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ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Civil Engineering

IMPLEMENTATION AND ANALYSIS OF STATE-OF-THE-ART SUSTAINABLE TECHNIQUES TO IMPROVE THE CONSTRUCTION PERFORMANCE: A CASE STUDY

Huda Farhan IBRAHIM

Master’s Thesis

Supervisor

Assoc. Prof. Dr. Sepanta NAİMİ

Istanbul, 2023

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The thesis titled IMPLEMENTATION AND ANALYSIS OF STATE-OF-THE-ART SUSTAINABLE TECHNIQUES TO IMPROVE THE CONSTRUCTION PERFORMANCE: AN IRAQI CASE STUDY prepared by HUDA FARHAN IBRAHIM and submitted on 19/04/2023 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Huda Farhan IBRAHIM

Signature

DEDICATION

I dedicate my research to my lovely father and my dear mother, who have continuously shown their love, support, help, and enthusiasm to me while I have pursued my research. The staff at Altınbaş University, my supervisor, and all civil engineering doctors are also thanked for their assistance, guidance, and the invaluable expertise they provided in this study. In addition, my supervisor gave me a ton of support and direction for my study analysis and survey.I also want to express my gratitude to everyone at Altınbaş University who offered me time and assistance so I could conduct my research and complete my thesis analysis.

ABSTRACT

IMPLEMENTATION AND ANALYSIS OF STATE-OF-THE-ART SUSTAINABLE TECHNIQUES TO IMPROVE THE CONSTRUCTION PERFORMANCE: AN IRAQI CASE STUDY

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Date: April / 2023

Pages: 108

This work is carried out to address the importance and significant contributions of sustainability and green building principles in improving construction energy efficiency, performance, resilience, energy stability, and reducing its negative impact on the environment. This research adopted two critical research approaches, including (1) quantitative cross-sectional descriptive study and (2) case study analysis. The research results revealed that using sustainable methods, intelligent energy-efficient techniques, and green building principles play a critical role in improving building sustainability and achieving various essential benefits in terms of better economic feasibility, lower maintenance and operation costs, indoor environment quality, and reducing Greenhouse Gas (GHG) emissions and negative impact on the environment. Also, the study concluded the importance of linking the principles of sustainability and design elements in order to implement and analyze the latest sustainable technologies to improve building performance. In the study, the researcher focused on the importance of controlling and estimating construction costs in order to achieve effective sustainability that contributes to improving construction performance. The researcher emphasized the achievement of the desired sustainable work goals that would increase the quality of the performance of construction projects. The study concluded the importance of controlling costs in the event of future

changes in order to avoid problems in construction and weaken the performance of the project. Also, achieving high-performance speed in calculating quantities could ensure the application of effective techniques that increase the sustainability and performance of construction projects. Also, it was found that monitoring project scheduling plays a vital role in improving construction performance and not causing delays in project delivery.

Keywords: Sustainable Facility, Thermal Performance, Case Study, Iraqi Building Sector, Innovative Construction Methods.

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ABBREVIATIONS

AI	:	Artificial Intelligence
ANNs	:	Artificial Neural Networks
BEM	:	Building Energy Modeling
BMSs	:	Building Management Systems
BIM	:	Building Information Modeling
D&C	:	Design and Construction
DRPs	:	Demand Response Programs
GHG	:	Greenhouse Gas
IMA	:	Intelligent Metaheuristic Algorithms
IoT	:	Internet of Things
LED	:	Light-Emitting Diodes
LEED	:	Leadership in Energy and Environmental Design
MFNNs	:	Multi-layer Feed-forward Neural Networks
MOGA	:	Multi-Objective Genetic Algorithm
MOPSO	:	Multi-Objective Particle Swarm Optimization
NSGA-II	:	Nondominated Sorting Genetic Algorithm
O&M	:	Operation and Maintenance
R&D	:	Research and Development
SBToolPT	:	Sustainability Assessment Tool
SLR	:	Systematic Literature Reviews

SPSS	:	The Statistical Package for Social Sciences
TOA	:	The Objective Analysis
VOSviewer	:	The Visualization of Similarities
WoS	:	The Web of Science

LIST OF SYMBOLS

N_{it}	:	The Number of Items
f_i	:	The Frequency
x_i	:	The Degree of The Criterion Importance
C	:	The Average Inter-Item Variance Between Items
V	:	The Average Variance of All Items
X	:	The Mean Score
Z	:	The Standard Score Corresponding To The Significance Level.
μ	:	The Hypothesized Population Mean
$Expected\ Value$	:	The Parameter (Population Mean) Which Would Expect To Obtain If The Null Hypothesis Were (Hypothesized Value)
Ms	:	The Mean Score (1 ≤ Ms ≤ 5)
N	:	The Size of The Population
Nr	:	The Total Number of Responses For That Factor or Option
$Observed\ Value$	:	The Statistic (Sample Mean), Which Is Computed From The Sample Data
S	:	The Standard Deviation
SSL	:	Statistical Significance Level
$Standard\ Error$	:	The Error Which Is Being Tested.

1. INTRODUCTION

1.1 RESEARCH BACKGROUND

The building and construction sector has significantly been growing and expanding in developed and developing countries due to the rapid growth in global populations in the last few years [1]–[12]. As a result of this growth, several state-of-the-art techniques and innovative methods were applied to improve the construction industry's resilience, reliability, performance, thermal equilibrium, and energy stability [13]–[27]. Sustainability can be described as an approach through which renewable construction materials and waste handling and management methods (including recycling, recovering, reusing, and reducing wastes) are applied during and after the construction phases [28]–[38]. In addition, the sustainability approach is associated with lowering the buildings and facilities' energy consumption by utilizing energy-efficient techniques, such as the employment of Light-Emitting Diodes (LED) lighting systems, using passive and natural sunlight methods, and using energy-efficient cooling and heating equipment [34], [36]. Moreover, sustainability can increase the facilities' performance and effectiveness by applying sufficient insulation for the building's interior spaces, including the insulation of walls, ceilings, floors, and roofs, and using double- or triple-pane windows. Examples of insulation materials for walls, ceilings, floors, and roofs contain fiberglass, cellulose, polystyrene, polyurethane foam, and mineral wool [39]. In addition, one of the energy-efficient techniques used in the construction industry is painting walls and ceilings with a light color to enable the reflection of light and avoid absorbing thermal energy that can affect the amount of cooling and heating load required for the building. Figure 1.1 shows the ratios related to the thermal losses of buildings during winter. It indicates the percentage of heat transfer outside the building when no insulation is applied in winter. For instance, around 26% of thermal energy inside the building flows out of the building through the roof. This value is greatly significant. Thus, insulation techniques are remarkably important and recommended to apply.

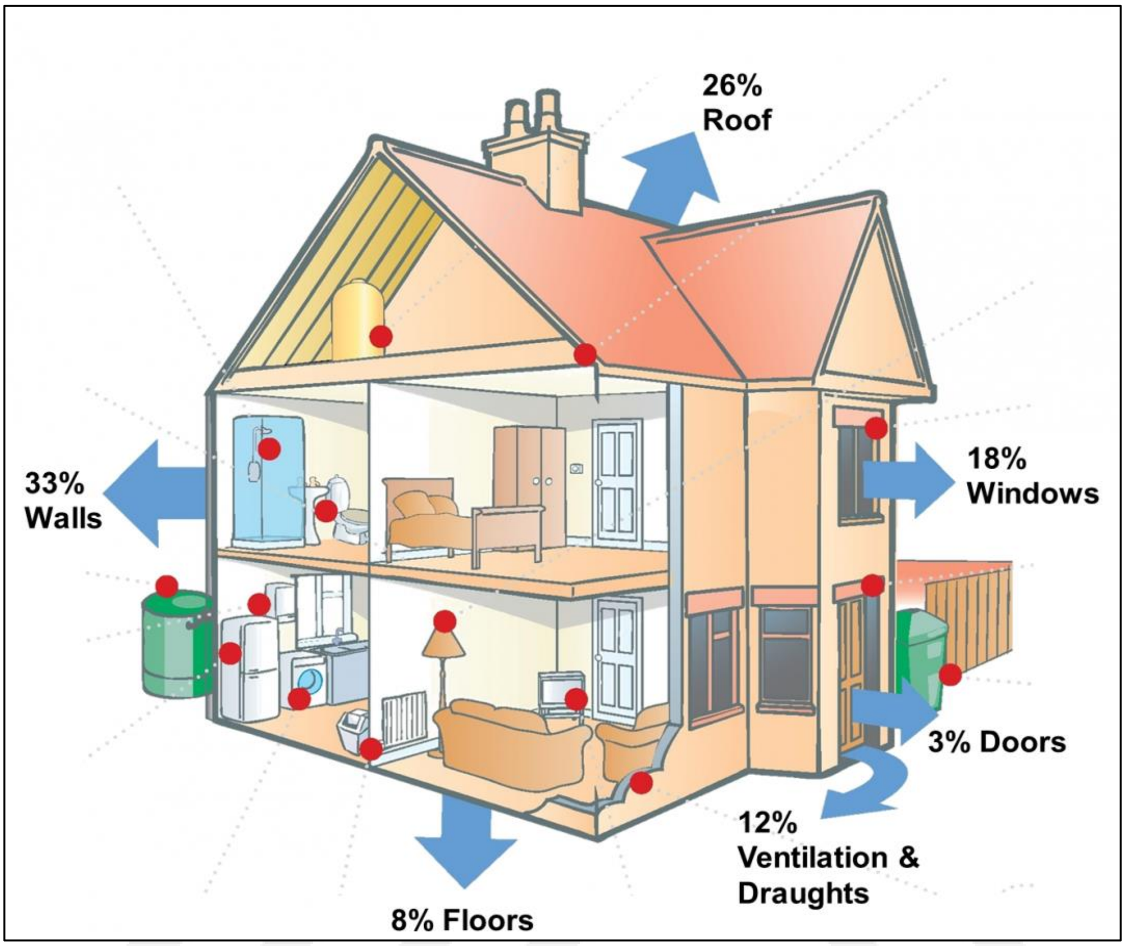

Figure 1.1: Thermal Losses From The Building When No Insulation is Applied In Winter [40].

1.2 PROBLEM STATEMENT

In the past, the construction industry has been associated with considerable consumption of energy and cost to build and operate different buildings and small-, medium-, and large-scale facilities. In addition, the construction industry is accountable for environmental pollution resulting from the disposal of various construction materials and significant building resources into the natural environment. Several efforts have been conducted to mitigate these issues. In this context, the terms' sustainability', 'green,' 'energy-efficient,' and 'environmentally friendly have been broadly used in the construction sector in the last decades [41]. These terms aim to improve the facilities' energy efficiency and performance. Moreover, numerous building modeling software tools have been developed to assess and evaluate the energy consumption and performance of facilities. One of these software tools is Building Energy Modeling (BEM) Software. BEM can carry out simulations, modeling, and numerical analysis to determine and assess critical improvements and strategic methods to improve the building's resilience, reliability, performance, thermal equilibrium, and energy stability [42], [43]. Figure 1.2 represents the use of BEM principles for buildings.

