as concrete and steel, significantly contribute to the carbon footprint of a building. Sustainable materials, such as recycled steel, low-carbon concrete and reclaimed wood, are favored because they reduce the embodied energy and thus minimize the environmental impact of the construction process. The embodied energy indicator allows project managers to compare different materials and select the ones with the lowest environmental footprint, making it a critical tool for sustainable material selection.

Another important indicator is the percentage of recycled content in materials, which measures how much of the material used in construction is derived from recycled sources rather than virgin raw materials. This indicator is widely used in green building certification systems like LEED and BREEAM, where points are awarded for using materials with a high percentage of recycled content. For example, recycled steel, crushed concrete aggregates, and reclaimed bricks can significantly reduce the demand for new raw materials. Research by (Kleijn and van der Voet 2010) shows that using recycled content in construction can reduce raw material extraction by up to 30%, conserving natural resources and reducing the environmental degradation associated with mining and material processing. These findings underscore the importance of indicators that promote the use of recycled materials in building projects.

In addition to recycled content, resource efficiency indicators measure how efficiently materials are used during construction. These indicators help track the amount of material waste generated, as well as the reuse and recycling rates of construction materials. For example, the material efficiency ratio compares the amount of material used in a project to the amount of material that is wasted or recycled. Higher material efficiency means that less waste is generated, and more materials are either reused on-site or recycled for future projects. Studies by (Pacheco-Torgal et al. (2013) indicate that improving material efficiency can lead to cost savings, reduce the environmental impact of waste disposal, and decrease the overall resource demand of construction activities.

The local sourcing indicator is another critical metric used to assess the sustainability of materials in construction. This indicator measures the percentage of materials that are sourced locally, within a specified distance from the construction site. Using locally sourced materials reduces transportation-related energy consumption and emissions, while also supporting local economies. In a study by (Zabalza Bribián et al, 2011) locally sourced materials were found to lower the overall carbon footprint of a project by reducing transportation distances and the associated fuel consumption. The local sourcing indicator is particularly relevant in green building projects, where reducing the environmental impact of transportation is a priority. It also promotes the use of regionally available materials, which can be more suited to local climate conditions and construction practices.

Another key area where sustainable materials indicators are used is in the life cycle assessment (LCA) of building materials. LCA evaluates the environmental impacts of materials from cradle to grave, including raw material extraction, manufacturing, transportation, use, and end-of-life disposal. Indicators generated through LCA, such as **global warming potential (GWP) and acidification potential, provide comprehensive data on the environmental impact of specific materials. A study by (González and Navarro 2006) illustrates how LCA-based indicators can be used to select materials that have lower environmental impacts throughout their lifecycle, helping architects and engineers design buildings with a reduced carbon footprint. LCA tools are increasingly being used to inform decision-making in sustainable construction, ensuring that material choices align with broader sustainability goals.

Moreover, the literature highlights the importance of indicators related to renewable material use. Renewable materials, such as bamboo, timber from sustainably managed forests, and agricultural by-products like straw, are gaining popularity due to their low environmental impact and renewability. The percentage of renewable materials used is a common indicator in sustainable building projects, reflecting the shift toward materials that are rapidly renewable and have a smaller ecological footprint compared to non-renewable materials like steel and concrete. Studies by (Pittau et al. (2018) show that buildings made with a higher percentage of renewable materials can significantly reduce the depletion of non-renewable resources and lower overall carbon emissions, making renewable material use a critical indicator in sustainable design and construction.

Sustainable materials indicators are also closely tied to the circular economy concept, which focuses on minimizing waste and promoting the reuse of materials at the end of their life cycle. Indicators such as material recovery rate and reuse rate measure how effectively materials are recovered or reused in new construction projects. According to (Stahel, 2016), the circular economy framework, when applied to construction, encourages the design of buildings with dismantling and material recovery in mind. This reduces the amount of waste sent to landfills and increases the recycling rate of construction materials, thereby conserving resources and promoting sustainability. These indicators are essential for measuring progress toward a circular economy in construction, where the goal is to close the loop on material use.

The use of sustainable materials and resources indicators is critical for assessing and promoting environmentally responsible practices in the construction industry. Indicators such as embodied energy, recycled content, material efficiency, local sourcing, and renewable material use provide quantitative measures that help project managers, architects, and engineers make informed decisions that reduce environmental impacts. The integration of life cycle assessment tools and circular economy principles further enhances the ability to assess the sustainability of materials throughout their lifecycle, from extraction to end-of-life disposal. As the construction industry continues to face pressure to reduce its environmental footprint, the role of sustainable materials indicators will become increasingly important in ensuring that buildings are designed and constructed with sustainability at the forefront.

2.4. Project Quality Management (PQM)

A project is a task that is performed by a temporary organization in order to achieve a predetermined result. Projects are not limited in size or in persons involved but are always temporal and have a clear start and end. Projects can be used for different kinds of purpose, but most commonly they are used for realizing organizational goals (Lund, 2011).
Moreover, one of the most commonly accepted definition of project is that a sequence of unique, complex, and connected activities that have one goal or purpose and that must be

completed by a specific time, within budget, and according to specification (Robert K.Wysocki, 2014).
Likewise, the organization of Governance Commerce defines a project as "a unique set of coordinated activities with definite starting and finishing points undertaken by an individual or team to meet specific objectives within defined time, cost and performance parameters as specified in the business case". Also a project is "a unique endeavor to produce a set of deliverables within a clearly specified time, cost, and quality constraints"(UNCRD,2000).

Project management refers to the application of knowledge, skills, tools and techniques to project activities to meet a relatively short-term objective that has been established to complete specific goals and objectives (PMI, 2008). It is accomplished through the planning, organizing, directing, and controlling of company resources (Kerzner, 2009). Today, the concept of project management has been increasingly applied in diverse industries and organizations (Kerzner,2009; Packendorff, 1995).

Project management has become a scientific field with its own professional associations, the Project Management Institute (PMI) and the International Project Management Association (IPMA). These associations are known as promoters of the standardization of project management and certification programs for project managers (Soderlund, 2004).
A Guide to the Project Management Body of Knowledge (PMBOK Guide), published by PMI, presents a set of standard terminology and guidelines for project management. The PMBOK Guide is process-based, describing project management as being accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing. Further, it assumes that all project management practices fall into ten knowledge areas, which are project integration management, project scope management, project time management, project cost management, project quality management, project resource management, project communications management, project risk management, project stakeholder management, and project procurement management.
Quality has been characterized by many authors as something that relates to the results of an ongoing improvement that includes products, services, processes and people to fulfill customer expectations and customer satisfaction. Formal writing on the concept of quality can be found from quality gurus such as Deming (1986), Crosby (1979), Feigernbaum

(1991) and Ishikawa (1985). As literature indicate that Gurus have laid the foundation for understanding most concepts of quality management such as TQM, Total Quality Control and Quality Management systems.

The Kodak definition of quality is those products and services that are perceived to meet or exceed the needs and expectations of the customer at a cost that represents outstanding value. Additionally, the ISO 9000 define quality as "the totality of feature and characteristics of a product or service that bears on its ability to satisfy stated or implied needs" (Abdulaziz, 1999).

Additionally Wysocki identified two types of quality as part of every project; the first is product quality which refers to the quality of the deliverable from the project. The second type of quality is process quality, which is the quality of the project management process itself. The later mainly focus on how well the project management process works and how can it be improved (R. K.Wysocki, 2003). Moreover, he described projects with the following constraints: scope, cost, time, resources, quality and risk. Except for risk these constraints are connected, a change in one constraint will affect at least another constraint. The scope triangle clearly illustrate variables of the project and there interdependence. Similarly PMI illustrates project quality through the concept of the triple constraint project scope, time and cost. Project quality is affected by balancing these three interrelated factors.

According to Crawford the overall aim of quality management is to satisfy the customer, conform to requirements, ensure fitness for purpose, and to ensure the product for use. Project model looks at quality management as set of activities or tasks that are required to ensure the project satisfies all the needs for which it was undertaken based on documented in the state of work and includes a focus on quality management from the perspective of product, processes, and the people needed to make quality an effective and efficient aspect of successful project completion (Crawford, 2002).

Moreover, Wysocki in his effective project management book states that: A sound quality management programs with processes in place that monitor the work in a project is a good investment. It is not only contributes to customer satisfaction but also it helps organizations use their resources more effectively and efficiently by reducing waste and rework. He further described "Quality management is one area that should not be compromised. The payoff is a higher probability of successfully completing the project and satisfying the customer" (Wysocki, 2014).

PMBOK Guide explains that "Project Quality Management includes the processes and activities of the performing organization that determine quality policies, objectives and responsibilities so that the project will satisfy the needs for which it was undertaken. It implements the quality management system through policy and procedures with continuous process improvement activities conducted throughout, as appropriate" (PMBOK, 2000).

Furthermore, the PMI's PMBOK states that project quality management include: To identify all the quality standards relevant for the project and plan how to satisfy them, To evaluate the project to ensure that the relevant quality standards will be met, to monitor, to compare with the relevant quality standards, and to correct the product and the processes.

The concept of quality has existed for many years, but its meaning and perception has changed and evolved over time. Before the early twentieth century, quality management meant inspecting products to ensure that they met specifications (Reid and Sanders, 2007 cited inSabah 2011).

2.4.1 Key Components of Project Quality Management

Quality of construction is more difficult due to the uniqueness of the project. Chang stated that "the product is usually not a repetitive unit but a unique piece of work with specific characteristics. Secondly, the needs to be satisfied include not only those of the client but also the expectations of the community into which the completed building will integrate.

The construction cost and time of delivery are also important characteristics of quality." (Chang,1999). For Rumane, construction project quality management is defined as the fulfillment of owner's needs per defined scope of works within a budget and specified schedule to satisfy the owner's / user's requirements. The phenomenon of these three components can be the construction project trilogy (Rumane, 2011). Construction projects are custom oriented and custom designed, having specific requirements set by the customer to be completed within a finite duration and assigned budget. Every project has elements that are unique that means no two projects are identical. It is always the owner's desire that his project be unique and better. To a great extent, each project has to be designed and built to serve a specified need. Construction projects are more customized than a routine and repetitive business (Rumane, 2011).

The importance of PQM lies in its ability to prevent defects, reduce rework, improve efficiency, and enhance overall project success. In the construction sector, where large-scale projects like government buildings are complex and resource-intensive, effective quality management ensures durability, safety, and compliance with environmental and structural regulations.

2.4.1.1 Quality Planning

The first step in quality management is to define quality which is under taken by the project manager and the team to identify what quality standards will be in the project from perspectives of key stakeholders of the project depending upon the area of specialization of the projects. Identifying the quality standards that are relevant to the project and determining how to meet them. It is one of the Key facilitating processes during the project planning. Quality planning is usually involved during preparation phase, Design phase, and pre-construction phase. Quality planning should be performed regularly and parallel with the other project planning processes. According to Lydia (2010), the guidelines to ensure the quality in planning are: (i) Ensure that all relevant parties involved including consultants, subcontractors and suppliers are included in the task of quality planning for the project; (ii) Establish and define the purpose of the quality system; (iii) minimize the effort required to amend copies of documents; (iv) Set up a quality system development team so that the team can produce an effective plan; (v) Ensure that throughout the quality planning task constantly focused on the customer requirements.(Liydia, 2010).

Harris and McCaffer, (2001) defined quality planning as a set of activities whose purpose is to define quality system policies, objectives, and requirements, and to explain how these policies will be applied, how these objectives will be achieved, and how these requirements will be met. Subsequent to this definition, Construx, (2003) stressed that quality plan is different from a test plan. The study continued that quality plan defines the quality goals, is realistic about where defects come from, Selects appropriate detection and prevention methods, and has means not to “go dark”. The Project Management Book of Knowledge “PMBOK” for also addressed quality planning has a process input generated by predecessor processes referred to as the Project Scope Statement and Project Management Plan. These processes are introduced by external units like Enterprise Environmental Factors and Organizational Process Assets. PMBOK for further defined quality planning as the process for "identifying which quality standards are relevant to a project and determining how to satisfy them"

Quality planning is the foundational process where the project team determines the quality standards and objectives to be achieved during the project. This component involves identifying relevant quality standards (such as industry regulations or client specifications) and defining how those standards will be met. It also involves developing metrics and criteria that will be used to measure project performance. Quality planning is crucial for ensuring that everyone involved in the project understands the expected quality requirements from the start.

According to (Juran's, 2016) Quality Planning Roadmap**,** effective quality planning requires understanding customer needs and translating those into quality goals that guide the project. This process ensures that the project team is aligned with stakeholder expectations and sets the groundwork for quality assurance and control.

2.4.1.2. Quality Assurance

Harris and McCaffer, (2001) defined quality assurance as a set of activities whose purpose is to demonstrate that an entity meets all quality requirements. Quality assurance activities are carried out in order to inspire the confidence of both customers and managers, confidence that all quality requirements are being met. Moreover, the main objective of quality assurance measures in information processes is to fulfill a required quality level (Harris and McCaffer, 2001). In general quality assurance is a process to provide confirmation based on evidence to ensure to the donor, beneficiaries, organization management and other stakeholders that product meet needs, expectations, and other requirements. It assures the existence and effectiveness of process and procedures tools, and safeguards are in place to make sure that the expected levels of quality will be reached to produce quality outputs. Therefore, quality assurance occurs during the implementation phase of the project and includes the evaluation of the overall performance of the project on a regular basis to provide confidence that the project will satisfy the quality standards defined by the project.