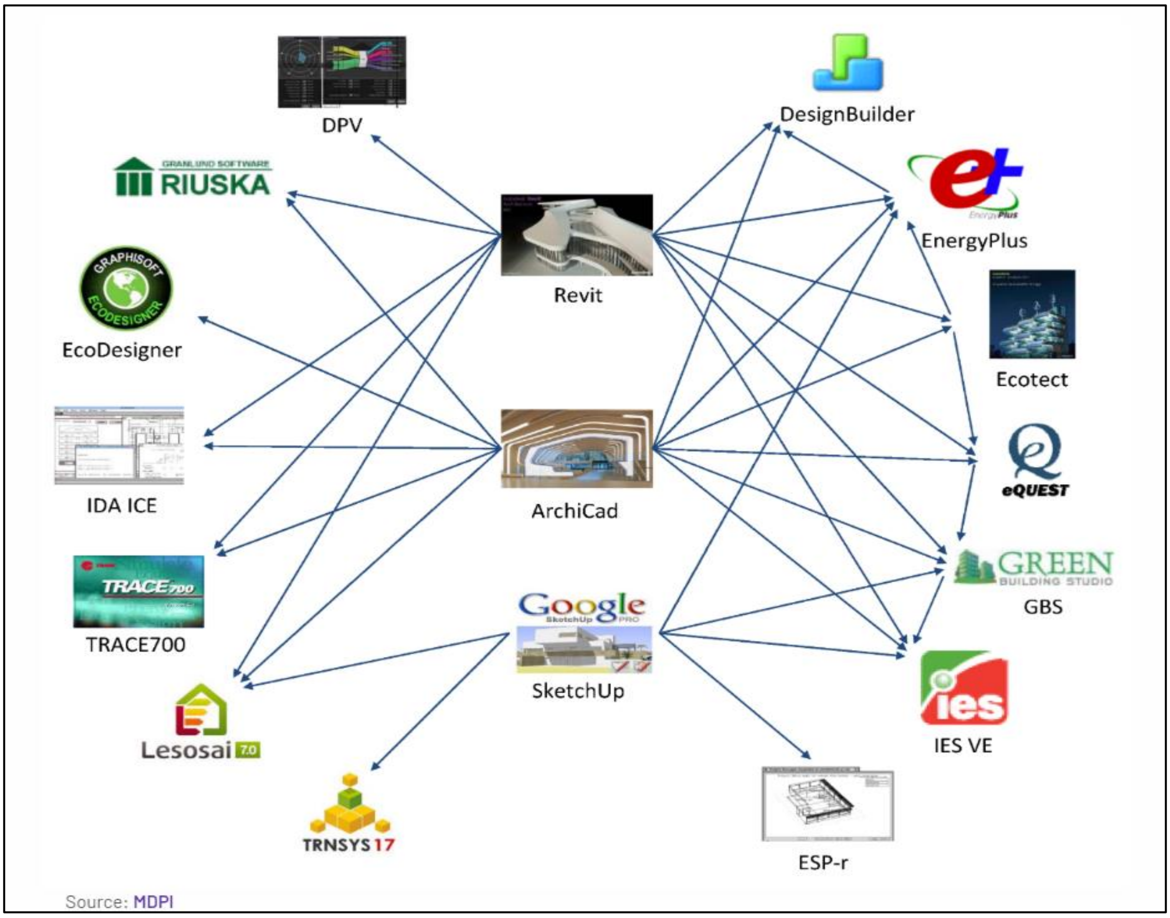

Figure 1.2: Major Software Tools Employed For Conducting BEM Analysis For Buildings [44].

In addition, the use of BEM software is greatly practical to reduce the facility's energy consumption and make it green and environmentally friendly. These green strategic and intelligent methods of enhancement include using renewable energy resources for the building, optimizing energy consumption, and using intelligent materials in construction that can achieve significant improvements in the performance and efficiency of the building. In this work, simulations and numerical analysis are executed for a case study (of a building) to identify innovative techniques and determine critical approaches to improve the building's energy efficiency, cost-effectiveness, sustainability, and performance.

1.3 RESEARCH SIGNIFICANCE

This work holds various unique significances. Firstly, this research will define some critical terminologies of this research, including sustainability, green building, innovative construction techniques, and environmentally friendly facility. The second relevance of this work includes the identification of major construction industry obstacles and challenges to offer higher performance and effectiveness of buildings. The third relevance of this study is to shed light on smart techniques and intelligent methods implemented to improve buildings' sustainability and promote facilities' energy effectiveness. These data are collected using a comprehensive literature review through which secondary data are collected from several recent peer-reviewed articles and research publications. Moreover, the theoretical research significance is as follows:

a. To enrich the literature review with state-of-the-art frameworks and intelligent techniques that can be implemented in the construction industry to enhance its performance and effectiveness.
b. To review a set of solutions and smart methods that can be used to increase buildings' sustainability and energy efficiency.
c. To employ numerical analysis and simulations using BEM software to verify the critical contributions and major role of smart and green techniques in boosting buildings' energy efficiency and performance.
d. To conduct further Research and Development (R&D) work on smart methods and green techniques that can foster construction industry sustainability and performance.

The practical significance of this research can be categorized into the following aspects:

a. The need for intelligent methods and innovative approaches that can remarkably improve the facilities' energy performance and effectiveness.
b. The requirement for higher performance construction materials and intelligent approaches to foster construction industry performance.
c. The necessity to help engineers, project managers, architects, and designers conduct further improvements on the construction sector's performance.

1.4 RESEARCH MAJOR AIM AND MINOR OBJECTIVES

The main purpose of this study is to investigate and analyze important strategies and intelligent approaches that can be utilized in the construction industry to enhance the sustainability and energy efficiency of buildings. Moreover, several secondary goals have been identified to accomplish the main objective of the thesis, which are outlined in the following sections:

a. To shed light on major limitations and challenges of the construction industry that limit the performance, sustainability, and effectiveness of buildings and facilities.
b. To identify the practical significance and beneficial contributions of smart construction methods that can improve buildings' sustainability and effectiveness.
c. To select a case study of a building that requires modifications and sustainable methods to promote its effectiveness.
d. To apply numerical analysis and simulation work using BEM software to assess and evaluate the critical role of intelligent construction approaches in fostering the building's performance and making it environmentally friendly and green.
e. To validate, verify, modify, and adjust the research findings according to a panel of construction experts' and sustainability professionals' points of view.

1.5 RESEARCH QUESTIONS

The work is conducted to examine the practical relevance and critical role of innovative construction approaches in improving the buildings' sustainability and performance. The numerical analysis conducted in the research will provide responses to the inquiries raised in the subsequent paragraphs.

a. What are the main difficulties and challenges of the construction industry that limit higher buildings' performance and effectiveness?
b. Could the utilization of intelligent construction techniques resolve these limitations?
c. What are smart construction methods' critical benefits and contributions that foster buildings' energy efficiency and sustainability?
d. Can the employment of green construction methods make buildings environmentally friendly and enhance their workability and performance?

1.6 RESEARCH HYPOTHESES

This research is conducted to examine the critical contributions of sustainable methods and smart strategies implemented to promote the construction industry's performance and energy efficiency. The research hypothesis will be validated or invalidated according to the simulation findings of this research (using BEM software). These hypotheses are presented in the following paragraphs:

a. Null Hypothesis, H_o – which assumes that: "Green methods and sustainable construction strategies could not improve the construction effectiveness and facilities' energy efficiency."

b. Alternative Hypothesis, H_a – which assumes that "Smart construction techniques are important to enhance the buildings' sustainability and make them green."

c. Sub Hypothesis, $H_{a,1}$ – which assumes that: "Using smart construction methods is beneficial as they can foster the energy savings in the buildings and make them reach zero-consumption goals."

d. Sub Hypothesis, $H_{a,2}$ – which assumes that: "Utilizing intelligent construction approaches is effective and practical due to their critical role in reducing facilities pollution and making them environmentally friendly."

e. Sub Hypothesis, $H_{a,3}$ – which assumes that "Applying smart construction techniques can boost buildings effectiveness due to the employment of smart and sustainable construction materials, passive lighting techniques, renewable resources, and energy-efficient cooling and heating methods."

1.7 THESIS STATEMENT

The title of this study is "*Implementation and Analysis of State-of-the-Art Sustainable Techniques to Improve the Construction Performance: An Iraqi Case Study*." This research is executed to investigate the critical role of novel sustainable methods and green building strategies in enhancing construction effectiveness and efficiency.

1.8 THESIS ORGANIZATION

The layout of this thesis includes five chapters. These chapters will cover several topics and key ideas associated with the beneficial role and importance of green strategies and smart methods that can promote construction performance and improve buildings' sustainability. The thesis layout can be summarized through the following articles:

a. Chapter One, with the section titled "Introduction" provides essential information related to the study's background, problem statement, significance, research questions, hypotheses, and primary and secondary objectives.
b. Chapter Two, which has the title of LITERATURE REVIEW, this chapter presents a discussion of strategies, methods, and approaches that are crucial for enhancing the performance of the construction sector and promoting the development of green and sustainable buildings and facilities. Chapter two also addresses the significant challenges and issues facing the construction industry, including high energy consumption and the use of unsustainable construction methods. Chapter two's information has been collected from a range of sources, including published master and Ph.D. dissertations, as well as web research engines such as ResearchGate, ScienceDirect, Academia, and Google Scholar. Furthermore, a variety of conference proceedings have been utilized to compile a database of green and sustainable construction methods, which contribute to the creation of environmentally friendly and intelligent buildings.
c. Chapter Three, which the section titled "RESEARCH METHODOLOGY" outlines the primary approach and methods utilized to conduct and execute this study. Also, chapter three explains critical study variables and parameters tested and investigated via the BEM software. The numerical analysis, modeling, and simulations of the building are crucial to identify significant methods and smart techniques to increase the buildings' energy efficiency and make it sustainable and green.
d. Chapter Four has the title RESULTS AND DISCUSSIONS. This chapter presents major thesis findings associated with the numerical analysis and simulations executed by the BEM software to predict critical improvements and fundamental methods to enhance construction performance and building sustainability.
e. Chapter Five, with the section titled CONCLUSIONS AND RECOMMENDATIONS, indicates the main study's conclusions associated with the research's numerical findings

from the BEM software. Further, chapter five illustrates a set of recommendations and key suggestions related to future work to provide critical ideas for scientists and engineers to carry out further improvements on enhancing construction performance and sustainability of facilities.

2. LITERATURE REVIEW

2.1 AIM AND INTRODUCTION

In the second chapter, various effective strategies and intelligent methods are discussed to enhance the sustainability of the construction industry and enable the creation of green and eco-friendly buildings and facilities. The chapter also highlights the major challenges and issues faced by the industry, such as high energy consumption and the use of unsustainable construction methods. To gather information for this chapter, a range of sources were consulted, including master and PhD dissertations, as well as research engines such as ResearchGate, ScienceDirect, Academia, and Google Scholar. Additionally, several conference proceedings were used to compile a database of sustainable construction methods that promote environmentally responsible and intelligent building practices.