Quality assurance "is oriented towards prevention of quality deficiencies. It aims at minimizing the risk of making mistakes in the first place, thereby avoiding the necessity for rework, repair or reject" (Chang, 1999). He also stated factors that staffs at organizational levels must know, these are; to have appropriate organization structure, clear lines of responsibility and communication, clear definition and description of duties, correct specifications and drawings, proper training, appropriate procedures, and ready access to necessary instructions, motivation, have the right resources, plant and materials; appropriate checking, measurement or testing of products and keeping proper records (Chang, 1999).

According to Crosby (2019), quality assurance is primarily about building a culture of "doing it right the first time." This prevents costly errors and ensures that project processes are optimized to produce quality results. This involves periodic audits, evaluations, and reviews of project activities to verify that the defined quality objectives are being met. Quality assurance focuses on the prevention of defects by ensuring that the processes used to create the deliverables are working as intended.

2.4.1.3. Quality Control

The PMBOK refers to quality control as the technical aspect of quality management. Project team members who have specific technical expertise on the various aspects of the project play an active role in quality control. They set up the technical processes and procedures that ensure that each step of the project provides a quality output from design and development through implementation and maintenance. Each step's output must conform to the overall quality standards and quality plans, thus ensuring that quality is achieved (PMI, 2008).

According to Harold (2003) a good quality control system will; "Select what to control, set standards that provide the basis for decisions regarding possible corrective action, establish the measurement methods used, compare the actual results to the quality standards, act to bring nonconforming processes and material back to the standard based on the information collected, monitor and calibrate measuring devices and include detailed documentation for all processes" (Harold, 2003). Similarly (Juran, 1999) quality control relies on five basics: a clear definition of quality; a target, a clear goal; a sensor, a way to measure actual performance; a way to interpret the measurement and compare with the target; and a way to take action, to adjust the process if necessary (Juran, 1999). Quality control is the use of techniques and activities that compare actual quality performance with goals and define appropriate action in response to a shortfall. It is the process that monitors specific project results to determine if they comply with relevant standards and identifies different approaches to eliminate the causes for the unsatisfactory performance. The goal of quality control is to improve quality and involves monitoring the project outputs to determine if they meet the quality standards or definitions based on the project stakeholder's expectations. Quality control also includes how the project performs in its efforts to manage scope, budget and schedule (PDEM, 2014).

Quality control in construction is the process of verifying that the project is built to plan, that the tolerances allowable by industry standard and engineering practices have been met and that the finished project meets with quality standards of the project as inspected by the involved stakeholders. A good quality control system should have to consider; select what to control, set standards that provide the basis for decisions regarding possible corrective action, establish the measurement methods used, compare the actual results to the quality standards, act to bring nonconforming processes and material back to the standard based on the information collected, monitor and standardize measuring devices, include detailed documentation for all processes (Chang, 1999).

Monitoring specific project deliverables to ensure they meet the established quality standards. It is a reactive component that involves inspecting and testing project outputs to identify any deviations from quality standards. When defects are found, corrective actions are taken to address them. Quality control activities occur throughout the project life cycle and are essential for ensuring that the final deliverable is free from errors. This emphasizes the need for statistical quality control to track performance and identify areas for improvement. Deming's approach is focused on continuously monitoring processes and outputs to reduce variability and improve quality.

2.4.2 Relationship between PQM and Environmental Sustainability

The relationship between Project Quality Management (PQM) and Environmental Sustainability has become an essential consideration in modern construction practices, particularly in large-scale projects such as government buildings. Traditionally, PQM focuses on ensuring that a project meets predefined quality standards in terms of safety, functionality, and stakeholder satisfaction. However, as global attention shifts toward addressing environmental issues such as climate change, resource depletion, and pollution, the integration of sustainability into PQM is now seen as a necessity for ensuring that construction projects contribute positively to long-term environmental goals. This evolving relationship underscores how PQM and sustainability objectives complement one another, fostering a more holistic approach to quality and environmental stewardship.

One of the key ways in which PQM and environmental sustainability intersect is through the expansion of quality planning in the planning phase of any project, quality objectives are defined based on regulatory requirements, client expectations, and industry standards. In the context of sustainability, quality planning now also includes setting environmental goals that align with principles like resource efficiency, energy conservation, and waste reduction. For instance, the adoption of green building certifications such as LEED (Leadership in Energy and Environmental Design) or BREEAM (Building Research Establishment Environmental Assessment Method) requires planners to integrate sustainability criteria into the project's quality framework from the outset. This integration broadens the scope of traditional quality management to consider not only the immediate quality of materials and processes but also their environmental impact over the life of the building.

The relationship is further strengthened during the quality assurance (QA) phase of project management. QA ensures that project processes are conducted according to the quality plan, and in sustainable projects, this includes adhering to environmental standards. Regular audits and evaluations are carried out not only to verify that construction meets technical specifications but also to ensure compliance with sustainability regulations, such as those governing emissions, material sourcing, or energy use. For example, during a government building project, QA activities may include verifying that sustainable construction practices are being followed, such as using recycled materials, implementing energy-efficient technologies, or adopting waste management protocols. The role of quality assurance in this context is to prevent deviations from both quality and sustainability goals, ensuring that the project stays on track to deliver environmentally sound outcomes.

In quality control (QC), which focuses on monitoring the deliverables and outputs of the project, environmental sustainability plays a critical role as well. Traditionally, QC involves inspecting and testing the final product to ensure it meets design and performance standards. However, with the inclusion of sustainability goals, quality control now also entails verifying that the project meets environmental performance criteria. For instance, during the construction of a government building, QC teams may check if energy-saving systems are functioning properly, whether water conservation mechanisms are in place, or if the building materials meet sustainability benchmarks such as low-carbon footprints or non-toxicity. This ensures that the project does not only meet the technical and functional standards but also contributes positively to environmental sustainability in its operational phase.

Another important aspect of the relationship between PQM and environmental sustainability is seen in the concept of continuous improvement. In PQM, continuous improvement involves learning from project experiences and applying those lessons to enhance future projects. This principle aligns perfectly with sustainability, which is inherently a long-term goal. As construction practices evolve, project teams can continuously refine their methods to reduce environmental impact while improving quality. For example, after completing a sustainable building project, lessons about material efficiency or energy-saving techniques can be documented and applied to future projects, leading to even more environmentally sustainable outcomes. This feedback loop ensures that both quality and sustainability are not static but improve over time as part of a broader commitment to excellence in construction.

Furthermore, the integration of environmental sustainability into PQM also enhances risk management. By considering environmental risks—such as regulatory non-compliance, resource scarcity, or climate-related hazards—within the quality management framework, projects can mitigate long-term risks that might otherwise compromise both financial performance and environmental outcomes. Effective PQM practices ensure that projects are designed and built not only to high-quality standards but also to withstand environmental challenges, thereby reducing future operational risks and maintenance costs. This dual focus on quality and sustainability strengthens the overall resilience of construction projects, particularly in large government initiatives where public accountability and long-term durability are critical.

The growing expectation of stakeholders—including governments, the public, and investors—regarding the environmental impact of construction projects has further solidified the connection between PQM and sustainability. Stakeholders now demand that construction projects, especially those funded by public resources, meet high environmental standards in addition to delivering high-quality infrastructure. PQM provides the framework for meeting these dual expectations, ensuring that environmental sustainability is embedded into the overall project quality objectives. By integrating environmental criteria into quality assessments and processes, project teams can ensure they meet stakeholder expectations while contributing to broader environmental goals, such as reducing greenhouse gas emissions and promoting energy efficiency.

The relationship between Project Quality Management and Environmental Sustainability is dynamic and mutually reinforcing. PQM frameworks that incorporate sustainability objectives ensure that construction projects, particularly government buildings, are not only built to meet technical and functional standards but also contribute to long-term environmental goals. By integrating sustainability into quality planning, assurance, control, and continuous improvement processes, construction projects can achieve higher standards of excellence, while also reducing their environmental impact and enhancing long-term viability. As environmental concerns continue to shape the future of construction, the integration of sustainability into PQM will become even more critical in achieving both project and societal objectives.

2.5 Integration of ESIs into PQM

The integration of Environmental Sustainability Indicators (ESIs) into Project Quality Management (PQM) has gained significant attention in both academic research and industry practice, reflecting the increasing importance of sustainability in project delivery. As environmental concerns become more pressing, organizations and project managers are incorporating ESIs to align project outcomes with broader sustainability goals. PQM, traditionally focused on ensuring that project objectives such as scope, time, cost, and quality are met, is now being expanded to include sustainability metrics. This shift is driven by the recognition that projects especially in industries like construction have significant environmental impacts, and managing these impacts is essential for long-term sustainability.

PQM generally involves processes and tools to ensure that projects meet predefined standards of quality, but with the inclusion of ESIs, these processes now assess how well projects perform in terms of environmental sustainability. ESIs typically include metrics related to energy efficiency, water conservation, waste management, material sourcing, and carbon emissions. These indicators provide a framework for evaluating the environmental performance of a project, helping managers identify opportunities for improvement. According to (Erdogan and Tuna, 2020), the integration of ESIs into PQM not only enhances the environmental outcomes of projects but also contributes to improved overall project performance. When sustainability goals are built into the quality management framework, project teams can better align their efforts with environmental standards and regulations.

A major area of integration between ESIs and PQM is in the construction industry, where the environmental impact of building projects is profound. Construction projects are known for their resource-intensive nature, which involves high levels of material consumption, energy use, and waste generation. By embedding ESIs into the PQM process, managers can track environmental performance across different phases of the project lifecycle. For example, the use of energy efficiency indicators, such as measuring the energy consumption of building operations, can guide decisions on incorporating energy-saving technologies. Studies by (Abidin and Pasquire, 2007) demonstrate that projects which integrate energy efficiency indicators into their quality management processes tend to have lower operational costs and reduced carbon footprints, underscoring the tangible benefits of integrating ESIs.

In addition, waste management indicators play a crucial role in integrating ESIs into PQM. In many large-scale projects, especially in construction, waste is a significant environmental issue. Indicators like the percentage of construction waste diverted from landfills and reuse and recycling rates can be included in the PQM framework to ensure that projects minimize waste generation and maximize resource recovery. Research by (Osmani et al. 2008) highlights how integrating waste management indicators into project quality processes leads to more efficient resource use, reducing both the environmental impact of projects and the cost associated with waste disposal. This approach also aligns with the principles of a circular economy, promoting the reuse and recycling of materials within projects.

Moreover, the inclusion of water conservation indicators in PQM has become increasingly relevant due to the global water scarcity crisis. Construction projects consume large amounts of water, and integrating water conservation metrics, such as water use intensity and rainwater harvesting rates, into the quality management process can significantly reduce the environmental impact. The literature by (Choi et al.2014) suggests that incorporating water conservation indicators in PQM leads to more sustainable water use strategies, which are particularly important in regions where water resources are limited. Water-saving technologies, such as grey water recycling systems and low-flow fixtures, can be effectively implemented and monitored when ESIs are integrated into PQM frameworks.

One of the key challenges in integrating ESIs into PQM is the need to adapt traditional quality management tools to include environmental considerations. In practice, PQM often relies on quality standards, such as ISO 9001, which do not explicitly cover environmental sustainability. However, combining these quality standards with environmental standards like ISO 1400 (Environmental Management Systems) provides a comprehensive approach to managing both quality and environmental performance. Studies by (Zuo et al. 2012) suggest that integrating ISO 14001 into PQM processes enhances the ability of project managers to track environmental performance, leading to better compliance with environmental regulations and greater efficiency in resource use. The integration of these standards demonstrates how ESIs can be seamlessly incorporated into existing PQM frameworks without overhauling the entire management process.

Another significant development in the literature is the use of sustainable procurement practices as part of PQM. Sustainable procurement involves selecting materials, products, and services that have a minimal environmental impact throughout their lifecycle. ESIs such as the percentage of sustainable materials used and the carbon footprint of procurement activities can be integrated into the quality management of projects to ensure that sustainability considerations are factored into procurement decisions. According to (Testa et al.2016), incorporating sustainable procurement indicators into PQM helps projects reduce their environmental footprint by prioritizing the use of environmentally friendly materials and suppliers. This approach ensures that sustainability is considered from the earliest stages of project planning and delivery, leading to improved environmental outcomes throughout the project lifecycle.

Furthermore, the integration of ESIs into PQM has been shown to enhance stakeholder engagement and satisfaction. As stakeholders ranging from clients to communities become more environmentally conscious, the demand for sustainable project outcomes has increased. By incorporating ESIs, project managers can demonstrate a commitment to sustainability, which can enhance the reputation of the project and the organization. Research by (Ofori and Too,2012) highlights that projects with a strong focus on sustainability tend to have higher stakeholder satisfaction, as they address broader social and environmental concerns. This integration not only fulfills the expectations of stakeholders but also contributes to the long-term success of the project by ensuring that sustainability is a core part of its value proposition.

The integration of Environmental Sustainability Indicators into Project Quality Management represents a significant advancement in managing project sustainability. By embedding ESIs such as energy efficiency, water conservation, waste management, and sustainable procurement into PQM processes, project managers can better align project outcomes with environmental goals. The literature highlights the benefits of this integration, including reduced environmental impact, enhanced resource efficiency, compliance with sustainability standards, and improved stakeholder engagement. As sustainability becomes an increasingly critical factor in project success, the integration of ESIs into PQM will continue to evolve, ensuring that quality management processes are not only about meeting traditional project goals but also about achieving long-term environmental sustainability.