2.2 CRITICAL ISSUES AND MAJOR CHALLENGES OF EFFICIENCY AND PERFORMANCE IN THE CONSTRUCTION INDUSTRY

Conducted a study investigating major obstacles and critical challenges associated with implementing significant energy efficiency and high performance of buildings in the construction sector [45]. reported that considering innovative methods by engineers, project managers, and policymakers is remarkably important for achieving buildings' energy efficiency and using intelligent approaches to provide valid structures' performance, as buildings contribute to approximately 40% of worldwide annual energy consumption. [45] stated that facilities are required to offer a higher level of comfort, a healthy environment, and better living conditions for humans. In addition, smart building methods are vital to reducing facilities' Greenhouse Gas (GHG) emissions and minimizing the overall buildings' energy consumption. [45] applied a comprehensive literature review through which innovative building methods, milestones, vital issues, and building classifications were classified. In addition, the literature identified major obstacles in implementing energy efficiency practices in buildings. The literature results revealed that energy efficiency and performance concepts play a critical role in reducing buildings' energy consumption and improving their performance. In addition, the research findings confirmed a strong relationship between building energy use and occupants' activities. Therefore, a shortage of awareness and understanding of occupants' behavior in buildings is considered a challenge to offering better building energy performance. Furthermore, another critical challenge associated with efficiency and performance measures implementation in the construction industry is the limited effect and application of energy efficiency concepts in buildings since 1970. [46] carried out research examining key obstacles and critical challenges of applying sustainable measures and energy efficiency practices in buildings. [46] reported that several environmental issues in buildings had been significantly growing and, at the same time, not adequately addressed. This aspect indicates people's incapability and insufficiency to manage and resolve such concerns.[46] depended on secondary data collection via a systematic literature review to collect and analyze their data. The results confirmed that the natural environment and buildings are subjected to some obstacles and challenges mirrored by climatic disturbances, threats, repetitive flooding events, and heavy and sudden rain because of the change in the tropical climates. In addition, it was found that negative human impact and the increase in industrial activities put a burden on implementing sustainability principles and reducing the energy consumption of buildings. For these reasons, it is highly significant to apply sustainable building strategies, which are considered a critical element in the ecological balance for buildings and human comfort. For instance, hydrogen fuel can be used to replace fossil fuel resources that are not sustainable and cause remarkable environmental pollution, air pollution, and GHG emissions. [47] performed an analysis to identify and determine critical challenges and obstacles in implementing ecological performance and energy efficiency measures in buildings. They conducted a cross-sectional study in which four buildings used survey questionnaires to assess and evaluate users' satisfaction regarding the sustainability and energy efficiency of the facilities in Brazil. Additionally, the authors made a detailed energy auditing process covering thirty-three Brazilian office buildings to address the obstacles and difficulties in implementing sustainability and energy efficiency in these buildings. Based on the survey questionnaires and energy auditing process, the research results confirmed that several buildings in Brazil failed to achieve the optimum design levels, including occupants' satisfaction, higher indoor environmental quality, and energy efficiency. Besides, the study identified an overall 333 failure indicators associated mainly with errors in Operation and Maintenance (O&M) and Design and Construction (D&C). Moreover, it was found that small- and medium-sized office buildings typically perform similar failure problems repeatedly, causing a reduction in the building's performance. Also, the results indicated that large-size offices require significant experience to operate the facility and attain higher sustainability and energy efficiency. Figure 2.1 presents the major energy analysis of building investigated in their study.

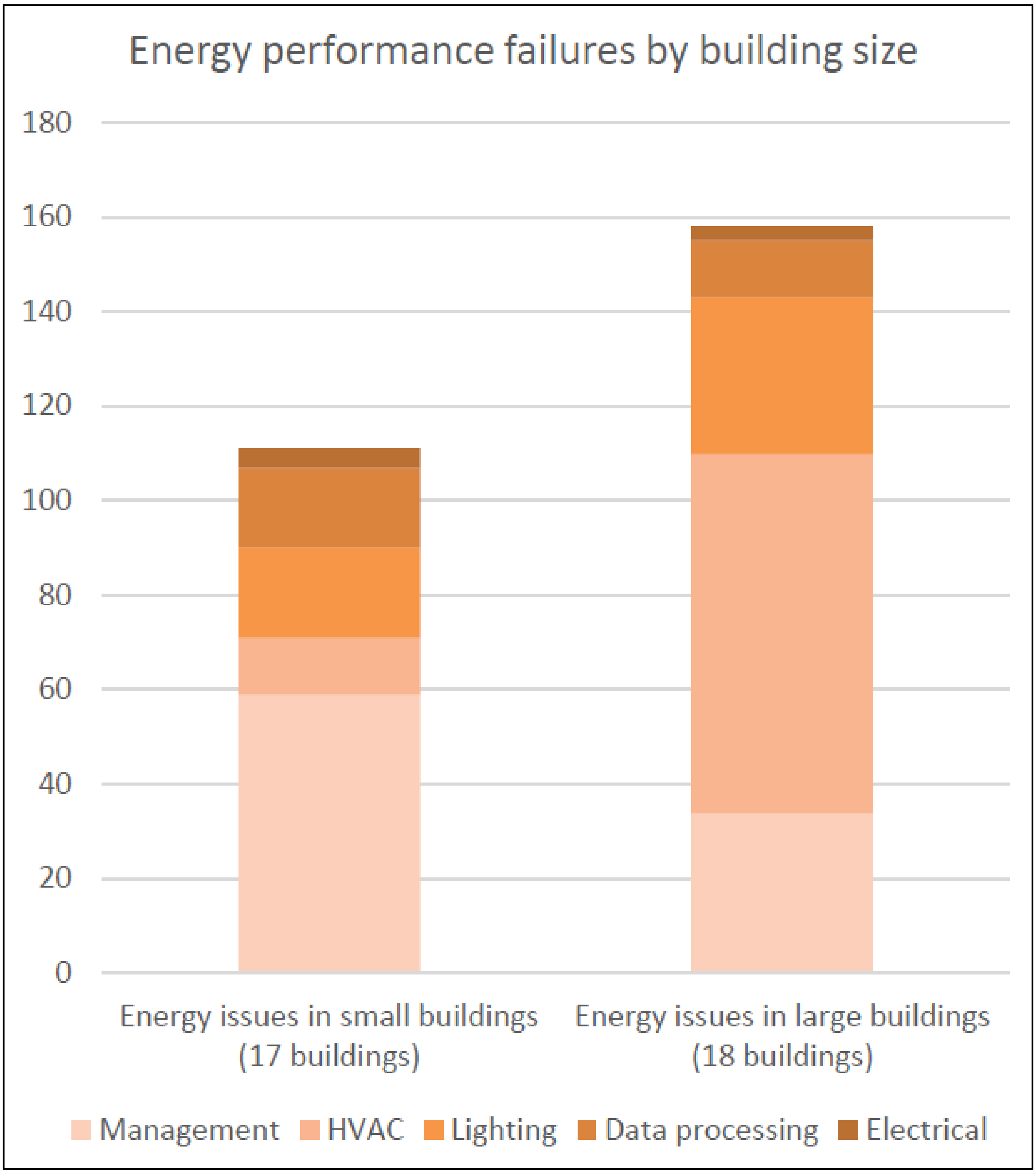

Figure 2.1: The Major Energy Analysis of a Building [47].

2.3 INNOVATIVE STRATEGIES AND GREEN TECHNOLOGIES TO IMPROVE FACILITIES' SUSTAINABILITY

Executed a study examining innovative approaches and green technologies to improve facilities' sustainability. They applied Artificial Intelligence (AI) to design and develop smart buildings with higher energy efficiency and sustainability levels [48]. reported that using AI principles enables the improvements of smart buildings and optimizes their energy consumption via the use of sensors and devices that provide big data to enhance the overall buildings' energy efficiency through automation, higher reliability, and better control. The authors relied on secondary data collection to highlight and address the significance of AI in improving the buildings' sustainability and energy consumption, depending on recent publications and peer-review articles. The research results confirmed that AI principles, Demand Response Programs (DRPs), and Building Management Systems (BMSs) are remarkably beneficial and valuable in improving the energy efficiency of facilities and optimizing the buildings' energy consumption. These approaches can predict energy use, evaluate buildings' energy performance, and assess human living comfort in buildings. Also, the research outputs that these AI strategies help achieve optimum building' design and maintenance that ensure acceptable energy efficiency and better energy performance. Figure 2.2 represents the cyber-physical energy system implemented in energy-saving buildings .

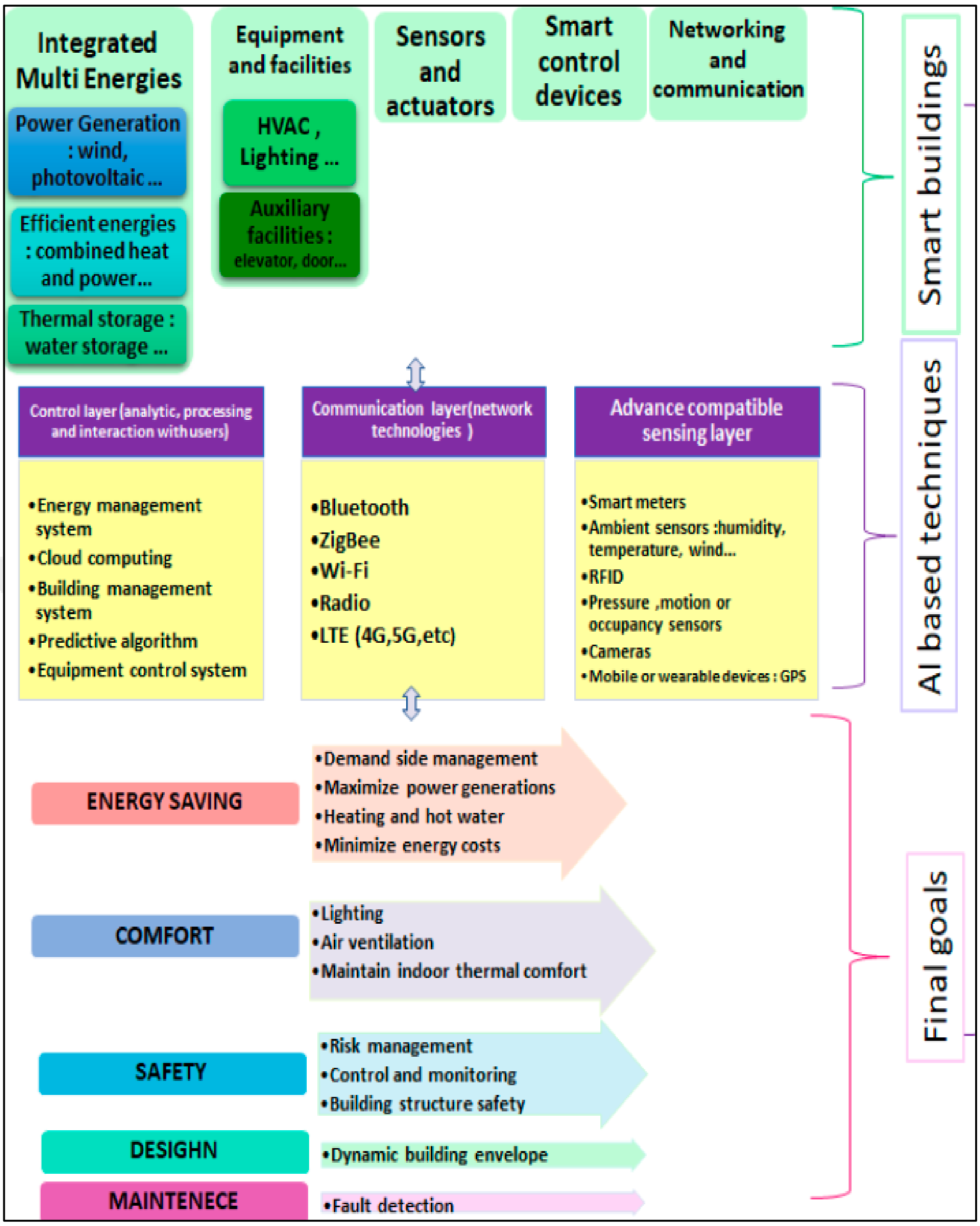

Figure 2.2: The Cyber-Physical Energy System Implemented in Energy-Saving Buildings [48].