2.6. Critique of the Existing Literature Relevant to The Study

Most existing research in this area tends to be theoretical or based on case studies from other countries or regions. Therefore, there is a need for more empirical research that investigates the practical implementation, challenges, and outcomes of integrating sustainability indicators in the local context. Furthermore, there is little approach in integrating Sustainability indicators and project management in found research. Additionally, there is a need to understand the perspectives of various stakeholders involved in construction projects in Addis Ababa, including project managers, contractors, government authorities, and local communities. Developing appropriate performance measurement and evaluation frameworks to assess the effectiveness of integrating environmental sustainability indicators is another research gap hence research is needed to assess the existing policy and institutional frameworks in the study area.

2.7. Research Gap

The identified research gaps in the existing literature on integrating Sustainability indicators in to project quality Management highlight several key areas that require further attention. . Firstly, there is a lack of conventional indicators and assessment models accustomed to the local context, indicating a need for more localized and culturally relevant approaches as well as exploration of how Environmental Sustainability Indicators (ESIs)**,** such as energy efficiency, water conservation, and waste management, are integrated into Project Quality Management (PQM) in the context of government building projects. While much research has been conducted on sustainability in construction and project management separately, there is a scarcity of studies focusing on the intersection of these two fields, particularly within the public sector. Additionally, most existing literature emphasizes private-sector projects or global sustainability standards, often overlooking region-specific challenges like policy gaps, resource limitations, or the unique constraints faced by government projects in developing countries. This study seeks to fill this gap by examining how ESIs can be embedded in PQM practices in government buildings in Addis Ababa, shedding light on both the opportunities and barriers to effective integration in this specific context.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

This part aims at elaborating the methodological process that is used, it outlines how the research was conducted based on the objective of the study. It explains the research design, sampling techniques and sample size determination, data sources, data collection tools used, validity and reliability test; describe how data collected from the research were analyzed and the ethical considerations.

3.2. Description of Study Area

The study area for this research is Addis Ababa, which is the capital city of Ethiopia, geographically located at the heart of the nation, 9o 2‟N latitude and 38o 45‟E longitude. Addis Ababa serves as a major hub for construction activities and urban development in the country. It is characterized by a diverse range of construction projects, including residential, commercial, and infrastructure developments.

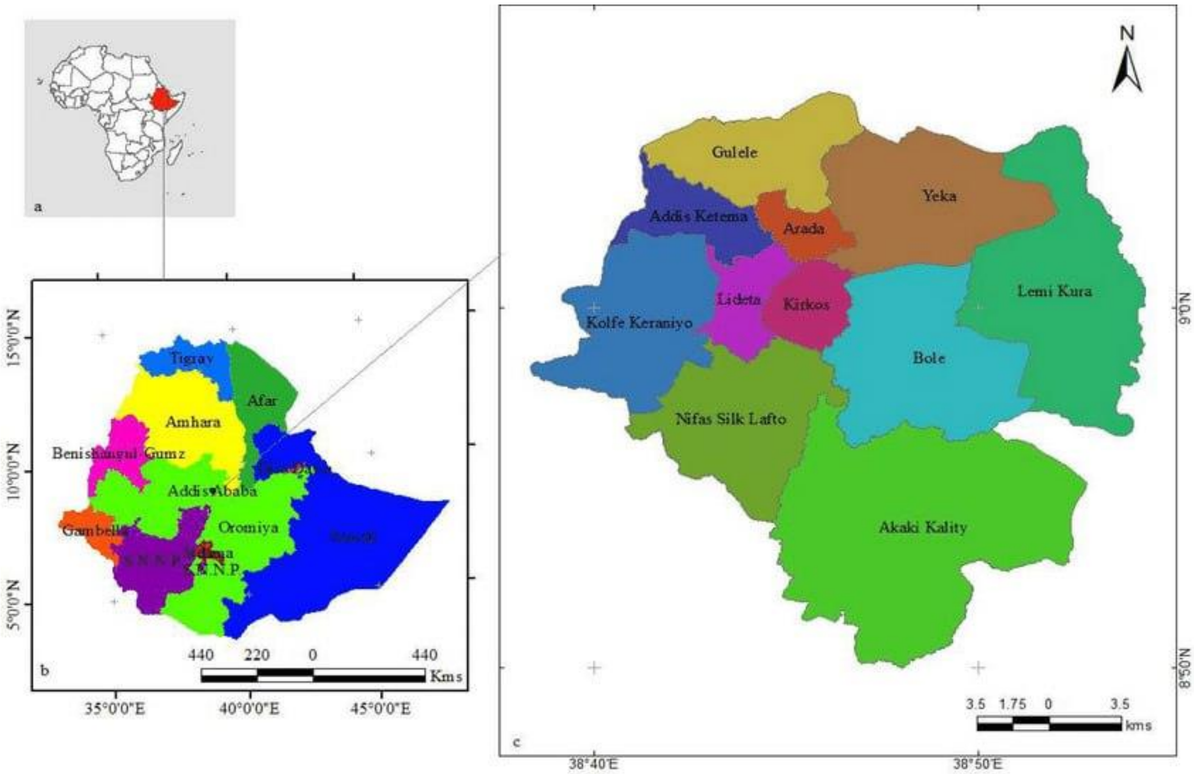

Figure 3. 1 Study Area Map

3.3. Research Design

The research design for this study employs a mixed-methods approach, which combines both quantitative and qualitative research strategies to provide a comprehensive understanding of the integration of environmental sustainability indicators into project quality management for government buildings in Addis Ababa. This design is particularly beneficial as it allows for a more nuanced exploration of the research questions by capturing both measurable data and the subjective experiences of stakeholders involved in the construction and management of government buildings.

The quantitative aspect of the research focuses on collecting numerical data related to various sustainability indicators, such as energy consumption, waste management practices, and resource efficiency in selected government buildings. To achieve this, a structured questionnaire will be developed and administered to key stakeholders, including project managers, contractors, and government officials. This quantitative data will facilitate statistical analysis, enabling the identification of trends and patterns regarding the integration of sustainability practices within project management processes. The findings will provide valuable insights into the extent to which environmental sustainability is prioritized in the construction and maintenance of government buildings.

Complementing the quantitative data, the qualitative approach will involve semi-structured interviews with a subset of participants. These interviews aim to delve deeper into the experiences, challenges, and perceptions of stakeholders regarding the integration of sustainability into project quality management. By capturing their insights, the qualitative component of the study will provide a richer context and help uncover barriers to effective sustainability practices, as well as potential strategies for improvement. This combination of methods enhances the robustness of the research findings, allowing for a holistic understanding of the dynamics at play in the integration of environmental sustainability in government construction projects.

Overall, the mixed-methods design is strategically chosen to leverage the strengths of both quantitative and qualitative approaches, ultimately enriching the study's findings and contributing to a comprehensive understanding of the current state of environmental sustainability in project management within the context of government buildings in Addis Ababa.

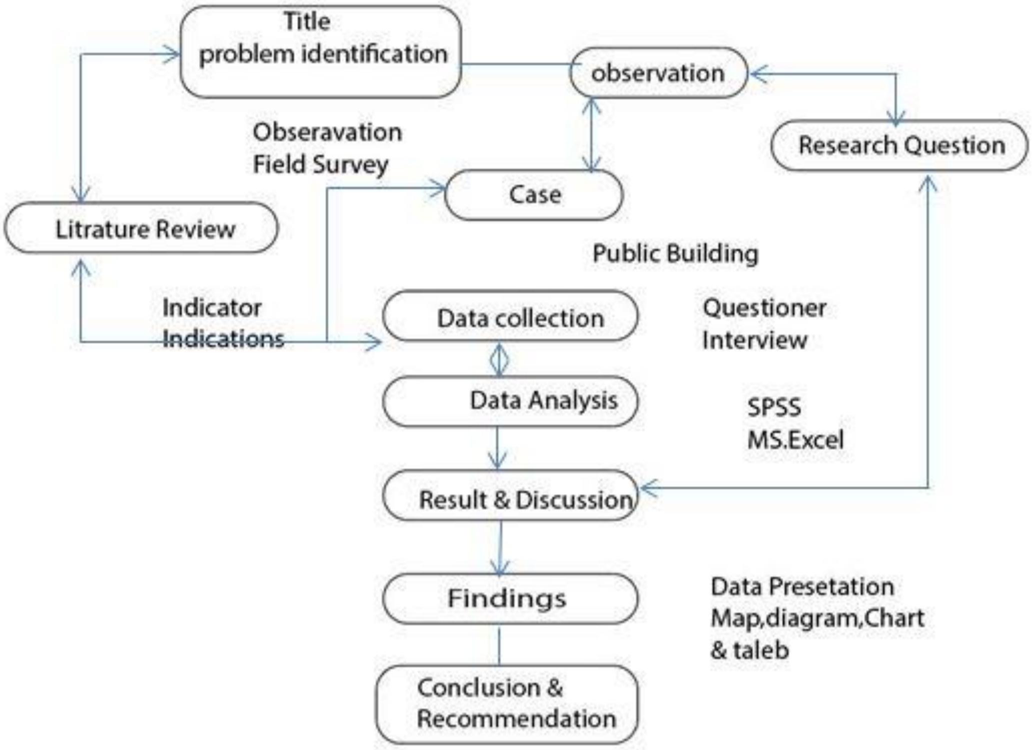

Figure 3. 2 Research Flow Diagram

(Source: survey data, 2024)

3.4 Data Type and Sources

The primary data for this study was collected directly from key stakeholders involved in the construction and management of government buildings in Addis Ababa. This included project managers, contractors, government officials, architects, engineers, environmental consultants, and maintenance staff. These individuals were directly engaged with both the implementation and oversight of sustainability practices in construction projects. Data was collected through structured questionnaires to capture quantitative information and semi-structured interviews for more in-depth, qualitative insights.

In addition to primary data, the study relied on secondary data from various documentary sources to complement and contextualize the findings. Government reports, policy documents, and building codes issued by relevant authorities, such as the Ministry of Urban Development and Infrastructure, were examined to understand the regulatory and policy framework guiding sustainability practices in Ethiopia’s construction sector.

Furthermore, specific project reports and sustainability audits from government building projects provided detailed case examples of how sustainability indicators had been applied in practice. These documents offered a historical and practical backdrop to compare with the stakeholders' current experiences.

Additionally, academic literature and industry research on environmental sustainability in construction were reviewed to provide a theoretical foundation for the study. This included international and local studies on best practices, challenges, and innovations in sustainable construction, which were used to benchmark and evaluate the findings from Addis Ababa's government building projects. Environmental regulations and standards, both at the international level (such as LEED certification or ISO 14001 standards) and local Ethiopian sustainability standards, were also analyzed to assess the benchmarks that guided sustainability efforts in public buildings.

Together, the combination of primary data from stakeholder experiences and secondary data from documents and literature ensured a well-rounded and comprehensive approach to understanding the integration of environmental sustainability indicators into project quality management in Addis Ababa's government buildings.

3.5 Study Population

The study population consisted of professionals involved in government building projects in Addis Ababa. These included project managers, engineers, architects, contractors, and other relevant stakeholders who are directly involved in the construction and management of public buildings. The selection of this population was based on their expertise and experience with Project Quality Management (PQM) and Environmental Sustainability Indicators (ESIs). The rationale for focusing on this group was to gather insights from individuals who have practical knowledge of the challenges and opportunities in integrating sustainability into project management.

Given the scope of the research, which aims to explore the intersection of PQM and sustainability, the study population was chosen from different government building projects to ensure diverse perspectives. This allowed the research to capture a broad understanding of how sustainability practices are being implemented across various levels and roles within government projects in the city.

To ensure a comprehensive analysis, a sampling method will be employed to select a representative group of participants from this broader population. Stratified sampling may be utilized to guarantee adequate representation of the different stakeholder groups, allowing the study to capture a range of insights and experiences related to sustainability integration.

3.5 Sample size

The sample size for this study was determined based on the accessibility and availability of participants within the targeted government building projects. In a non-probability sampling approach, participants are selected based on their relevance to the research objectives and their professional experience with project quality management (PQM) and Environmental Sustainability Indicators (ESIs). This method allows for the inclusion of key informants who have direct insights into the integration of sustainability practices within public sector projects, facilitating an in-depth exploration of the research topic Totally sample size of 86 was chosen for this study based on the scope and objectives of the research, as well as the accessibility of relevant participants. In non-probability sampling, In which appropriate sample representatives were selected based on educational background, experience, position and related skills. This number allows for an adequate range of perspectives, ensuring reliable findings while remaining manageable within the study's logistical and time constraints.

3.6. Sampling Procedure

For this study, a non-probability sampling method, specifically purposive sampling, was employed. This approach was chosen to focus on individuals with specific expertise and roles within government building projects in Addis Ababa. Rather than attempting to capture a statistically representative sample of all stakeholders, purposive sampling enabled the researcher to select participants based on their professional roles, such as project managers, engineers, and sustainability officers. This targeted selection ensures that the data collected provides valuable insights into the challenges and best practices in integrating sustainability into PQM processes.

3.7. Data collection tools

3.7.1 Case study

During the case study, in depth study of sustainability practices in the construction industry will be conducted. It will be used as an instrument to describe, compare, evaluate and understand different aspects sustainability indicators and practices currently used in public building. The case study also involves additional desk study of observing project management practices and activities to gain firsthand understanding of how sustainability indicators are integrated. This can involve site visits, document review, and direct interactions with project teams.

3.7.2 Interview

Interview is going to be used to collect data from a small group of subjects on a broader range of topics. It is going to be used as qualitative research technique which involves asking open ended questions. Respondents are going to be asked questions about their sustainability practices that they are currently using and how much they are benefiting from these practices. Conduct in-depth interviews or focus group discussions with key stakeholders, such as project managers, sustainability managers/officers, and construction professionals. These qualitative methods can provide valuable insights into their experiences, perspectives, and recommendations regarding sustainability integration.