Conducted an analysis exploring the critical role of new methods and modern strategies in improving the buildings' performance and energy efficiency. They employed an approach that combines Intelligent Metaheuristic Algorithms (IMA) and Artificial Neural Networks (ANNs) to assess and examine their building's indoor thermal comfort and energy performance depending on multiple objective optimization processes. Figure 2.3 represents their investigated case study related to the ground floor - 2D plan besides thermal zoning [49].

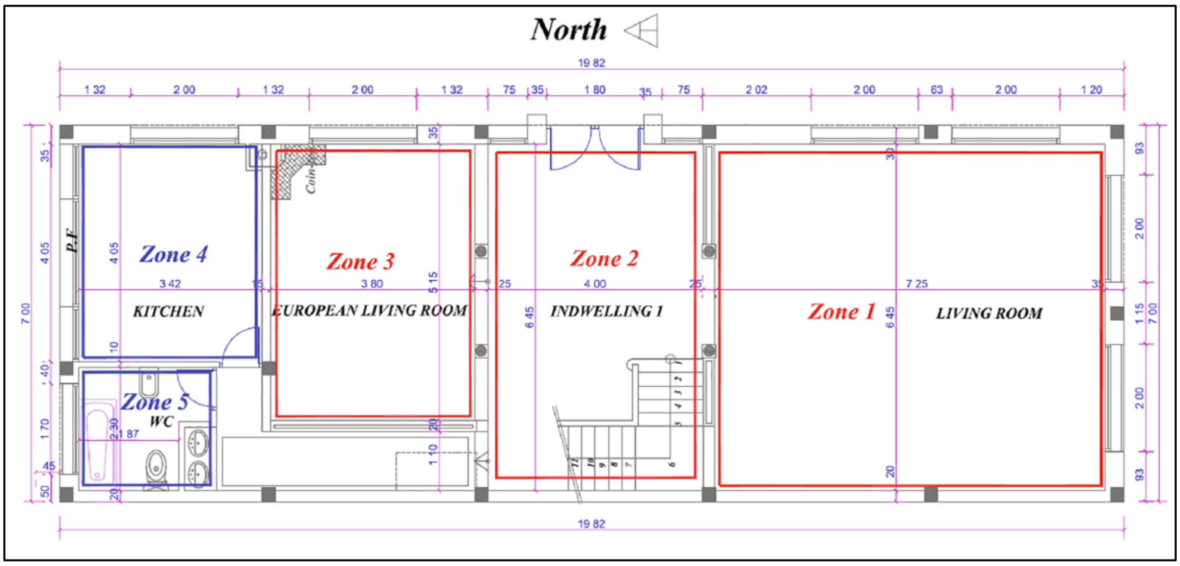

Figure 2.3: Their Investigated Case Study Related to The Ground Floor - 2d Plan Besides Thermal Zoning [49].

Furthermore, Figure 2.4 indicates their investigated case study related to the first floor - 2D plan besides thermal zoning.

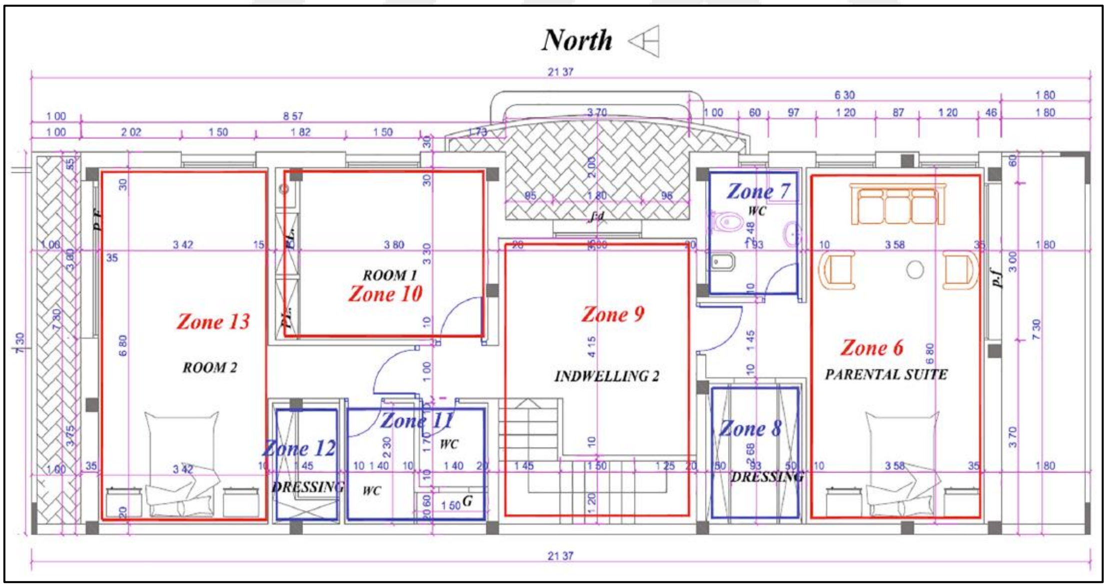

Figure 2.4: Their Investigated Case Study Related to The First Floor - 2d Plan Besides Thermal Zoning [49].

Reported that multiple objective optimization processes had been widely employed due to their beneficial role in estimating the energy efficiency of several buildings [49]. They investigated a case study, which included a two-floor residential building in Morocco (including the ground and first floors). This building is located in the Marrakech zone (considered the 5th climatic region depending on the Moroccan Thermal Building Codes). The most effective and influential parameters used in the building design and thermal comfort were assessed. Also, they used Multi-layer Feed-forward Neural Networks (MFNNs) and Multi-Objective Genetic Algorithm (MOGA), Multi-Objective Particle Swarm Optimization (MOPSO), and Nondominated Sorting Genetic Algorithm (NSGA-II). These algorithms are essential to reduce the computation time of the problem. Moreover, they implemented numerical modeling and simulations via the TRNSYS software to generate thermal simulation datasets needed for training the algorithms. The research results revealed that their proposed methodology was successful in achieving the study goals. The results indicated that thermal and cooling loads of the Moroccan residential building had been remarkably minimized to roughly 74.52% of the overall heating and cooling demand. In addition, it was found that indoor thermal comfort was improved to around 4.32% compared with the original design. Based on these results, they strongly affirmed and recommended their successful approach to use in buildings' thermal performance and thermal comfort for engineers, architects, and designers. [50] carried out research classifying the critical role and benefits of innovative methods in optimizing the energy consumption of buildings, achieving better performance, and improving their sustainability. [50] relied on AI. They listed the current status, future opportunities, and major challenges associated with AI implementation in the construction industry from recent publications and peer-reviewed articles. Their literature analysis showed that the development in the construction industry is limited by some factors, including labor shortages and productivity, safety and health, and time and cost overruns. Furthermore, the results indicated that the construction sector had the lowest digitalization rate compared with other sectors. For these reasons, considering the use and application of AI approaches (such as optimization, computer vision, knowledge-based systems, and machine learning) in the construction industry and building could improve construction sustainability, waste, and resources optimization, risk management, and activity monitoring. However, AI application in the construction industry faces some challenges mirrored by a lower level of skills, talents, and experience associated with AI principles and implementation. [51] executed research identifying the substantial role of Building Information Modeling (BIM) technology in assessing and estimating building energy consumption with a higher degree of accuracy and considering sustainability aspects. reported that buildings consume a higher amount of energy and electrical power, which puts some burdens on their sustainability and energy efficiency [51]. Therefore, they investigated the major contributions of BIM principles in estimating the facilities' energy consumption, sustainability, and energy performance, considering residential buildings in Portugal. They applied numerical simulations via the Sustainability Assessment Tool (SBToolPT) software package. The results revealed that using BIM technology and software tools that take into account sustainability measures is greatly beneficial, as they can save much time and effort for designers to calculate the buildings' energy consumption under sustainability requirements. Additionally, their research findings affirmed that the SBToolPT software package is an excellent simulation tool that can help enhance the building's energy performance, optimize energy consumption, and develop thermal energy evaluation based on sustainability standards. [52] carried out a study examining the critical contributions of BIM technology in achieving higher sustainability and energy efficiency of buildings. [52] relied on a case study investigation in which they selected a school building and implemented BIM principles and optimization to estimate the energy efficiency and performance of the school buildings considering sustainability aspects. The research results indicated that the use of the optimization process and BIM technology led to significant enhancements in indoor environmental quality (by roughly 11.5%). In comparison, the life cycle cost of the building was minimized by around 36.8%. Also, the research findings affirmed that their BIM framework was practical and could be used for several designs associated with data-driven green buildings. Also, they suggested that their model could be employed for future estimations of energy efficiency and performance of buildings depending on sustainability considerations. [53] conducted research classifying major contributions and critical relevances of BIM technology in evaluating buildings' energy efficiency and performance. [53] depended on Monte Carlo simulation analysis (for improving accuracy), BIM software tools, and the regression method to achieve the research goals. They investigated a case study of Abercrombie Business School and estimated energy consumption and performance. They used the Autodesk REVIT Green Building software package to estimate the energy consumption of the building. They considered some factors in their analysis, including ceiling construction, wall construction, floor construction, floor-to-ceiling height, analysis year, building area, location, and building types. Their research results indicated that the accuracy of their proposed model provided by the Monte Carlo simulation method provided higher accuracy in estimating the building'. They validated their proposed model through 35 runs, and the results showed that they gave an error of less than 5%, which means that this result is acceptable in the estimation process. (7) [53] proposed a regression model based on building information modeling (BIM) tools to evolve a green building energy simulation. They determined the important parameters for the performance of the building energy system that help the engineering during the early stages of building design. Then, they used the energy simulation results to build the multilinear regression model. They also used REVIT as a BIM tool to create energy models based on building models, which reduced processing time. They used the data preprocessing steps to clean the dataset before applying the statical analysis to carry out the relationship between features and the amount of energy. REVIT software can incorporate numerous design factors, such as building orientation, wall construction, infiltration, lighting efficiency, roof construction, plug load efficiency, daylighting, and occupancy control. The findings indicated that the regression models had a lower margin of error, within 10%, indicating a satisfactory outcome. [54] summarized the current state of zero-energy buildings and the corresponding technological solutions in the field of energy consumption. The technical solution is categorized into three parts: energy efficiency measures, power supply, and generation systems, and control and management strategies. Each solution in this study was composed of multiple sub-parts. For example, the first solution included passive solutions for space heating and cooling, lighting, and other equipment, as well as active solutions for those same areas. The second solution considered a variety of renewable energy sources, including wind and solar energy, heat pumps, district heating and cooling, and bioenergy. The study also presented case studies of both new zero-energy buildings and retrofitted buildings. Overall, the projects and technologies featured in these case studies demonstrate effective ways to use energy and reduce the environmental impact of buildings, providing valuable insights for researchers and engineers. [55] aimed to investigate the impact of combining blockchain and Building Information Management (BIM) on the sustainability of building construction and design in smart cities. The researchers conducted a bibliometric analysis and micro-scheme analysis to visually analyze the relationships between blockchain, BIM, and sustainable building within the context of smart cities and CIM. They used keywords to search the Web of Science (WoS) database and retrieved relevant publications. The results of the study showed that the integration of BIM, blockchain, and facility management can greatly enhance construction project execution, maintenance management, and construction performance evaluation. Additionally, the study demonstrated the significance of the proposed integrated method in highlighting the interconnections between these three topics and spotting research trends, thereby providing a clear research direction for future investigations. [56] explored the potential of Internet of Things (IoT) and data visualization in enhancing safety and sustainability in Cesena (Smart) Campus. Their proposed framework consists of two parts and three layers. The first part is an edge-based system that uses cameras to count individuals, while the second part is composed of environmental sensors that gather data on various factors such as temperature, humidity, air pressure, formaldehyde, PM1.0, PM2.5, PM10 levels, and air pollutants. The three layers include the data acquisition layer, which collects data and utilizes Intel RealSense D415 Depth cameras, the prediction layer, which obtains data from these cameras, and the API layer, which retrieves information from specific servers. Through the implementation of their system, they demonstrated that it is possible to enhance sustainability (by saving energy) and security (in compliance with COVID-19 regulations) on the campus. [57] reviewed the smart city research paradigm in order to determine the potential hazards, inconsistent findings, and areas that could use more investigation. They reviewed the smart city concept in terms of goals, smart city initiatives, building blocks in a smart city, and stakeholders in a smart city. Also, they determined three key characteristics that can be used to define a smart city: 1) the extent to which ICT infrastructure is used to boost urban development efficiency; 2) the competitiveness the city offers to boost wealth, and 3) the extent to which sustainability and social inclusion are supported. The key finding of this study was that the interdependencies, conflicts, and complex nature of smart city objectives are not well addressed by current research on smart cities. The study also discovered that because the current methods and rankings of smart cities vary greatly, it is difficult to assess the success of smart cities. As a result, the study concluded that smart city initiatives form complex and multidisciplinary platforms that require holistic evaluation. [58] integrated a machine learning model with model-based control strategies to include arbitrary biological influences in building management architecture. They presented this integrated model as a solution to two major issues in the initial study on building management and control. The initial issue is the absence of any attempts to incorporate real-time learning of subjective building attributes into model-based control design. The concentration on improving a building's thermal or visual characteristics without properly managing all of its subsystems and goals, such as its environmental conditions, physical models, comfort requirements, inhabitants' preferences, and safety in the design, is the second problem. Another benefit of their proposed solution is the integration of model-based and learning-based control schemes into a single management framework, which manages multiple elements of building performance. According to the study findings, the accuracy of the building mechanism model is usually essential for current model-based building control methods. Furthermore, the recommended management system ensures optimal overall comfort in buildings, while using the least energy in appropriate subsystems, such as thermal, visual, auditory, olfactory, and hygienic comfort. [59] T proposed a novel framework that integrates Building Information Modeling (BIM) applications in smart buildings through three dimensions: Project phases, smart attributes, and BIM attributes. They discussed the advantages of using BIM to attain varying levels of smartness, the use of BIM applications in different stages of smart building construction, and smart building functions achievable through BIM. The primary contribution of the paper is to identify research gaps and emerging trends, which include enhancing BIM software interoperability, exploring the role of BIM in operating and renovating smart buildings, researching BIM technology in transportation infrastructure, emphasizing the financial benefits of BIM projects, and integrating BIM with other technologies. [60] utilized a dataset from Bangladesh as a case study to assess the potential of green building practices as a means of adapting to climate change. They conducted interviews with various experts from both government and non-government sectors in Bangladesh, collecting data from 21 key informant interviews and four in-depth interviews. Despite the existence of several organizations in Bangladesh that focus on green buildings, the majority of experts (57 percent) expressed their concerns that the assessment tools are still insufficient. In addition, negative public views of a new change and a lack of governmental oversight are cited as important barriers to the adoption of green construction principles. Fair laws and regulations must be upheld to address these issues. [61] conducted research identifying the critical role and major contribution of IoT principles in achieving green and sustainable energy systems. [61] implemented a comprehensive literature survey through which they addressed the importance and beneficial impacts of employing IoT tools to make buildings and facilities green. Their literature survey revealed that using IoT helps manage the buildings and provides large databases of buildings to minimize the significant energy consumption throughout the operation, design, and construction process of these buildings. Additionally, using IoT contributes to an enhanced design of buildings and reduces their monthly energy bill. Also, the survey results indicated that IoT could provide efficient and effective employment of resources used in buildings. [62] introduced several hybrid methods to enhance the comprehension of sustainability in construction project management. The study had three main objectives: (1) to explore the concept of sustainability in construction project management; (2) to determine sustainability indicators for construction projects based on relevant literature; and (3) to classify the identified indicators based on the triple-bottom-line sustainability framework, which includes environmental, social, and economic dimensions. The hybrid approaches involved carrying out a Systematic Literature Review (SLR) to analyze literature and identify indicators previously discussed in building projects, as well as conducting semi-structured interviews with experts to validate the identified indicators for sustainable project management practices in construction projects. The researchers gathered 4,772 documents and eliminated 3,535 duplicate documents. The results of the study showed that the SLR and semi-structured interviews found a total of 27 indicators, comprising 18 indicators related to the environmental dimension and 37 indicators related to the social/management dimension. [63] conducted a quantitative bibliometric analysis using a meta-analysis approach based on the Web of Science search. This is done by using a group of keywords and filtering methods applied to 433 papers which were published in 18 years. They used the Visualization of Similarities (VOSviewer) as quantitative analysis software to analyze the documents. They have demonstrated that, in comparison to the environmental pillar, the social and economic pillars are less commonly addressed. Additionally, it was felt that additional research needed to be done on the stages of operation and maintenance because the majority of publications only cover the planning and implementation of on-site work. Future research can refer to these findings as a source of reference.