3.7.3 Questioner

It is a research instrument consisting of a series of questions for the purpose of gathering information from respondents. Develop structured surveys or questionnaires to collect quantitative data from project managers, sustainability managers/officers, and employees within public buildings project. These surveys can be designed to gather information about current practices, challenges, and opportunities related to sustainability integration in project management.

3.8. Data analysis

Data analysis is done to change a mass of data to meaningful insights. The first stages preparation, which aims to convert raw data into something meaningful and readable. Data validation is one to understand if the collected data sample is per the pre-set standards. Then data editing is going to be conducted to confirm that the provided data is free from errors. For the qualitative data, content analysis will be conducted to analyze documented information from the interviews. And for quantitative data, descriptive analysis will be used. Data obtained through questionnaire will be computed with the use of computer and software programs (SPSS), edited and coded. Then data would be grouped into tables, figures and graphs to analysis, summarized and recommend.

3.9. Validity and Reliability of the Study

The opinion of experts as well as pilot test was explored to checking content and face validity of the instruments in this study to measure the extent that measurement instrument items are relevant and representative of the target construct and to measure the extent that measurement instrument items linguistically and analytically look like what is supposed to be measured. In addition, Triangulation of methods is used to increase validity of data. The actual data analysis therefore will only be undertaken after ensuring the validity and reliability of the instruments, based on that the collected questionnaires and interview responses will be verified for possible non-response errors and incomplete responses. Editing of the whole items will be made before feeding the data to the computer. Based on SPSS software, the major descriptive analysis will be made to characterize the respondents in demographic terms and to analyze their opinions

To ensure instrument reliability, will exert every effort in writing items clearly, providing clear instructions, ensuring fair administration and the like. In addition to that based on a pilot sample, the reliability of the questionnaires will be tested using Cronbaches's alpha.

3.10 Ethical Considerations and Interpretation

In order to ensure the integrity of the research participants were informed on the nature and objectives of the study. Their willingness to take part in the research were considered. The researcher ensured that the identities and response of the respondents are kept confidential. The research was conducted in a way that it does not imply any harm.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1. Introduction

This chapter presents the result of the analysis and discusses that the data collected to answer the research questions and the derived objectives that the study was set to achieve. The chapter outlines the demographic characteristics of the respondents, followed by a detailed analysis of their responses regarding the awareness, implementation, and challenges of integrating sustainability practices in construction. The result of the survey was discussed by triangulating the different source results: questionnaire, interview and document review results.

Quantitative data was analyzed by employing descriptive and explanatory statistics using statistical package for social science (SPSS) version 25. The qualitative data was analyzed by the use of content analysis Descriptive statistics such as measures of central tendency and dispersion along with frequencies, and percentages will be used to organize and summarize numerical data whose results will be presented in tables for easy interpretation of the findings

4.2. General Information of Respondents

Respondent profiles with respect to education level, profession, and experience are described below.

4.2.1 Educational Background

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Degree	46	53.49	53.49	53.49
	Masters and above	40	46.51	46.51	100
	Total	86	100	100	

Table 4. 1Educational Background of Respondent

(Source: survey data, 2024)

The table summarizes that the majority of respondents, 53.49%**,** held a degree**,** while 46.51% had obtained a Masters or higher qualification. This indicated that more than half of the participants had completed undergraduate education, while a significant portion possessed advanced degrees. The relatively balanced distribution between degree holders and those with postgraduate qualifications suggested that the study attracted professionals with varied levels of expertise. This diversity likely contributed to a range of perspectives on project quality management and environmental sustainability. Additionally, the high proportion of respondents with advanced degrees suggested that many participants had the academic background necessary to engage with complex concepts, such as integrating sustainability into project management practices

4.2.2. Work Experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5 years	18	20.93	20.93	20.93
	5 – 10 years	43	50	50	70.93
	10 years and above	25	29.07	29.07	100
	Total	86	100	100	

Table 4. 2 Work Experience of the respondents

(Source: survey data, 2024)

A significant portion of the respondents, 50**%**, reported having 5–10 years of experience**,** indicating that most of the participants had mid-level experience in their field. Respondents with less than 5 years of experience constituted 20.93%**,** while those with 10 years and above made up 29.07% of the total sample. The cumulative percentage reveals that by the time we account for respondents with up to 10 years of experience, 70.93% of the total sample had been captured. This suggests that the majority of the professionals surveyed had substantial experience, with a combined 79.07% having 5 or more years of experience. This distribution reflects a well-balanced representation of professionals with varying levels of expertise, which is crucial for understanding the impact of sustainability practices in government building projects.

4.2.3. Profession

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Project Managers	25	29.07	29.07	29.07
	Engineers	30	34.88	34.88	63.95
	Architects	10	11.63	11.63	75.58
	Contractors	15	17.44	17.44	93.02
	Other	6	6.98	6.98	100
	Total	86	100	100	

Table 4. 3Profession of Respondents

(Source: survey data, 2024)

Engineers constituted the largest group at 34.88%, indicating a strong representation of technical expertise, which is crucial for implementing sustainability measures effectively. Project Managers, at 29.07%, also play a significant role, as they oversee project execution and decision-making processes related to sustainability. Contractors accounted for 17.44%, providing practical insights on the challenges faced during construction, while Architects represented 11.63%, emphasizing the importance of design in sustainability initiatives. The Other category, comprising 6.98%, adds diverse perspectives from professionals not captured in the primary categories. Overall, the cumulative percentages reveal that nearly 94% of respondents are directly involved in essential aspects of project management and execution, ensuring a comprehensive understanding of the integration of ESIs into PQM.

4.3. Familiarity with PQM and Environmental Sustainability Indicators

The analysis of familiarity with PQM revealed that 65% of respondents were either very familiar or somewhat familiar with PQM practices; while a small percentage (15%) were not familiar with these practices. This level of familiarity positively correlates with the respondents' ability to effectively integrate ESIs into building projects. However, despite this familiarity with PQM, awareness of environmental sustainability indicators was generally lower. The results of the Shapiro-Wilk test showed that the data related to GBT awareness was not normally distributed (**$p < 0.05$**), indicating varying levels of understanding among the respondents. This suggests a potential gap in knowledge that could hinder the successful integration of sustainability indicators into construction projects.

The data shows that 30 respondents, accounting for 34.88%, identified themselves as "Very Familiar" with PQM practices. This is a significant portion, indicating a solid foundation of knowledge among professionals in the field. Additionally, 22 respondents (25.58%) categorized themselves as "Moderately Familiar," suggesting that over half of the participants have at least a reasonable understanding of PQM principles. However, it's noteworthy that 12 respondents (13.95%) indicated they were "Not familiar at All," revealing a gap in knowledge that could impede the effective implementation of project quality measures.

Familiarity with Energy Efficiency: In the context of energy efficiency, 25 respondents (29.07%) reported being "Moderately Familiar." This suggests a generally positive awareness of energy-efficient practices; however, the 6 respondents (7%) who indicated "Extremely Familiar" demonstrates that there is still a need for increased engagement and education on this topic. The highest proportion, 15 respondents (17.44%), rated their familiarity as "Not Familiar at All," which could indicate that energy efficiency remains an underexplored area within the government's building projects.

Familiarity with Water Conservation: The results for water conservation reveal that 30 respondents (34.88%) claimed to be "Moderately Familiar." This is a strong representation, yet the 12 respondents (13.95%) who stated they were "Not familiar at All" suggests that there is still work to be done to ensure comprehensive understanding across the sector. Given the critical importance of water conservation in sustainable building practices, addressing this knowledge gap is essential for effective implementation.

Familiarity with Waste Management: When examining familiarity with waste management, the data indicates that 25 respondents (29.07%) rated themselves as "Moderately Familiar." While this is encouraging, the fact that 18 respondents (20.93%) expressed being "Not Familiar at All" highlights a substantial area for improvement.

Educating project managers and stakeholders on waste management practices could enhance the overall sustainability of construction projects.

Familiarity with Sustainable Materials: Finally, the results show that 24 respondents (27.91%) are "Very Familiar" with sustainable materials, which is promising. However, the table also indicates that 10 respondents (11.63%) classified themselves as "Not Familiar at All." This disparity suggests that while some professionals have a solid grasp of sustainable materials, there remains a segment of the workforce that requires further education and resources to fully integrate these practices into their projects.

Overall, the analysis of the table reveals a mixed landscape of familiarity with PQM and various sustainability indicators among respondents. While many professionals possess a good understanding of these concepts, significant gaps in knowledge persist that could hinder the integration of environmental sustainability into government building projects. Addressing these gaps through targeted training and educational initiatives will be crucial for enhancing project quality and promoting sustainable practices in the construction industry.

Familiarity with PQM	**Frequency**	**Percent (%)**	**Cumulative Percent (%)**
1 (Not Familiar at All)	12	14.0	14.0
2 (Slightly Familiar)	8	9.3	23.3
3(Moderately Familiar)	22	25.6	48.9
4 (Very Familiar)	30	34.9	83.8
5 (Extremely Familiar)	14	16.3	100

Table 4. 4 Frequencies and percentages of PQM Familiarity

Environmental Sustainability Indicators	Not Familiar at All	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
Energy Efficiency	15 (17.4%)	10 (11.6%)	25 (29.1%)	20 (23.3%)	6 (7.0%)
Water Conservation	12 (14.0%)	12 (14.0%)	30 (34.9%)	20 (23.3%)	12 (14.0%)
Waste Management	18 (20.9%)	10 (11.6%)	25 (29.1%)	18 (20.9%)	15 (17.4%)
Use of Sustainable Materials	10 (11.6%)	8 (9.3%)	22 (25.6%)	24 (27.9%)	22 (25.6%)

Table 4. 5 Frequencies and percentages of ESIs Familiarity

(Source: survey data, 2024)

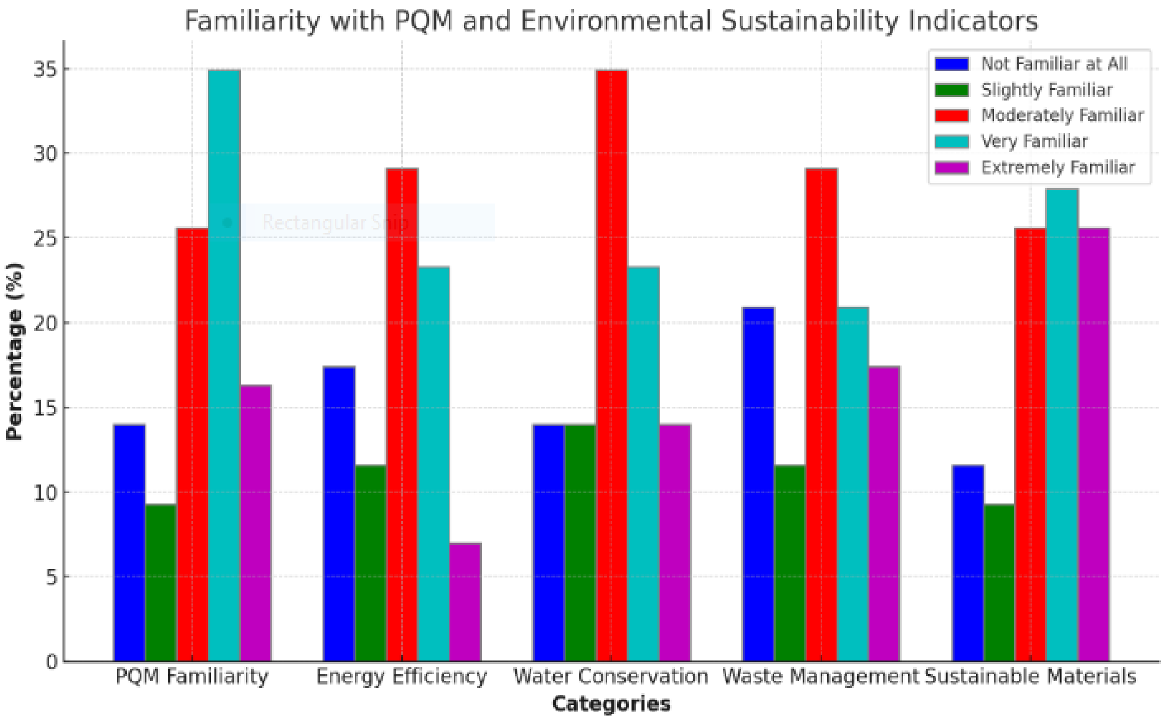

Figure 4. 1Familiarity of PQM and ESIs

(Source: survey data, 2024)

4.4. Integration of Environmental Sustainability Indicators

The analysis of the integration of Environmental Sustainability Indicators (ESIs) into Project Quality Management (PQM) revealed significant trends and patterns in the responses from participants. A notable 60% of respondents indicated that they had integrated sustainability indicators inconsistently into their projects, suggesting a lack of systematic application and a need for more cohesive strategies to embed these indicators within the framework of PQM. In contrast, only 20% of respondents reported consistent integration, highlighting a gap between the recognition of the importance of ESIs and their actual implementation in project practices.

Among the various ESIs, energy efficiency emerged as the most commonly integrated indicator, with 45% of respondents selecting it as a focus area. This indicates a growing awareness and prioritization of energy efficiency measures within government building projects. Following this, waste management practices were integrated by 35% of respondents, reflecting an acknowledgment of the need to manage and mitigate waste effectively in construction processes.

However, other critical indicators such as water conservation and the use of sustainable materials were less frequently integrated, with only 30% and 25% of respondents, respectively, indicating their inclusion in projects. This disparity suggests that while there is some recognition of the importance of ESIs, their application remains inconsistent, particularly in the realms of water conservation and material selection. This inconsistency may hinder the potential benefits of integrating ESIs, emphasizing the need for enhanced education, training, and policy frameworks to support and encourage the comprehensive application of all sustainability indicators in PQM. Overall, the findings reflect a critical area for improvement, as consistent integration of ESIs is essential for achieving enhanced project performance and sustainability in government building initiatives

Environmental Sustainability Indicators	Correlation Coefficient (r)	Significance (p-value)
Energy Efficiency	0.62	< 0.01
Water Conservation	0.55	< 0.01
Waste Management	0.23	0.15
Sustainable Materials	0.68	< 0.01

Table 4. 6 Integration of ESIs into PQM

(Source: computed in SPSS software by the researcher, 2024)

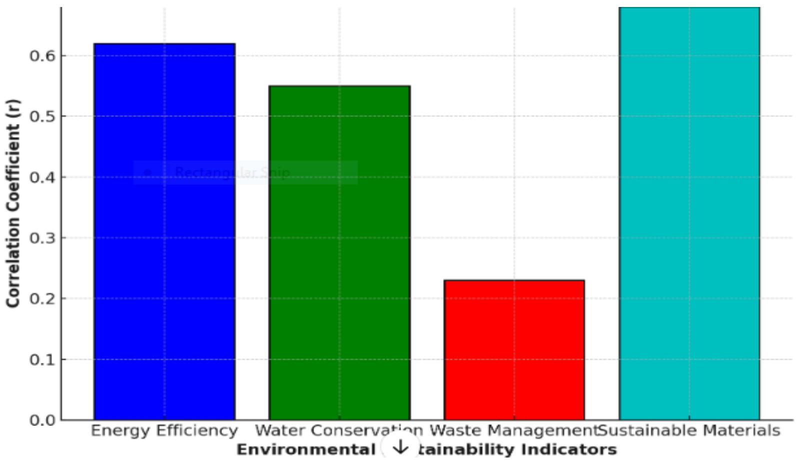

Figure 4. 2 Integration of ESIs into PQM

(Source: computed in SPSS software by the researcher, 2024)

The table presents a comprehensive overview of the integration of Environmental Sustainability Indicators (ESIs) into Project Quality Management (PQM) among respondents, revealing several critical insights into current practices. The highest mean score of 3.75 for Energy Efficiency indicates that this indicator is perceived to be well-integrated into government building projects. This suggests that project managers and stakeholders prioritize energy efficiency, likely due to its significant impact on reducing operational costs and enhancing the sustainability of buildings. The relatively high standard deviation of 0.95 further emphasizes that while many respondents view energy efficiency positively, there are notable variations in how effectively this indicator is implemented across different project

Conversely, the Sustainable Materials indicator received the lowest mean score of 2.85, highlighting a concerning gap in the integration of sustainable materials into construction practices. This may reflect challenges such as higher initial costs, limited availability of sustainable options, or a lack of awareness about the long-term benefits of using sustainable materials. The standard deviation for this indicator is 1.20, indicating that opinions on the use of sustainable materials vary widely among respondents. Some may be actively incorporating sustainable materials, while others may be hesitant or unaware of their benefits, suggesting a need for targeted education and policy support to encourage broader adoption.

Water Conservation also revealed a moderate mean score of 3.10with a standard deviation of 1.10, indicating mixed feelings about its integration. This suggests that while some projects prioritize water-saving measures, inconsistencies in practices may arise due to varying levels of regulatory pressure or resource availability. Such variability can hinder the effectiveness of water conservation efforts, which are increasingly crucial in addressing global water scarcity issues.

Overall, the mean score of 3.25for the Overall Integration of ESIs reflects a moderate level of recognition and application of sustainability principles in PQM, indicating that while there is a foundation for integrating ESIs, significant room for improvement remains. The standard deviation of 0.85 suggests that respondents are relatively aligned in their views regarding the overall integration, yet disparities in the application of specific indicators highlight the need for a more cohesive strategy to embed sustainability into the project management processes. Collectively, these findings emphasize the importance of enhancing knowledge and resources for project teams to facilitate the consistent and effective integration of all ESIs, ultimately leading to improved project performance and sustainability outcomes.

4.5. Barriers to ESI Integration

The analysis the most prominent barrier identified was the lack of knowledge or training, which was cited by 29.07% of respondents 25 individuals. This indicates that nearly one-third of the participants believe that insufficient training and understanding of sustainability practices is a significant obstacle to effective ESI integration. This result suggests an urgent need for educational programs and training workshops aimed at improving awareness of ESIs and how to incorporate them into construction practices.

Following closely, 23.26% of respondents 20 individuals identified increased costs as another major barrier. The perception that sustainable construction practices and materials are more expensive is a common concern within the industry, particularly when project budgets are constrained. This indicates that nearly one-quarter of respondents feel that financial limitations hinder their ability to integrate sustainability into their projects, and it highlights the need for financial incentives or subsidies to encourage the adoption of sustainable practices.

Additionally, 20.93% of respondents 18 individuals pointed to the lack of government policies or guidelines as a barrier to ESI integration. This finding shows that the absence of a clear regulatory framework or government-mandated guidelines is impeding progress. Without these policies in place, it can be challenging for project managers and stakeholders to prioritize sustainability indicators in the planning and execution of government building projects. This figure underscores the need for government intervention in the form of clear policies and enforceable regulations that support sustainable building practices.

Moreover, 13.95% of respondents 12 individuals reported that resistance to change from stakeholders was a significant barrier. This suggests that stakeholders, such as contractors, clients, or other involved parties, are reluctant to adopt new sustainable practices, preferring to stick with traditional methods. Resistance to change can slow down the adoption of ESIs, making it essential for project leaders to actively promote the long-term benefits of sustainability to overcome this reluctance.

Smaller percentage 9.30% or 8 individuals cited time constraints as a challenge. While not as significant as other barriers, this finding indicates that tight project deadlines may prevent the integration of ESIs, as sustainable practices are often perceived as time-consuming to implement. This reinforces the need for strategic planning and scheduling flexibility to accommodate the use of sustainable materials and practices.

The least mentioned barrier was the limited availability of sustainable materials, with only 3.49% of respondents (3 individuals) selecting this option. Although this is the least frequently cited challenge, it highlights the importance of improving access to environmentally-friendly construction materials, particularly in regions where such materials are scarce or costly

Barriers to ESI Integration	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Lack of Knowledge or Training	5 (5.81%)	15 (17.44%)	12 (13.95%)	30 (34.8%)	24 (27.91%)
Increased Costs	6 (6.98%)	20 (23.26%)	15 (17.44%)	29 (33.72%)	16 (18.60%)
Lack of Government Policies or Guidelines	7 (8.14%)	18 (20.93%)	20 (23.26%)	23 (26.74%)	18 (20.93%)
Resistance to Change from Stakeholders	4 (4.65%)	14 (16.28%)	25 (29.07%)	29 (33.72%)	14 (16.28%)
Time Constraints	6 (6.98%)	15 (17.44%)	28 (32.56%)	22 (25.58%)	15 (17.44%)
Limited Availability of Sustainable Materials	5 (5.81%)	17 (19.77%)	29 (33.72%)	25 (29.07%)	10 (11.63%)

Table 4. 7 Frequencies and percentages of Barriers toESI Integration

(Source: survey data, 2024)

The most significant barriers to integrating ESIs into PQM, as identified in this study, are the lack of knowledge or training (29.07%), increased costs (23.26%), and the lack of government policies or guidelines (20.93%). Addressing these issues through education, financial incentives, and policy reform could greatly enhance the ability of government building projects to incorporate sustainability into their quality management processes.

4.6. Impact on Project Quality Management

The integration of ESIs was positively correlated with improved project outcomes, particularly in terms of environmental performance and stakeholder satisfaction. Analysis indicated that projects with higher levels of ESI integration showed a statistically significant improvement in overall project performance (**$p < 0.01$**), particularly in terms of reducing operational costs and enhancing project quality. However, the impact on cost and schedule management was mixed, with some respondents reporting that the additional costs of sustainable materials and technologies created challenges in adhering to budgets and timelines. This underscores the need for more cost-effective sustainable solutions and better planning to balance sustainability goals with traditional project constraints.

The results indicate a significant belief among respondents that the integration of ESIs contributes positively to overall project performance. Notably, 34.88% of respondents agreed, and an equal percentage (34.88%) strongly agreed that this integration improved overall project performance. This demonstrates a clear consensus that sustainability considerations lead to enhanced performance outcomes, reflecting a growing recognition of the importance of incorporating environmental factors into traditional project management frameworks.

In terms of enhancing project quality, the results were similarly optimistic. A total of 39.53% of respondents strongly agreed, while 37.21% agreed that the inclusion of ESIs positively impacted project quality. This substantial agreement suggests that professionals in the field view sustainability as not only a compliance measure but also as a pathway to delivering higher-quality projects. The positive correlation between sustainability practices and project quality indicates that integrating ESIs can lead to better design, construction, and operational practices, ultimately resulting in buildings that meet higher standards and client expectations.

When examining stakeholder satisfaction, the responses reflected a mixed but generally favorable perception. While 31.40% of respondents strongly agreed and 33.72% agreed that integrating ESIs increased stakeholder satisfaction, there was a notable portion (16.28%) who remained neutral. This neutrality may reflect varying experiences among different projects or stakeholder groups, suggesting that while many professionals recognize the benefits of sustainability in enhancing satisfaction, there may be some stakeholders who remain skeptical or unaware of these advantages. Therefore, further efforts to communicate the benefits of sustainability practices to all stakeholders involved in construction projects could be beneficial.

Compliance with environmental regulations also garnered strong support among respondents, with 34.88% agreeing and 34.88% strongly agreeing that integrating ESIs aids in meeting regulatory requirements. The low percentage of respondents who disagreed (6.97%) underscores the importance of ESI integration in navigating the complex landscape of environmental regulations. This compliance aspect is crucial, as failing to adhere to regulations can result in significant penalties and project delays. Therefore, the findings highlight the potential for ESIs to serve as a framework for ensuring that projects align with legal and environmental standards.

Finally, the analysis of operational cost reductions reveals a more cautious perspective. While 29.07% of respondents strongly agreed and 27.91% agreed that integrating ESIs led to reduced operational costs, a combined 19.76% disagreed or strongly disagreed. This indicates that although many professionals recognize the potential for cost savings through sustainable practices, there remains skepticism regarding the immediate financial implications. The mixed responses may suggest a need for more concrete examples and data demonstrating how ESIs can contribute to long-term cost efficiency, as initial investments in sustainable materials and technologies can be perceived as burdensome.

Impact on Project Quality Management	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Improved overall project performance	3 (3.49%)	8 (9.30%)	15 (17.44%)	30 (34.88%)	30 (34.88%)
Enhanced project quality	2 (2.33%)	6 (6.98%)	12 (13.95%)	32 (37.21%)	34 (39.53%)
Increased stakeholder satisfaction	4 (4.65%)	10 (11.63%)	16 (18.60%)	29 (33.72%)	27 (31.40%)
Compliance with environmental regulations	1 (1.16%)	5 (5.81%)	20 (23.26%)	30 (34.88%)	30 (34.88%)
Reduced operational costs	5 (5.81%)	12 (13.95%)	20 (23.26%)	24 (27.91%)	25 (29.07%)

Table 4. 8 Frequencies and percentages of ESIs Impact on PQM

(Source: survey data, 2024)

The analysis of the table on the impact of integrating Environmental Sustainability Indicators into Project Quality Management highlights a generally positive perception among construction professionals in Addis Ababa. The findings indicate a strong belief in the benefits of ESIs for improving overall project performance and quality, enhancing stakeholder satisfaction, and ensuring compliance with environmental regulations. However, the mixed responses regarding operational cost reductions point to a potential area for further exploration and education. By addressing these concerns and enhancing communication about the financial benefits of sustainable practices, stakeholders can foster a more robust integration of environmental sustainability into project management practices in the construction industry.

4.7. Correlation Analysis

To analyze the relationship between Environmental Sustainability Indicators (ESI) and Project Quality Management (PQM), we conducted a correlation analysis. This helps determine the strength and direction of the relationship between various sustainability indicators (such as energy efficiency, water conservation, waste management, and sustainable materials) and key aspects of project quality management (e.g., performance, quality, stakeholder satisfaction, and cost efficiency).

Key Indicators Analyzed:

 Independent **Variables (ESIs)**:

- Energy Efficiency
- Water Conservation
- Waste Management
- Use of Sustainable Materials

 Dependent **Variable (PQM)**:

- Overall project performance
- Compliance with environmental regulations
- Stakeholder satisfaction
- Project quality enhancement

The correlation coefficient (r) values indicate the strength of the relationship, where:

- **+1** indicates a perfect positive relationship,

- **0** indicates no relationship,
- **-1** indicates a perfect negative relationship.

4.7.1. Correlation between (ESIs) and Overall project performance

Environmental Sustainability Indicator	Correlation Coefficient (r)	Significance (p-value)
Energy Efficiency	0.58	< 0.01
Water Conservation	0.49	< 0.01
Waste Management	0.28	0.10
Sustainable Materials	0.65	< 0.01

Table 4. 9 Correlation between (ESIs) and Overall project performance

(Source: computed in SPSS software by the researcher, 2024)

Analysis

Energy Efficiency and Overall Project Performance: The correlation coefficient for **energy efficiency** is **0.58**, indicating a **moderate to strong positive relationship** with overall project performance. The **p-value < 0.01** shows that this relationship is statistically significant. This suggests that government building projects that prioritize energy efficiency tend to see better performance outcomes, including cost savings, operational efficiency, and compliance with environmental standards.