2.4 CHAPTER SUMMARY

Depending on the systematic literature review carried out to assess the critical role and advantageous impacts of state-of-the-art sustainable methods in improving construction performance, it can be inferred that several peer-reviewed articles and research publications addressed beneficial methods and intelligent approaches that can be adopted in buildings to enable sustainable design, green operation and eco-friendly construction of buildings. These intelligent methods are considerably significant in reducing the energy bills and resources required in buildings. Major smart methods and intelligent techniques employed to make buildings green are the IoT, artificial intelligence, energy modeling and simulations tools of buildings, BIM technology to investigate energy consumption of buildings via the REVIT software package, smart buildings concept, zero-energy building notion, and energy efficient and effective building approaches. In this work, the critical role of novel sustainable mechanisms and green building techniques are addressed and investigated aiming to enhance construction effectiveness and efficiency.

3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

To achieve the research goals, it is essential to establish a methodology and procedures for conducting the research. The reliability and credibility of the research depend on selecting an appropriate methodology that is in line with the research's objectives and able to address the research questions accurately.

The stages of conducting the research and choosing the best methods for data collecting and analysis are covered in this section of the study.

A mixed research method (qualitative and quantitative) will be used to gain knowledge about the implementation and analysis of state-of-the-art sustainable techniques to improve construction performance. The selection of this strategy aids in making the construction indicators chosen from the literature to design the questionnaire more realistic and accurate.

The objective of the statistical investigation conducted in this chapter is to ascertain the ranking and relative importance of the key variables that influence the analysis and use of innovative sustainable construction techniques.

The questionnaire will be selected in the process of data analysis based on a set of questions related to the adoption and analysis of state -of- the art sustainable techniques to improve construction performance.

3.2 RESEARCH APPROACH

The study is founded on two primary methods:

a. Deduction Approach: This type of approach is used in the inference followed in order to derive theories and hypotheses from them, test those hypotheses, review the theory, and then move to the data. In this type, the relationship between all the variables must be determined, and quantitative data applied.

A graphical representation of the deduction approach process can be illustrated in Figure 3.1.

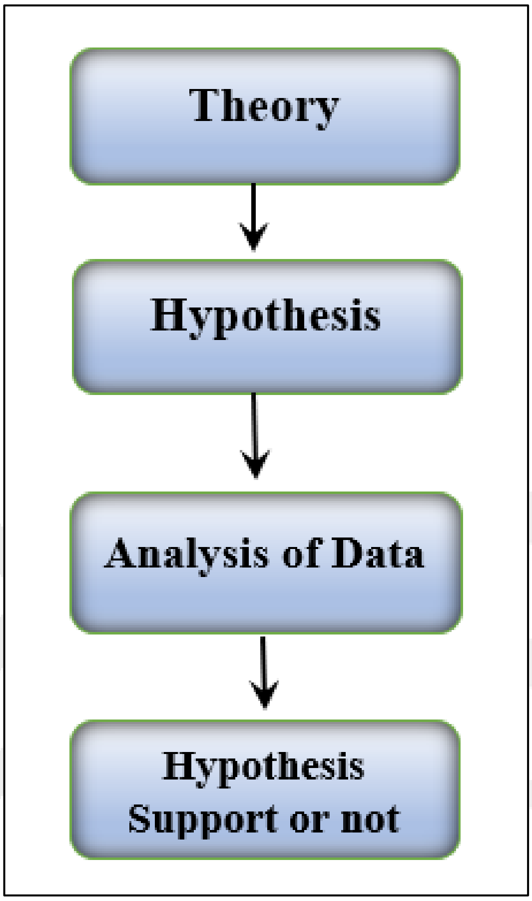

Figure 3.1: A configuration of The Deduction Approach Process.

b. Induction Approach: This type of approach is used to know and understand behavior about things in addition to collecting qualitative data [64]. This type depends on a group of deductive and inductive methods, as it depends on observations and theories, and the transition from data to approaches is carried out.

A graphical representation of the deduction approach process can be illustrated in Figure 3.2.

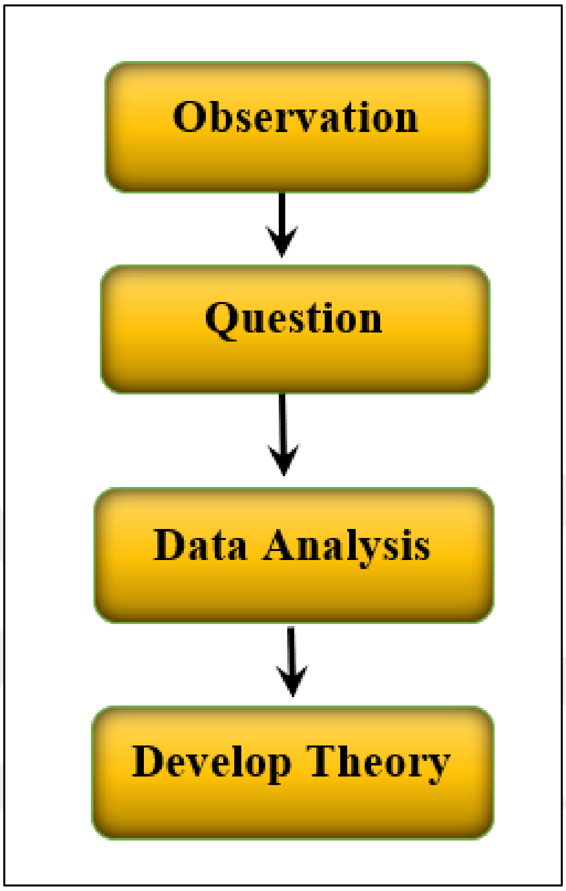

Figure 3.2: A Configuration of The Induction Approach Process.