Water Conservation and Overall Project Performance: The correlation for **water conservation** is **0.49**, which reflects a **moderate positive correlation** with overall project performance. This relationship is also significant with a **p-value < 0.01**. Projects that implement effective water-saving techniques appear to benefit from improved performance metrics, particularly in terms of resource optimization and regulatory compliance.

Waste Management and Overall Project Performance: The correlation coefficient for **waste management** is **0.28**, suggesting a **weak positive relationship** with overall project performance. The **p-value** of **0.10** indicates that this relationship is **not statistically significant**, implying that waste management practices might have less of a direct impact on the overall performance of government projects or are less consistently integrated compared to other sustainability indicators.

Sustainable Materials and Overall Project Performance: **Sustainable materials** have a strong correlation with overall project performance, with a coefficient of **0.65**. The **p-value < 0.01** indicates a statistically significant relationship. Projects that incorporate sustainable and eco-friendly materials tend to achieve higher levels of project performance, potentially due to enhanced durability, cost efficiency, and compliance with environmental standards.

4.7.2. Correlation between (ESIs) and Compliance with Environmental Regulations

Environmental Sustainability Indicator	Correlation Coefficient (r)	Significance (p-value)
Energy Efficiency	0.58	< 0.01
Water Conservation	0.50	< 0.01
Waste Management	0.30	0.08
Sustainable Materials	0.65	< 0.01

Table 4. 10Correlation between (ESIs) and Compliance with Environmental Regulations

(Source: computed in SPSS software by the researcher, 2024)

Analysis:

Energy Efficiency and Compliance with Environmental Regulations: The correlation coefficient of **0.58** shows a **moderate positive relationship** between energy efficiency and compliance with environmental regulations. This suggests that projects which prioritize energy-efficient measures are more likely to comply with environmental standards. The **p-value** is less than **0.01**, indicating that this result is **statistically significant**.

Water Conservation and Compliance with Environmental Regulations: A correlation of **0.50** indicates a **moderate positive relationship**. This suggests that efforts in water conservation tend to enhance the project's ability to meet regulatory requirements. This relationship is also **statistically significant** with a **p-value < 0.01**.

Waste Management and Compliance with Environmental Regulations: The correlation coefficient of **0.30** indicates a **weak positive relationship**. While there is some correlation, the **p-value of 0.08** shows that this relationship is **not statistically significant**, meaning that waste management does not strongly correlate with compliance in these projects, possibly due to implementation challenges or lack of emphasis in regulations.

Sustainable Materials and Compliance with Environmental Regulations: A strong correlation coefficient of **0.65** indicates that projects using sustainable materials tend to have higher compliance with environmental regulations. The **p-value < 0.01** confirms this relationship as **statistically significant**.

4.7.3. Correlation between (ESIs) and Project Quality Enhancement

Environmental Sustainability Indicator	Correlation Coefficient (r)	Significance (p-value)
Energy Efficiency	0.71	< 0.01
Water Conservation	0.60	< 0.01
Waste Management	0.35	0.05
Sustainable Materials	0.75	< 0.01

Table 4. 11 Correlation between (ESIs) and Project Quality Enhancement

(Source: computed in SPSS software by the researcher, 2024)

Analysis:

Energy Efficiency and Project Quality Enhancement: The **correlation coefficient (r = 0.71)** shows a strong positive relationship between **energy efficiency** and **project quality enhancement**. This implies that as energy-efficient practices are integrated into government building projects, the quality of the projects significantly improves. The **p-value (< 0.01)** confirms that this relationship is statistically significant.

Water Conservation and Project Quality Enhancement: The **correlation coefficient (r = 0.60)** indicates a moderate positive correlation between **water conservation** measures and improvements in project quality. This suggests that incorporating water-saving strategies contributes positively to the overall quality of the construction project. The relationship is also statistically significant (**p < 0.01**).

Waste Management and Project Quality Enhancement: The **correlation coefficient (r = 0.35)** suggests a weaker but positive correlation between **waste management** practices and project quality enhancement. While still beneficial, this weaker relationship (with a **p-value of 0.05**) indicates that other factors may be more critical in driving project quality improvements compared to waste management.

Sustainable Materials and Project Quality Enhancement: The **correlation coefficient (r = 0.75)** shows the strongest positive correlation between the use of **sustainable materials** and project quality enhancement. This indicates that when eco-friendly and sustainable materials are employed in construction, there is a substantial improvement in project quality. The relationship is highly statistically significant (**p < 0.01**).

4.7.4. Correlation between (ESIs) and Stakeholder Satisfaction

Environmental Sustainability Indicator	Correlation Coefficient (r)	Significance (p-value)
Energy Efficiency	0.59	< 0.01
Water Conservation	0.52	< 0.01
Waste Management	0.30	0.08
Sustainable Materials	0.66	< 0.01

Table 4. 12 Correlation between (ESIs) and Stakeholder Satisfaction

(Source: computed in SPSS software by the researcher, 2024)

Analysis

Energy Efficiency and Stakeholder Satisfaction: The correlation between **energy efficiency** and **stakeholder satisfaction** shows a **moderate to strong positive correlation** with a coefficient of **0.59**. This implies that projects focusing on energy efficiency tend to result in higher levels of stakeholder satisfaction. Since the **p-value is less than 0.01**, this result is statistically significant. The positive relationship may stem from the fact that energy-efficient buildings often lead to reduced operational costs and better environmental performance, which satisfies key stakeholders who prioritize both cost-effectiveness and environmental responsibility.

Water Conservation and Stakeholder Satisfaction: Water conservation also has a **moderate positive correlation** with stakeholder satisfaction, with a correlation coefficient of **0.52**. This means that projects that incorporate water-saving technologies and practices generally experience increased stakeholder satisfaction. The **p-value** of **less than 0.01** indicates that this relationship is statistically significant. This positive relationship might be attributed to the long-term benefits of water conservation, including reduced utility costs and compliance with sustainability goals, which align with the expectations of environmentally-conscious stakeholders.

Waste Management and Stakeholder Satisfaction: The correlation between **waste management** and stakeholder satisfaction is weaker, with a coefficient of **0.30** and a **p-value of 0.08**. While there is a positive relationship, it is not statistically significant at the 0.05 level. This suggests that while waste management practices are appreciated, they may not be as directly impactful on stakeholder satisfaction as other sustainability indicators like energy efficiency or sustainable materials. It's possible that stakeholders place less emphasis on waste management practices or that challenges in implementation reduce the effectiveness of these practices in enhancing satisfaction.

Sustainable Materials and Stakeholder Satisfaction: The strongest correlation is observed between the use of **sustainable materials** and stakeholder satisfaction, with a coefficient of **0.66**. This indicates a **strong positive relationship** between the two variables, meaning that projects that incorporate sustainable materials generally lead to higher stakeholder satisfaction. The **p-value of less than 0.01** further confirms that this relationship is statistically significant. This strong relationship may be due to the increasing demand for sustainable materials in construction projects, which align with stakeholder values related to sustainability, innovation, and long-term project viability.

4.7.5. Correlation between (ESIs) and (PQM)

Environmental Sustainability Indicator	Correlation Coefficient (r)	Significance (p-value)
Energy Efficiency	0.62	< 0.01
Water Conservation	0.55	0.15
Waste Management	0.23	< 0.01
Sustainable Materials	0.68	< 0.01

Table 4. 13 Correlation between (ESIs) and (PQM)

(Source: computed in SPSS software by the researcher, 2024)

Energy Efficiency and PQM ($r = 0.62$, $p < 0.01$): The positive correlation coefficient of 0.62 indicates a moderately strong positive relationship between energy efficiency and PQM. This suggests that when energy efficiency measures are integrated into building projects, the overall quality management tends to improve significantly. The low p-value (< 0.01) further supports the statistical significance of this relationship, meaning that energy-efficient practices are likely to positively impact the project quality, enhancing both performance and operational outcomes.

Water Conservation and PQM ($r = 0.55$, $p < 0.01$): A correlation of 0.55 also reveals a moderately strong positive relationship between water conservation practices and PQM. This indicates that implementing water-saving technologies and designs has a beneficial impact on project quality. With a significant p-value of less than 0.01, it's clear that water conservation contributes to improving the sustainability of building projects while also maintaining or enhancing the quality of management in these projects.

Waste Management and PQM ($r = 0.23$, $p = 0.15$): Waste management had the weakest correlation ($r = 0.23$) with PQM and was not statistically significant ($p = 0.15$). This suggests that, while there is some positive association, the relationship between waste management practices and project quality is weak, and its impact on PQM may not be as noticeable or consistent as with other sustainability indicators. This could be due to challenges in effective waste management practices or a lower emphasis placed on this indicator compared to energy efficiency and water conservation in the context of government buildings.

Sustainable Materials and PQM ($r = 0.68$, $p < 0.01$): The use of sustainable materials showed the strongest positive relationship with PQM, with a correlation coefficient of 0.68. This indicates that the integration of eco-friendly materials into construction projects has a significant and strong impact on improving project quality. The very low p-value (< 0.01) further supports the importance of using sustainable materials to achieve better management outcomes. This may be because such materials often lead to longer-lasting and higher-performing buildings, ultimately enhancing the quality of the project.

The correlation analysis confirms that environmental sustainability indicators, particularly energy efficiency, water conservation, and the use of sustainable materials, play a critical role in enhancing project quality management in government buildings. These practices contribute to better project performance, higher quality, and compliance with environmental regulations. On the other hand, waste management showed a weaker and less significant relationship with PQM, indicating that further attention is needed to effectively integrate waste management practices into project management frameworks. Overall, this analysis underscores the value of sustainability in improving the quality and success of construction projects, making the integration of ESIs a priority for future projects.

4.8. Regression analysis

The regression analysis table presents a binary logistic regression model used to evaluate the impact of integrating Environmental Sustainability Indicators (ESIs) on overall project performance in government building projects. The dependent variable is project performance, classified into two categories: improved performance (1) and not improved (0). This approach allows for an understanding of how various ESI components influence the success of construction projects.

Variable	B	S.E.	Wald	Sig.	Exp(B)
Energy Efficiency	0.45	0.12	14.36	0.000	1.572
Water Conservation	0.30	0.15	4.65	0.031	1.348
Waste Management	0.12	0.18	0.44	0.509	1.127
Sustainable Materials	0.61	0.14	19.14	0.000	1.841

Table 4. 14 Regression Analysis of ESIs on Project Performance

(Source: computed in SPSS software by the researcher, 2024)

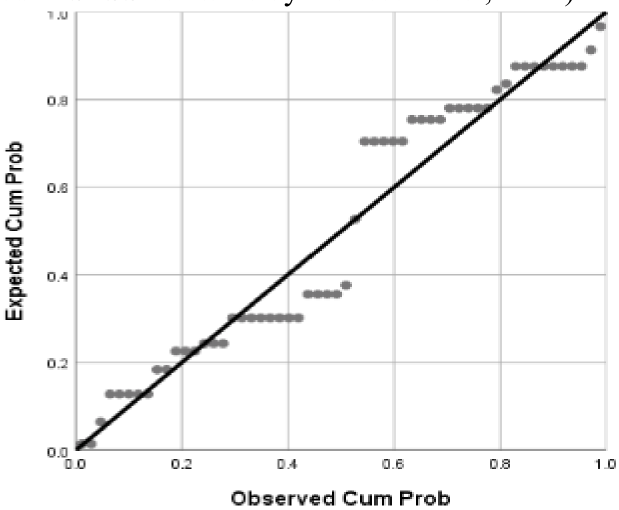

Figure 4. 3Normal P-P plot of regression between PQM and ESIs

(Source: generated in SPSS software by researcher, 2024)

Energy Efficiency emerged as a significant predictor of project performance, with a regression coefficient (B) of 0.45. The standard error (S.E.) of 0.12 indicates a relatively low level of variability around this estimate, while the Wald statistic of 14.36 and a p-value of 0.000 suggest that the relationship is statistically significant. The odds ratio (Exp(B)) of

1.572 implies that for every one-unit increase in the level of energy efficiency integration, the odds of experiencing improved project performance increase by approximately 57.2%. This finding highlights the critical role of energy efficiency measures in enhancing the overall effectiveness and sustainability of government building projects.

Water Conservation also displayed a statistically significant positive effect on project performance, with a coefficient of 0.30 and a p-value of 0.031. Although its impact is less pronounced than that of energy efficiency, the odds ratio of 1.348 indicates that improved water conservation practices can increase the likelihood of better project outcomes by approximately 34.8%. This result underscores the importance of water management in achieving sustainable project goals, suggesting that investments in water conservation strategies can contribute meaningfully to overall project success.

Conversely, Waste Management was found to have a regression coefficient of 0.12, with a p-value of 0.509, indicating that it does not significantly influence project performance in this context. The odds ratio of 1.127suggests a negligible effect, implying that integrating waste management practices alone may not lead to improved project outcomes. This finding may indicate the need for a more comprehensive approach that includes not only waste management but also other sustainability practices to drive project success.

The integration of Sustainable Materials demonstrated the most substantial positive impact, with a coefficient of 0.61 and a statistically significant p-value of 0.000. The odds ratio of 1.841 indicates that for each unit increase in the use of sustainable materials, the likelihood of achieving improved project performance increases by approximately 84.1%. This result suggests that sustainable materials play a crucial role in enhancing the quality and sustainability of government construction projects, emphasizing the need for policymakers and project managers to prioritize their use in future initiatives.

The assumption was to establish the strength and direction of the relationship between the independent variables and the dependent variable. A multiple regression model that was then fitted to determine the combined effect that the independent variables had on the dependent variable when acting jointly was expressed as follows: $Y = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \varepsilon$, Where; Y= successful project quality management practices; β_0 = constant (coefficient of intercept), X1 = Project quality planning; X2

=Quality assurance; X3 = Quality control; X4 = Quality management tools and techniques; X 5 = top management commitment; ε = error term; β1…β5=Regression coefficient of five independent variables. As can be observed in Table 4, the regression model of successful project quality management in road construction industry coefficient of determination R Square was 0.732 and R was 0.855. The coefficient of determination R Square indicated that 73.2% of the variation on successful project quality management in road construction industry can be explained by the set of independent variables, namely X1 = Project quality planning; X2 =Quality assurance; X 3 = Quality control; X4 = Quality management tools and techniques; X5 = top management commitment. The remaining 26.8% of variation in successful project quality management in road construction industry can be explained by other variables not included in this model. This shows that the model has a good fit since the value is above 60%. This concurs with Graham (2012) that R-squared is always between 0 and 100%: 0% indicates that the model explains none of the variability of the response data around its mean and 100% indicates that the model explains the variability of the response data around its mean. In general, the higher the R- squared, the better the model fits the data.

The study further used Analysis of Variance (ANOVA) in order to test the significance of the overall regression model. Green and Salkind (2013) posit that Analysis of Variance helps in determining the significance of relationship between the research variables. The result of Analysis of Variance (ANOVA) for regression coefficients in table below reveals that the significance of the F statistics is 0.000 which is less than 0.05. The F-table value (26.726) being significant at 95% confidence level. The value of F is large enough to conclude that the set coefficients of the independent variables are not jointly equal to zero. This implies that at least one of the independent variables has an effect on the dependent variable (successful project quality management in road construction industry).

As it can be observed from Table below, Project Quality Planning (X1) had a coefficient of 0.309 which is greater than zero. The t statics is 3.276 which has a p-value of 0.002 which is less than 0.05 implies that the coefficient of X1 is significant at 0.05 level of significance. This shows that project quality planning has a significant positive influence on versus successful project quality management in construction industry. The coefficient of quality assurance (X2) was 0.226 which was greater than zero. With a p value of 0.032 which is less than 0.05. This implies that the coefficient 0.032 is significant.

Since the coefficient of X2 is significant, it shows that quality assurance have a significant effect on versus successful project quality management in road construction industry. Table also shows that quality control (X3) had a coefficient of 0.228 which is greater than zero. which has a p-value of 0.006 which is less than 0.05 implies that the coefficient of X3 is significant at 0.05 level of significance. This shows that quality control has a significant positive influence on versus successful project quality management in road construction industry.

Further, shows that Quality management tools and techniques (X4) had a coefficient of 0.394 which has a p-value of 0.003 which is less than 0.05. This shows that a Quality management tools and techniques have a significant positive influence on versus successful project quality management in road construction industry. Furthermore, shows that top management commitment (X5) had a coefficient of 0.266 which has a p-value of 0.009 which is less than 0.05.

This implies that the coefficient of X5 is significant at0.05 level of significance. This shows that a top management commitment has a significant positive influence on versus successful project quality management in road construction industry. Finally, the constant term is -1.025. The constant term is the value of the dependent variable when all the independent variables are equal to zero. The constant term has a p value of 0.004 which is less than 0.05. This implies that the constant term is significant. The multiple regressions versus successful project quality management in road construction industry are thus an equation through the -1.025. If all the independent variables take on the values of zero, there would be a negative value of successful project quality management in road construction industry. Therefore the most significant factor was Quality management tools and techniques that followed project quality planning.

Finally, the finding revealed that holding independent variables, a unit increase in project quality planning would lead to increase in successful project quality management in construction industry by a factor of 0.309, a unit increase in quality assurance would lead to increase successful project quality management in road construction industry by factor of 0.226, a unit increase in quality control would lead to increase in successful project quality management in road construction industry by a factor of 0.228, a unit increase in top management commitment would lead to increase in successful project quality management in construction industry by a factor of 0.266, and a unit increase in quality management tools and techniques would lead to increase in successful project quality management in construction industry by a factor of 0.394

Model	R	R square	Adjusted R square	Std. Error of the Estimate
1	0.855[a]	0.732	0.704	0.356

a. Predictors: (Constant), quality management tools and techniques, quality planning, quality control, quality assurance, top management commitment

ANOVA[a]

Model		Sum of squares	df	Mean Square	F	Sig.
1	Regression	16.977	5	3.395	26.726	0.000[b]
	Residual	6.225	49	0.127		
	Total	23.202	54			

a. Dependent Variable: Successful Quality management

b. Predictors: (Constant), quality management tools and techniques, quality planning , quality control , quality assurance , top management commitment

Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	P-value
		B	Std. Error	Beta		
1	(Constant)	-1.025	0.343		-2.985	0.004
	Quality planning	0.309	0.094	0.295	3.276	0.002
	Quality assurance	0.226	0.102	0.184	2.211	0.032
	Quality control	0.228	0.079	0.236	2.896	0.006
	Top management commitment	0.266	0.098	0.252	2.722	0.009
	Quality management tools and techniques	0.394	0.126	0.288	3.126	0.003

Table 4. 15Multiple Regression Model Summary

(Source: computed in SPSS software by the researcher, 2024)

As per the SPSS generated table above, the model equation would be (Y = β 0 + β 1 X1 + β 2 X2 + β 3 X3 + β 4 X4 + β 5 X5 + ε) becomes: Y = -1.025+ 0.309X1 + 0.226X2 + 0.228X3 + 0.394X4 + 0.266X5. This indicates that successful Project quality management in road Construction Industry = -1.025+ 0.309(project quality planning) + 0.226(project quality assurance) + 0.228(project quality control) + 0.394(project quality management tools and techniques) + 0.266(Top management commitment).

The regression analysis reveals that integrating ESIs, particularly energy efficiency and sustainable materials, has a significant positive impact on project performance in government building projects. Water conservation also contributes positively, albeit to a lesser extent, while waste management does not appear to have a statistically significant effect. These insights underscore the importance of focusing on specific ESI components to enhance project outcomes, providing valuable guidance for future sustainability efforts in the construction sector.

4.8. Result and discussion for interview & paper reviews

Based on the interview questions related to integrating Environmental Sustainability Indicators (ESIs) into Project Quality Management (PQM) in government building projects, the results from the respondents revealed several key insights regarding their perceptions, challenges, and experiences.

First, the definition of Project Quality Management (PQM) varied among respondents but commonly emphasized the need for adherence to regulations, standards, and quality benchmarks specific to government projects. Many respondents highlighted that PQM should encompass not only traditional aspects like cost and time management but also include environmental sustainability as a critical component. This shift in perspective reflects a growing awareness of the need to integrate sustainability into project planning and execution, recognizing that government projects serve a public purpose and have broader societal impacts.

However, the integration of environmental sustainability into construction projects faced numerous challenges, as indicated by the respondents. A significant number of them pointed out barriers such as a lack of knowledge and training on sustainable practices, which hindered the effective implementation of ESIs. Financial constraints also emerged as a recurring theme, with many respondents noting that the initial costs associated with sustainable materials and technologies often deterred stakeholders from pursuing greener alternatives. Additionally, some mentioned the resistance to change from established practices, citing a preference for traditional methods over newer, more sustainable approaches. These challenges highlight the need for targeted interventions and educational initiatives to foster a culture of sustainability within the construction sector.

When asked about the most critical Environmental Sustainability Indicators (ESIs) for government building projects, respondents identified energy efficiency and water conservation as paramount. Many emphasized that these indicators not only contribute to reduced operational costs in the long term but also align with national and global sustainability goals. Interestingly, while waste management and the use of sustainable materials were recognized as important, they were often deemed secondary to energy and water concerns. This prioritization may reflect a need for greater awareness and emphasis on comprehensive sustainability strategies that encompass all ESIs.

Despite the barriers to integrating ESIs, respondents acknowledged several benefits stemming from their inclusion in PQM. Improved project performance was a commonly cited advantage, with many highlighting enhanced quality and stakeholder satisfaction. Additionally, compliance with environmental regulations was seen as a significant benefit, helping to mitigate legal risks associated with non-compliance. The consensus among respondents was that while integrating ESIs into PQM requires effort and investment, the long-term gains in sustainability and project viability justify these efforts.

When discussing additional measures to enhance the integration of ESIs into PQM, respondents suggested a multifaceted approach. They called for stronger government policies and regulations to incentivize sustainable practices, as well as increased funding for training and capacity-building initiatives. Collaboration among stakeholders, including government agencies, contractors, and environmental organizations, was also deemed essential to create a cohesive strategy for integrating sustainability into project management. These suggestions underscore the importance of a collaborative and informed approach to fostering sustainability within government building projects, ultimately aiming to create a built environment that is both functional and environmentally responsible.

The findings from the respondents reveal a complex landscape of perceptions and practices regarding the integration of Environmental Sustainability Indicators into Project Quality Management in government building projects. While there is a growing recognition of the importance of sustainability, significant barriers remain that necessitate targeted efforts to promote and facilitate its incorporation into project management processes.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The findings underscore the growing recognition of sustainability's role in enhancing project outcomes, from improving long-term building performance to reducing operational costs and aligning with global environmental goals. Despite these benefits, challenges such as financial constraints, resistance to change, and a lack of training continue to hinder the full integration of ESIs into construction practices.

Energy efficiency and water conservation emerged as the most impactful indicators, significantly contributing to improved project performance. However, waste management, while recognized, was seen as having a lesser effect, pointing to the need for a more holistic approach that encompasses all aspects of sustainability. The inclusion of sustainable materials, which had the greatest positive impact, highlights the value of focusing on environmentally friendly resources to drive project success.

Moving forward, it is essential for stakeholders, including government entities, contractors, and environmental agencies, to collaborate in addressing the barriers to ESI integration. This includes providing financial incentives, enhancing training programs, and fostering a stronger regulatory framework. By doing so, Addis Ababa can set a precedent in sustainable construction, ensuring that its government buildings not only meet immediate needs but also contribute to long-term environmental stewardship. This study serves as a foundation for future research and policy development aimed at embedding sustainability deeper into construction project management practices.

The research highlights that energy efficiency and water conservation are the most effectively integrated indicators, contributing to reduced operational costs and lower environmental footprints. Energy-efficient systems, such as advanced lighting and HVAC systems are increasingly being adopted, but retrofitting older buildings remains a challenge. Water conservation efforts, including the use of low-flow fixtures and rainwater harvesting, have also proven beneficial. However, barriers such as limited awareness and training among contractors prevent broader implementation.

On the other hand, waste management was found to be less integrated into PQM processes. Traditional waste disposal methods are still prevalent, with minimal emphasis on recycling and reusing materials. Although government policies exist to support waste management, inconsistent enforcement and the perception of high costs continue to hinder progress. Conversely, the use of sustainable materials had the greatest positive impact, with projects that incorporated recycled or low-carbon materials showing improved environmental performance, lower costs, and enhanced durability. The use of these materials, however, is limited due to availability and higher upfront costs.

The study also identifies several key barriers to ESI integration. Financial constraints were a major issue, as sustainable technologies and practices often require higher initial investments, despite long-term savings. Additionally, a lack of training and awareness among construction professionals remains a significant obstacle, emphasizing the need for capacity-building programs. Finally, regulatory and institutional gaps, particularly inconsistent enforcement of sustainability policies, have further complicated efforts to integrate ESIs into construction projects.

The research demonstrates that integrating ESIs into PQM significantly improves building performance, durability, and cost-effectiveness, while projects lacking these indicators tend to have higher operational costs and maintenance issues. The study underscores the potential of sustainable practices to enhance the social and environmental reputation of construction projects, aligning them with global sustainability standards. It also highlights the need for collaboration among stakeholders, including government agencies, contractors, and environmental organizations, to overcome barriers and accelerate the adoption of ESIs in future projects.

In conclusion, the study emphasizes that as Addis Ababa continues to grow, integrating ESIs into PQM will not only improve the performance and longevity of government buildings but also contribute to the city’s broader sustainability goals. Establishing stronger regulations, providing financial incentives, and raising awareness are crucial steps toward ensuring that sustainable construction becomes a core element of the city's urban development strategy.

5.2. Recommendation

Based on the findings of this study, the following recommendations are proposed to enhance the integration of Environmental Sustainability Indicators (ESIs) into Project Quality Management (PQM) for government buildings in Addis Ababa:

Strengthen Regulatory Frameworks and Enforcement There is a need for a stronger regulatory framework that mandates the integration of ESIs into all phases of government construction projects. This includes clearer guidelines and standards that ensure sustainability practices, such as energy efficiency, waste management, and the use of sustainable materials, are not optional but required. Additionally, the government should enforce these regulations more consistently to ensure compliance across all projects. Establishing penalties for non-compliance and incentives for adherence can help drive the adoption of sustainability practices.

Provide Financial Incentives for Sustainable Practices: One of the major barriers to ESI integration is the perceived high upfront costs of sustainable materials and technologies. To overcome this, the government should introduce financial incentives, such as tax breaks, subsidies, or low-interest loans, for construction projects that prioritize sustainability. These incentives would encourage contractors and developers to adopt eco-friendly materials and practices, balancing the initial costs with long-term savings in operational expenses.

Invest in Capacity Building and Training: A lack of knowledge and training among construction professionals and project managers was identified as a key challenge in integrating ESIs. The government, in collaboration with educational institutions and professional associations, should invest in capacity-building programs that train stakeholders on the benefits and implementation of sustainability practices. Workshops, certification programs, and continuous professional development should be made available to equip project managers, engineers, and contractors with the necessary skills to integrate ESIs effectively.