3.3 RESEARCH TYPES

In general, the types of research are divided into three basic types: qualitative, quantitative, and mixed. As the research inquiries demand gathering and analyzing data of both quantitative and qualitative nature, A mixed methodology will be utilized in this study.

3.3.1 Mixed Research

The mixed research methodology is a research approach that combines the use of quantitative and qualitative data in a single study. This involves the collection and sequential analysis of data, with the integration of data being a crucial aspect throughout the various stages of the research process. This is because the accuracy and validity of the findings depend on how well the research methods align with the research questions being investigated. [65]. To clarify, this method assists researchers in addressing inquiries that cannot be sufficiently resolved through purely quantitative or qualitative techniques. It furnishes a comprehensive representation by examining the viewpoints and understandings of participants.

3.3.2 Quantitative Research

Mentioned that quantitative research as a research approach based on the principle of collecting numerical data that is analyzed through statistical methods [66]. This makes the resulting data reliable and measurable and can be distributed over a large number of the population [67]. In other words, quantitative research is based on providing answers to the study questions with further explanation and interpretation based on graphs, statistics, numbers, and numerical results of the investigation.

3.3.3 Qualitative Research

Qualitative research is based on providing the researcher with an appropriate way to understand the research problem through observation or interaction with study participants [68]. The gathering of data, analysis of the findings, and behavior analysis based on expressions and concepts are all necessary for this form of research, though [69]. The Five-Likert scale was used in this study to combine qualitative and quantitative research into a single quantitative approach.

3.4 SAMPLING TECHNIQUES

One of the key procedures for conserving time, effort, and money is choosing the samples to be analyzed. Engineers who operate in Iraq's construction industry make up the research sample in this study. There are approximately 100 engineers who have specialized in this sector. A statistically representative sample of the population was discovered using the Stephen-Thomson equation [70].

$$n = \frac{N \times p \times (1-p)}{(N-1) \times \frac{d^2}{Z^2} + p \times (1-p)} \tag{3.1}$$

Where:

n : The sample size

p : The population proportion

Z : The standard score corresponding to the significance level (0.95), which is equal to (1.96)

d : The standard error of the sampling distribution (0.05)

N : The population size

Depending on [71], the suggestion (p) has a value of 0.5 if the p-value is uncertain. When necessary, a large sample size is obtained. The researcher employed a confidence level of 95% and a significance level of 5% in this investigation.

To determine the appropriate sample size for the population, the following calculation was performed:

$$\mathrm{n} = \frac{100 \times 0.5 \times (1 - 0.5)}{(100 - 1) \times \frac{0.05^2}{1.96^2} + 0.5 \times (1 - 0.5)} \approx 79. \tag{3.2}$$

Iraq's population (N) of engineers employed in the contracting and construction industry totals 100.

3.5 RESEARCH METHODOLOGY

To identify the factors affecting the implementation and analysis of cutting-edge sustainable techniques to improve construction performance, various methods with varying degrees of accuracy, complexity, and success are applied in the construction industry. The survey was used as a tool for this study, and a clear research methodology was devised to understand the research problem and its solution, as well as to answer the research questions. The methodology includes induction and deduction methods, qualitative and quantitative research methods, research strategies such as experiments and surveys, and the gathering and analysis of data from questionnaires, observations, and interviews. The survey approach utilized a Five-Likert scale to convert qualitative data into quantitative measurements. Figure 3.3 illustrates the stages of the research approach.

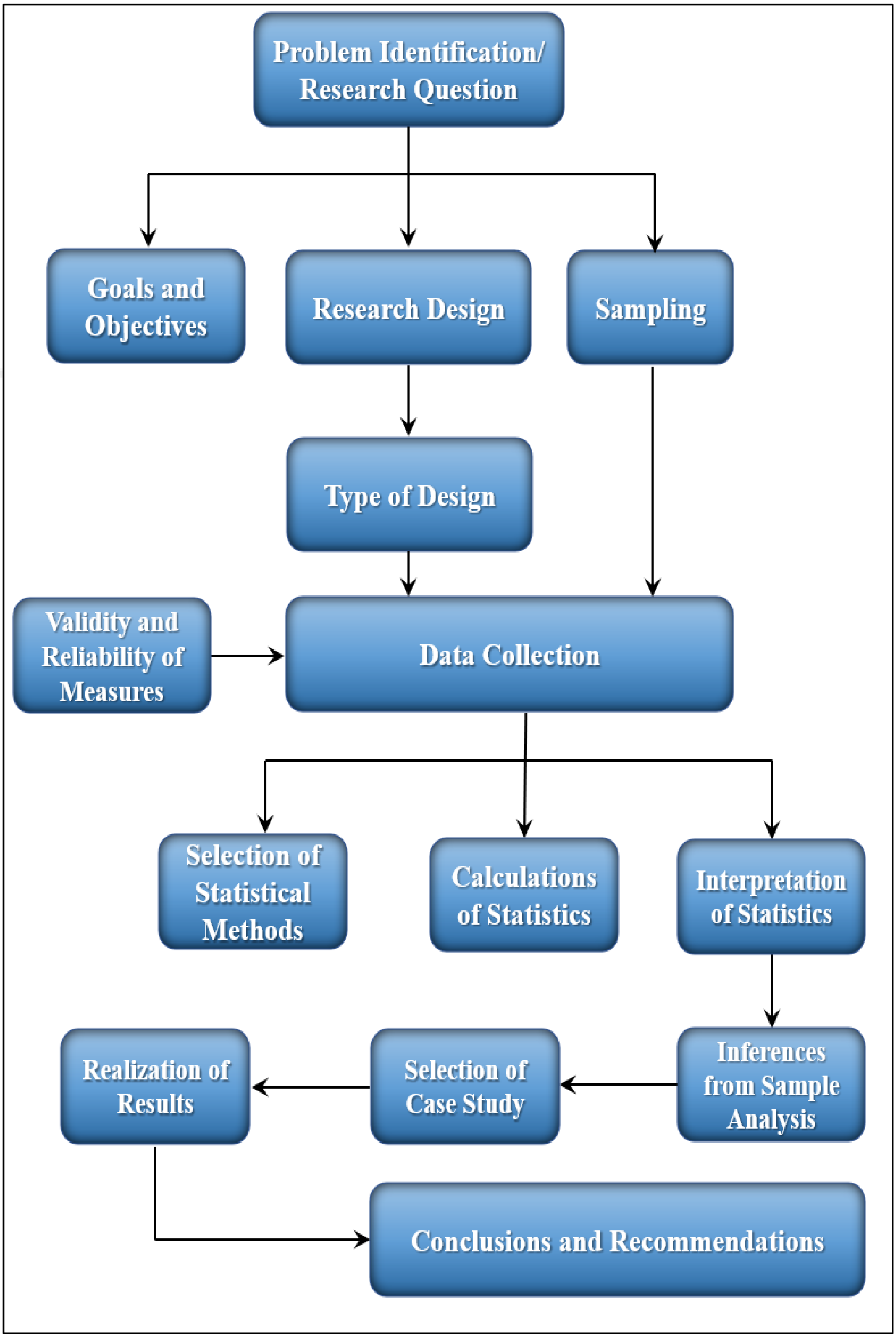

Figure 3.3: The Flowchart of The Research Methodology.

Furthermore, Figure 3.4 represents the diagram associated with the research methodology linked to all research types and study approaches employed in this work to collect the necessary primary data from the study respondents.

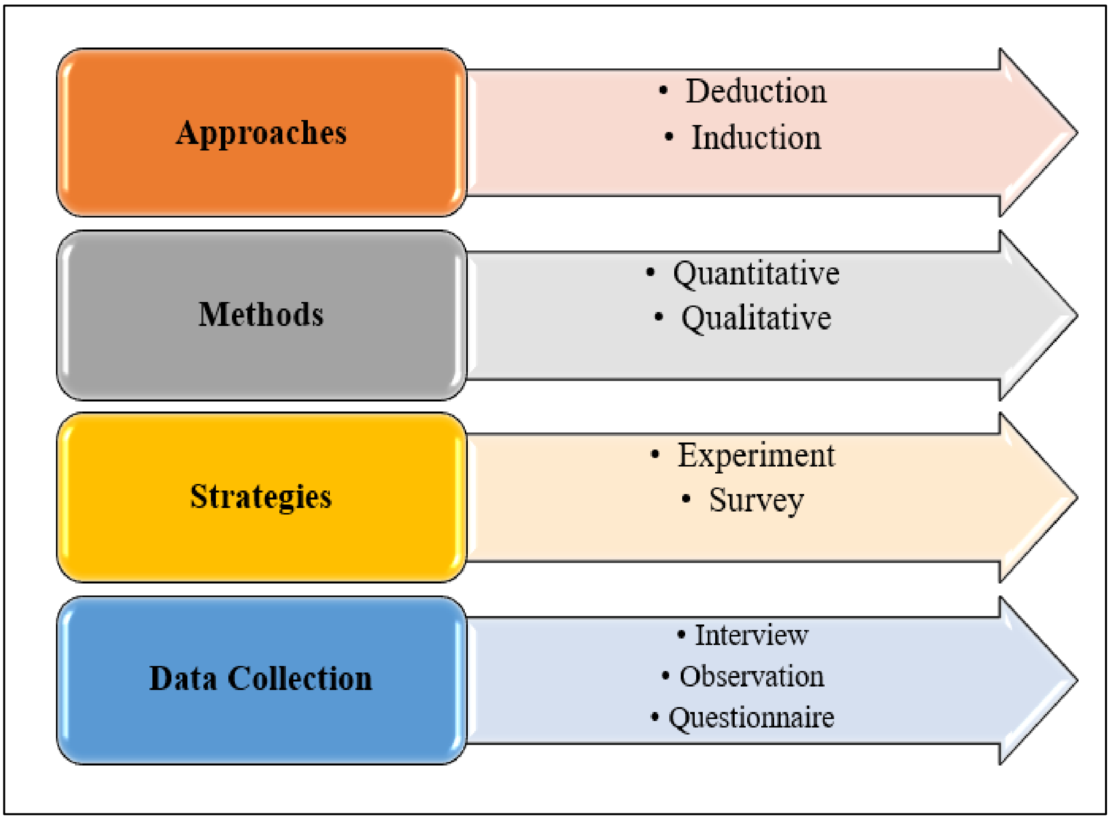

Figure 3.4: The Research Methodology of All Research Types and Approaches Employed in This Work.

3.6 DATA ANALYSIS TECHNIQUES

The Objective Analysis (TOA) approach, a practical instrument for exploratory analysis of qualitative data obtained from interviews, will be used. There will be six basic steps in the objective analysis [64]. Figure 3.5 indicates the data analysis techniques important for the research analysis and data collection.