Promote the Use of Sustainable Materials: The use of sustainable, locally sourced, and low-carbon materials should be promoted as part of construction practices. Government agencies should work on improving access to these materials by developing local supply chains and encouraging local manufacturers to produce eco-friendly materials.

Additionally, research and development into cost-effective, sustainable alternatives should be supported to overcome the barrier of high initial costs for these materials.

Foster Collaboration among Stakeholders: Successful integration of ESIs requires collaboration between all stakeholders, including government bodies, contractors, environmental agencies, and the public. Regular stakeholder forums should be organized to share knowledge, best practices, and challenges. By encouraging open communication and collaboration, stakeholders can work together to develop holistic approaches to sustainability that address both local challenges and global environmental standards.

Implement Monitoring and Evaluation Systems: To ensure ongoing success, it is essential to have monitoring and evaluation (M&E) systems in place. These systems should track the implementation and impact of ESIs throughout the project lifecycle. By establishing key performance indicators (KPIs) for energy use, water conservation, waste management, and other sustainability factors, project managers can assess the effectiveness of these practices and make improvements as necessary.

Encourage Retrofitting of Existing Buildings: While the study focuses on new government buildings, retrofitting existing buildings to improve energy efficiency and sustainability should also be prioritized. By upgrading older structures with modern, sustainable technologies, the city can extend the benefits of sustainability to a broader range of infrastructure, reducing operational costs and minimizing environmental impacts.

Align with Global Sustainability Standards: government building projects should strive to align with global sustainability frameworks such as the Leadership in Energy and Environmental Design (LEED) or the Building Research Establishment Environmental Assessment Method (BREEAM). These standards provide a structured approach to sustainability that ensures buildings meet rigorous environmental criteria, contributing to the city's global competitiveness in sustainable urban development.

By implementing these recommendations, Addis Ababa can effectively integrate ESIs into the PQM of its government buildings, ensuring that the city not only meets its immediate infrastructure needs but also contributes to long-term environmental sustainability and resource conservation

REFERENCES

Assefa, S., et al. (2022). "A building sustainability assessment system (BSAS) for least developed countries: A case of Ethiopia." Sustainable Cities and Society**87**: 104238.

Bell, S. and S. Morse (2012). Sustainability indicators: measuring the immeasurable?, Routledge.

Chan, A. P. C., et al. (2017). "Strategies for promoting green building technologies adoption in the construction industry—An international study." Sustainability **9**(6): 969.

Chawla, V., et al. (2018). "The sustainable project management: A review and future possibilities." Journal of project management **3**(3): 157-170.

Chofreh, A. G., et al. (2019). "The imperative and research directions of sustainable project management." Journal of Cleaner Production **238**: 117810.

Elliott, J. (2012). An introduction to sustainable development, Routledge.

Fathalizadeh, A., et al. (2021). "Barriers impeding sustainable project management:A Social Network Analysis of the Iranian construction sector." Journal of Cleaner Production **318**: 128405.

Hák, T., et al. (2012). Sustainability indicators: a scientific assessment, Island Press.

Harris, J. M. (2003). "Sustainability and sustainable development." International Society for Ecological Economics **1**(1): 1-12.

Hueting, R. and L. Reijnders (2004). "Broad sustainability contra sustainability: the proper construction of sustainability indicators." Ecological economics **50**(3-4): 249-260.

Hussin, J. M., et al. (2013). "The way forward in sustainable construction: issues and challenges." International Journal of Advances in Applied Sciences **2**(1): 15-24.

Kivilä, J., et al. (2017). "Sustainable project management through project control in infrastructure projects." International Journal of Project Management **35**(6): 1167-1183.

Lima, L., et al. (2021). "Sustainability in the construction industry: A systematic review of the literature." Journal of Cleaner Production **289**: 125730.

Moldan, B., et al. (2012). "How to understand and measure environmental sustainability : Indicators and targets." Ecological indicators **17**: 4-13.

Ortiz, O., et al. (2009). "Sustainability in the construction industry: A review of recent developments based on LCA." Construction and building materials **23**(1): 28-39.

Rajabi, S., et al. (2022). "Identification and assessment of sustainability performance indicators for construction projects." Environmental and Sustainability Indicators: 100193.

Rogers, P. P., et al. (2012). An introduction to sustainable development, Earthscan.

Said, I., et al. (2010). "Identifying the indicators of sustainability in the construction industry." International Journal of Organizational Innovation (Online) **2**(3): 336.

Stanitsas, M. and K. Kirytopoulos (2023). "Investigating the significance of sustainability indicators for promoting sustainable construction project management." International Journal of Construction Management **23**(3): 434-448.

Valentin, A. and J. H. Spangenberg (2000). "A guide to community sustainability indicators." Environmental impact assessment review **20**(3): 381-392.

Verma, P. and A. S. Raghubanshi (2018). "Urban sustainability indicators: Challenges and opportunities." Ecological indicators **93**: 282-291.

Wu, J. and T. Wu (2012). "Sustainability indicators and indices: an overview." Handbook of sustainability management: 65-86.

Zavadskas, E. K., et al. (2018). Sustainability in construction engineering, MDPI. **10:** 2236 Ahmed, A. M., Sayed, W., Asran, A., & Nosier, I. (2021). Identifying barriers to the implementation and development of sustainable construction. International Journal of Construction Management, 1–12. https://doi.org/10.1080/15623599.2021.1967577

Anzagira, L. F., Badu, E., & Duah, D. (2019). Towards an Uptake Framework for the Green Building Concept in Ghana: A Theoretical Review. Resourceedings,2(1), 57. https://doi.org/10.21625/resourceedings.v2i1.452

Anzagira, L. F., Duah, D., & Badu, E. (2019). A conceptual framework for the uptake of the green building concept in Ghana. Scientific African, 6, e00191. https://doi.org/10.1016/j.sciaf.2019.e00191

Chukwu, D. U., Anaele, E. A., Omeje, H. O., & Ohanu, I. B. (2019). Adopting green building constructions in developing countries through capacity building strategy: Survey of Enugu State, Nigeria. Sustainable Buildings, 4 ,4. https://doi.org/10.1051/sbuild/2019004

Cramer, D.1998 fundamental statistics for social research, London.

Darko, A., & Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. Building and Environment, 130, 74–84. https://doi.org/10.1016/j.buildenv.2017.12.022

D.U. Chukwu, E.A. Anaele, H.O. Omeje and I.B. Ohanu: Adopting green building constructions in developing countries through capacity building strategy: survey of Enugu State, Nigeria. Sust. Build. 4, 4 (2019)

Eğitim Fak ltesi Dergisi April 2016Cronbach s Coefficient Alpha: A Meta-Analysis Study.

Elfiky, U. (2011). Towards a green building law in Egypt: Opportunities and challenges. Energy Procedia, 6, 277–283. https://doi.org/10.1016/j.egypro.2011.05.031

Ellen A. Validity and Reliability in Social Science Research

Erena D. et.al, (2017) City profle: Addis Ababa. Report prepared in the SES (Social Inclusion and EnergyManagement for Informal Urban Settlements) project, funded by the Erasmus+

Program of the European Union. http://moodle.donau-uni.ac.at/ses Feng, P. (2011). Brief discussion of green buildings. Procedia Engineering, 21, 939–942. https://doi.org/10.1016/j.proeng.2011.11.2097

Gibberd, J. (2020). Green Building Technologies: In P. Yang (Ed.), Practice, Progress, and Proficiency in Sustainability (pp. 482–510). IGI Global. https://doi.org/10.4018/978-1- 5225-8559-6.ch017

Gou, Z. (Ed.). (2020). Green Building in Developing Countries: Policy, Strategy and Technology. Springer International Publishing. https://doi.org/10.1007/978-3-030-24650-1

Jesus, L. N., Almeida, M. G., & Almeida, A. C. Methodology for the application of sustainable construction.

Katherine L. Wright (2014) An Introduction to Cronbach's α: It's the GLM . Ji, S. (2016). Green Building Materials and their Common Use in Everyday Life. https://doi.org/10.13140/RG.2.1.1635.4323

Loumer, S. H. (2015). An Evaluation of Green Building Components & Their Relationship with Sustainable Development Objects. 2(2).

Mohajan, H. K. (2017). Two Criteria For Good Measurements In Research: Validity And Reliability. Annals Of Spiru Haret University. Economic Series, 17(4), 59–82. Https://Doi.Org/10.26458/1746

Research: Validity And Reliability. Annals of Spiru Haret University. Economic Series, 17(4), 59–82. https://doi.org/10.26458/1746

N Review on Barriers, Policies and Governance. NazirahIJTech.

Nikyema, G. A., & Blouin, V. Y. (2020a). Barriers to the adoption of green building materials and technologies in developing countries:. IOP Conference Series: Earth and Environmental Science, 410(1), 012079. https://doi.org/10.1088/1755-1315/410/1/012079

Nura M, Oct 2018. NURA M, unpublished MSC thesis submitted to Addis Ababa University.

Ojo-Fafore, E., Aigbavboa, C., & Remaru, P. (2018). Benefits of Green Buildings. 10.

Potbhare, V., Syal, M., & Korkmaz, S. (2009). Adoption of Green Building Guidelines in Developing Countries Based on U.S. and India Experiences. Journal of Green Building, 4(2), 158–174. https://doi.org/10.3992/jgb.4.2.158

Shen, W., Tang, W., Siripanan, A., Lei, Z., & Hui, F. K. P. (n.d.). Understanding the Green Building Industry in Developing Countries: A Case Study of Thailand. 22.

Simpeh, E. K. (n.d.). FACTORS INFLUENCING THE GROWTH OF GREEN BUILDING IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY. 9.

Singh, C. S. (2018). Green Construction: Analysis on Green and Sustainable Building Techniques. Civil Engineering Research Journal, 4(3). https://doi.org/10.19080/CERJ.2018.04.555638

Taherdoost, H. (2016). Validity and Reliability of the Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3205040

Wallhagen, M. (n.d.). WHAT IS A “GREEN” BUILDING ACCORDING TO DIFFERENT ASSESSMENT TOOLS?

APPENDICES

Appendix I – Interview Questions

Dear Respondents, this interview questions are prepared to conduct a study on "Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Government buildings in Addis Ababa" for the partial fulfillment of MSc degree in Construction Engineering Management. Information you provided is only used for academic purposes and it is confidential, so you are kindly requested to answer all the questions.

Thank you for your kind cooperation!

1. How do you define Project Quality Management (PQM) in the context of government building projects?
2. What challenges do you face in integrating environmental sustainability into construction projects?
3. Which Environmental Sustainability Indicators (ESIs) are the most critical for government building projects?
4. Do you currently integrate ESIs into your PQM processes? If yes, how?
5. What are the barriers to fully integrating sustainability indicators into PQM for public sector projects?
6. What benefits do you believe arise from integrating ESIs into PQM?
7. What additional measures or strategies do you think could enhance the integration of ESIs into PQM?

Appendix II – Questioner

Dear Respondents, this questionnaire is prepared to conduct a study on "Assessment on Integrating Environmental Sustainability Indicators into Project Quality Management, In Case of Government buildings in Addis Ababa" for the partial fulfillment of MSc degree in Construction Engineering Management. Information you provided is only used for academic purposes and it is confidential, so you are kindly requested to answer all the questions.

Thank you for your kind cooperation! NO.___

1. What is your profession?

☐ Project Manager ☐ Engineer

☐ Architect ☐ Contractor

☐ Other (please specify): _______________

2. How many years of experience do you have in the construction industry?

☐ Less than 5years ☐ 5–10 years

☐ 10–15years ☐ More than 15 years

3. How familiar are you with the concept of Environmental Sustainability Indicators (ESIs)?

☐ Not familiar ☐ Somewhat familiar

☐ Familiar ☐ Very familiar

4. Which of the following sustainability indicators have you implemented in your projects? (Check all that apply)

☐ Energy Efficiency

☐ Water Conservation

☐ Waste Management

☐ Use of Sustainable Materials

☐ None

5. How often do you consider environmental sustainability in project planning?

☐ Never ☐ Sometimes

☐ Often ☐ Always

6. To what extent are sustainability practices integrated into the Project Quality Management (PQM) process in your projects?

☐ Not integrated ☐ Partially integrated

☐ Mostly integrated ☐ Fully integrated

7. What are the key benefits of integrating ESIs into PQM in your experience? (Check all that apply)

☐ Cost savings

☐ Improved building performance

☐ Reduced environmental impact

☐ Compliance with regulations

☐ None

8. What barriers have you encountered when attempting to integrate sustainability practices into your projects? (Check all that apply)

☐ Lack of financial resources

☐ Lack of technical expertise

☐ Lack of regulatory support

☐ Resistance from stakeholders

☐ Other (please specify): _______________

9. What would encourage you to integrate more sustainability practices into your projects? (Check all that apply)

☐ Financial incentives (subsidies, tax breaks)

☐ Training and capacity building

☐ Stricter regulations

☐ Access to sustainable materials

☐ Other (please specify): ________________

10. Do you believe that government regulations are adequate to enforce sustainability in construction projects?

☐ Yes

☐ No

☐ Not sure

11. What strategies would you recommend to improve the integration of ESIs into PQM in government projects?

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Appendix III - List of Selected Government Buildings and Bureau

- Ministry of Urban Development and Infrastructure
- Addis Ababa City Administration Building
- Addis Ababa City Construction Bureau
- Ethiopian Building Construction Project Office
- Ethiopian Public Procurement and Property Administration Agency (Government Buildings Management Section)
- Addis Ababa Housing development Corporation
- Addis Ababa construction permits and controls Bureau