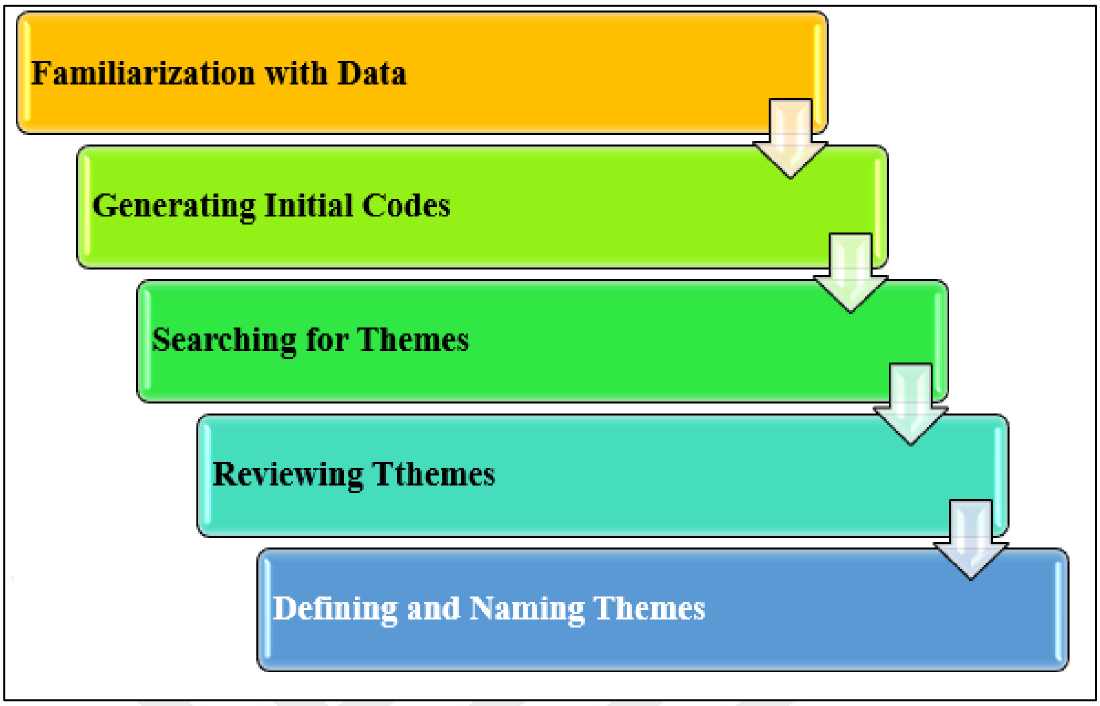

Figure 3.5: The Major Stages of The Research Analysis.

Conducting this research is extensive research in the work literature related to the implementation and analysis of state -of- the art sustainable techniques to improve construction performance. The measures that will be taken for collecting and analyzing quantitative data are as follows:

a. Literature survey:

We were able to grasp perspectives on the application and analysis of cutting-edge sustainable ways to increase construction performance through research material found in books, conferences, journals, publications, the internet, and related research theses.

b. Fieldwork (data collection):

To gather information for the study, semi-structured interviews will be held with a group of engineers employed by construction firms. An update will be prepared for the initial lists of implementation and analysis of state -of- the art sustainable techniques to improve the construction performance. The survey tool will then be created and beta-tested before being used fully [72].

c. Arrange information in a Word sheet to indicate and arrange the data.

d. Using the Statistical Package for Social Sciences (SPSS) program to analyze the data gathered to test hypotheses.

Figure 3.6 represents a graphical illustration of the steps and research procedures linked to the data analysis techniques.

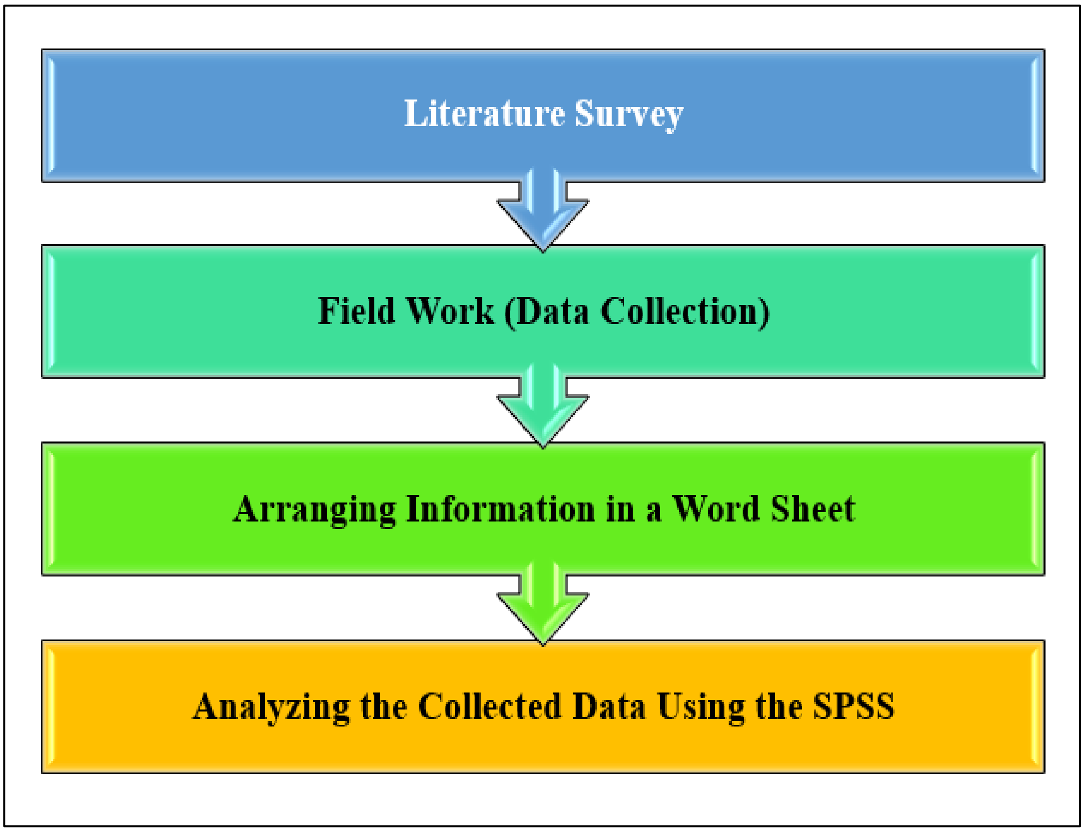

Figure 3.6: The Steps and Research Procedures Linked to The Data Analysis Techniques.

3.7 QUESTIONNAIRE DESIGN

Because it was being utilized as a survey method with engineers from Iraqi construction businesses as the target sample, the questionnaire was created with accuracy in mind. The main goal of the questionnaire is to discover the variables that influence the analysis and application of cutting-edge sustainable construction practices in order to improve construction performance.

The questionnaire utilized various sources, including prior research and studies, and also involved the distribution of an open-ended questionnaire to a group of construction engineers to identify the most crucial factors impacting the application and analysis of advanced sustainable techniques for enhancing construction performance.

The questionnaire is examined for these three essential components:

3.7.1 Questionnaire Validity

The validity of the questionnaire is determined by the amount of inaccuracy in its form and components. Its accuracy is confirmed by submitting it to a committee of specialists who will carefully review the questionnaire's content and sections [73].

3.7.2 Questionnaire Reliability

When examining the data from the various samples, the reliability of the questionnaire is taken into account as a metric that upholds the stability and consistency of the questionnaire. It is possible to lower the questionnaire's reliability if a divergence is seen because of the respondents or if issues start to appear with the measuring devices. Experimental instruments are used in the measuring procedure, after computing the sample mean, the reliability of the questionnaire is evaluated by calculating the Cronbach's alpha coefficient [73].

3.7.3 Content Validity

This step focuses on assessing the validity of the material and highlighting the clarity and question sequencing of the questionnaire. The questionnaire is given to experts in order to discover any deficiencies, and those weaknesses are subsequently addressed in accordance with the experts' recommendations [73].

Figure 3.7 represents the major processes and steps adopted and executed to design the thesis questionnaire.

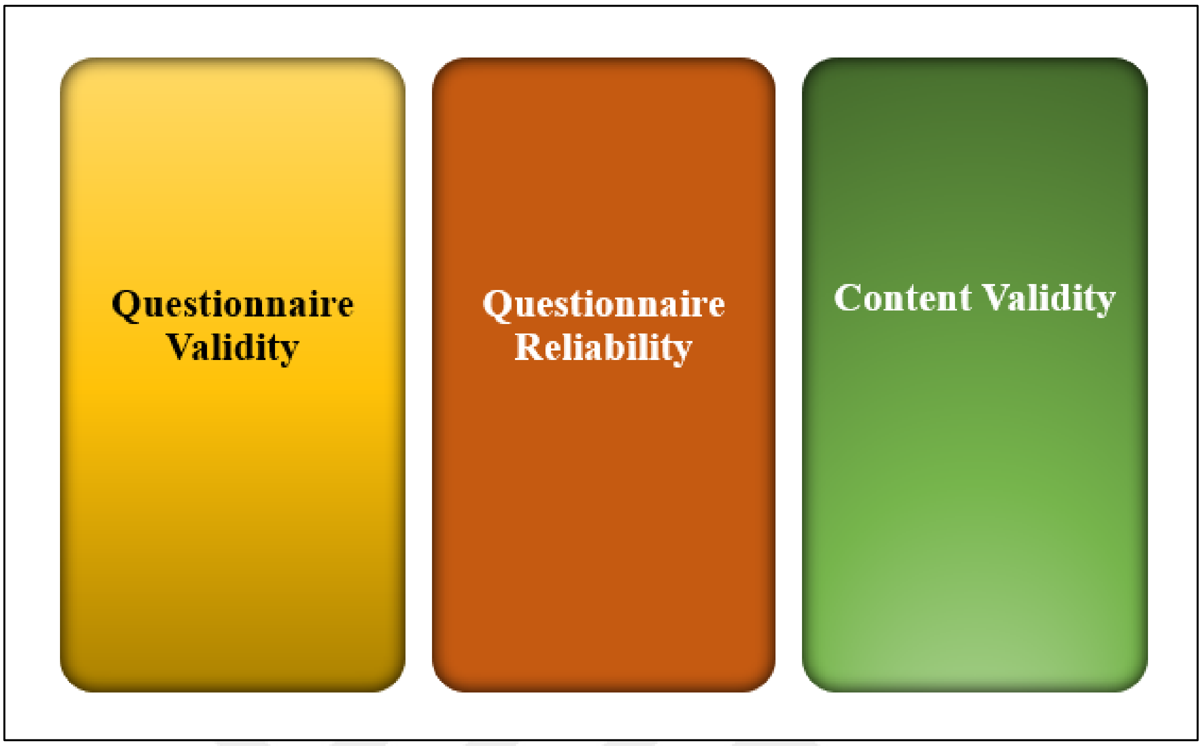

Figure 3.7: The Major Steps Adopted And Executed to Design The Thesis Questionnaire.

3.8 MEASUREMENT DEVELOPMENT

To assess the importance and value of variables, a measurement scale was created taking into account the various types of measurement scales available, such as:

a. Nominal Scale: Measurement of categorical data and numbers that appear as names and identifiers is done using the nominal scale.
b. Ordinal scale: This type displays relationships in an organized and distinct manner.
c. Interval scale: The zero point on an interval scale is just another point of measurement, as quantities are measured using comparable units.
d. Ratio scale: Similar to how the Interval scale does, this scale also represents the quantity and equality of units. On this scale, however, there is additionally an absolute zero, which means that there aren't numbers below zero.

In order to quantify the values and the level of importance for this study, the Likert scale was used in addition to the ordinal scale, which was based on the use of integers for this scale [73].

$$\text{Statistical Significance Levels} = \frac{\text{Max value} - \text{Min. value}}{\text{Max. value}} \tag{3.3}$$

Statistical significance levels, SSL, equals:

$$SSL = \frac{5 - 1}{5} = 0.8$$

Table 3.1 illustrates the significance levels that are employed in this work.

Table 3.1: Significance Levels Utilized in this Work.

Level	Interval of Mean	Description
(1)	1.00-1.80	Strongly disagree
(2)	1.81-2.60	Disagree
(3)	2.61-3.40	Neutral
(4)	3.41-4.20	Agree
(5)	4.21-5.00	Strongly agree

3.9 STATISTICAL ANALYSIS

The SPSS program analyzes the data after it has been collected and uses the results to create the following metrics:

a. Arithmetic means. Only quantitative data is used for this scale, which is affected by anomalies.
b. Sample normal distribution test. To ensure high-quality survey responses, this test compares the average of a group of measures with a particular constant.
c. Frequency and percentage.
d. Standard deviation. It measures the degree to which responses deviate from the arithmetic mean and is the positive square root of the variance.
e. Impact score: The mean score and standard deviation are relevant to this scale.
f. Cronbach's alpha coefficient. Through comparing each item to the overall mean of all the items in the questionnaire, and by demonstrating the correlation between the number

of test items and the average correlation among all the items, this scale is used to assess internal consistency. The stability coefficient has values between zero and one, and the closer it is to one, the more stable the system is, and the closer it is to zero, the less stable it is.

g. Ranking. The average score is correlated with this scale.

3.9.1 The Regression Coefficient Test

A statistical test called the regression test uses the values of another variable to predict the future value of one variable. The regression test defines the numerical and graphical directions of the association via the regression line and indicates the shape and nature of the link between two variables. Figure 3.8 represents the major categories of the regression tests.

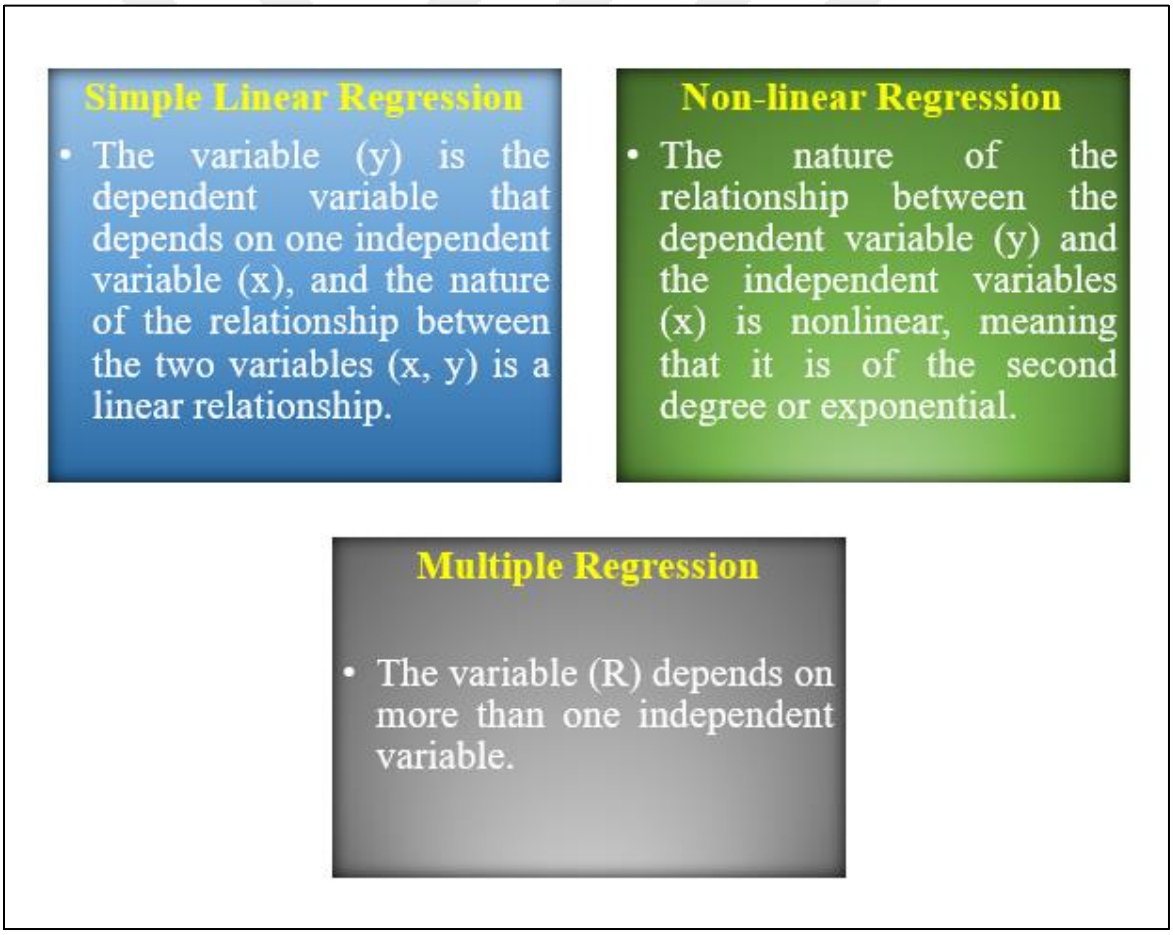

Figure 3.8: The Critical Categories of The Regression Tests.

3.9.2 Z -Distribution Test

The normal distribution is utilized to test hypotheses, and its value is calculated for each question in the questionnaire, and it fluctuates between (-1.96 and 1.96) depending on the 95% confidence level, as illustrated in Figure 3.9.

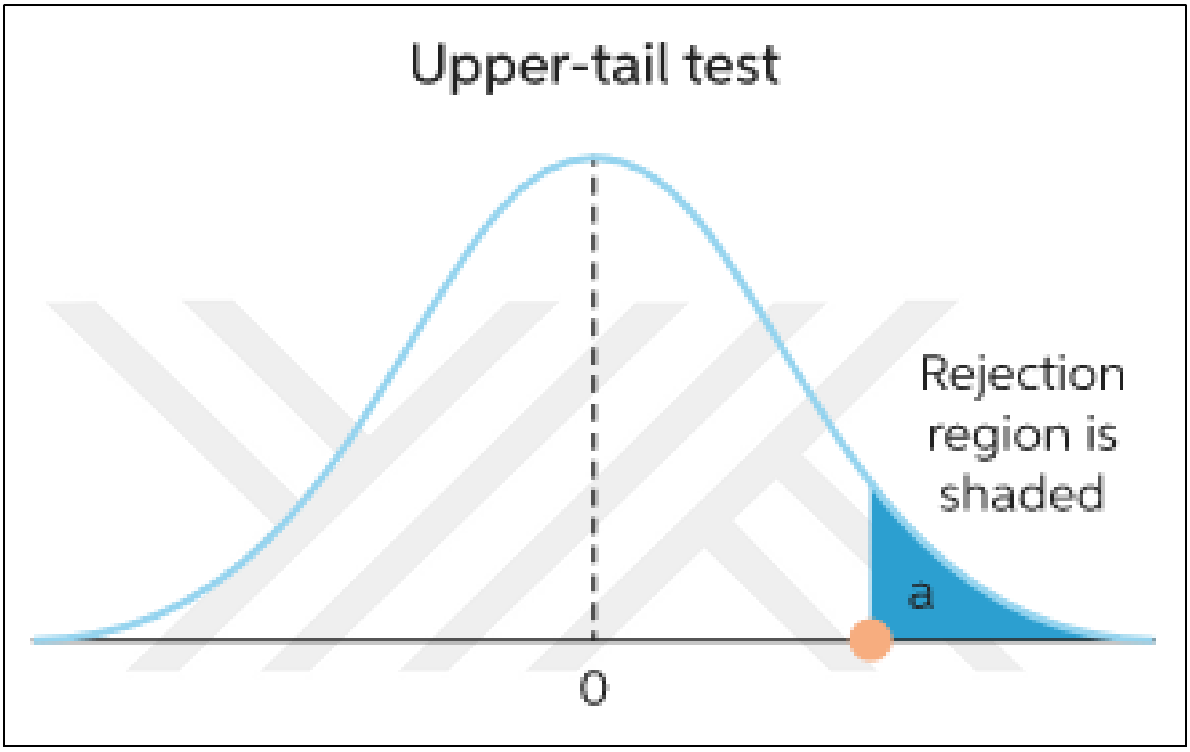

Figure 3.9: Rejection Region Shaded Shown For Two Tails [74].

Many hypotheses are tested statistically depending on the following equation [74].

$$\text{Test value} = \frac{observed\ value - expected\ value}{standard\ error} \tag{3.4}$$

Where:

$Standard\ Error$: The error that is being examined.

$Expected\ Value$: The population mean (hypothesized value) that would be anticipated if the null hypothesis were true.

$Observed\ Value$: The statistical metric derived from the specimen data is called the sample mean.

Additionally, the Z-test can be defined in the following formula:

$$\text{Z calculated} = \frac{\mathrm{X} - \mu}{s/\sqrt{Nr)}} \tag{3.4}$$

Where:

Nr : The Total number of responses for that factor or option

S : The standard deviation

μ : The hypothesized population mean

X : The mean score

This formula is used to determine the value of (Zc) and compare it to the Z tabulated value. Finding Zc using this formula and comparing it to the values of Z tabulated as (Zt = 1.96) and (Zt = -1.96).

As a result, accepting or rejecting the questionnaire's values is simple.

3.9.3 Standard Deviation

The equation below is utilized to calculate the standard deviation, which measures the dispersion of data around the mean. If the data points are clustered closely around the mean, the standard deviation will be low. However, if the data points are widely spread across a range of values, the standard deviation will be high. In such cases, the mean is referred to as the expected value.The following equation is used to compute the standard deviation (S) [74]:

$$S = \sqrt{\left(\frac{\sum_{k=0}^{n}(xi-x)^2 * fi}{n-1}\right)} \quad (3.5)$$

Where:

S : The standard deviation

N : The Number of samples

X : The mean score

3.9.4 Mean Score Ranking

The questionnaire data is analyzed by calculating the average score for each factor using a point scale. The average value is obtained by adding all scores and dividing by the number of respondents. The factors are then ranked in descending order based on their mean score. The Mean Score Ranking can be calculated using the formula below [75].

$$Ms = \frac{\sum_{xi=1}^{n} fi * xi}{\sum_{xi=1}^{n} xi} \quad (3.6)$$

Where:

f_i : The frequency

Ms : The mean score ($1 \leq Ms \leq 5$)

x_i : The degree of the criterion importance

3.9.5 Cronbach's Coefficient Alpha

The purpose of the tool is to assess the internal consistency and reliability of a test by examining the association between the average test item score for each dimension and the total number of items on the test, compared to the overall average of all dimensions in the questionnaire [76].

The following formula is used to compute Cronbach's alpha coefficient [76]:

$$\alpha = \frac{N_{it} \,.\, C}{V+(N_{it}-1) \,.\, C} \tag{3.7}$$

Where:

V : The average variance of all items

C : The average inter-item variance between items

N_{it} : The number of items

When the number of items and the average correlation between them increase, the Cronbach's alpha coefficient also increases. Conversely, a lower average correlation between the items leads to a lower Cronbach's alpha.

A Cronbach's alpha coefficient lower than the accepted limit will not be considered, as a higher value indicates better internal consistency. The accepted range for Cronbach's alpha is between 0.0 and +1.0.

3.9.6 Correlation Coefficient Test

One of the statistical tests used to ascertain the degree of association between two variables, whose values vary from (1 to -1), is the correlation test. The independent variable (x) in this test is determined by the researcher who will carry out the research; this variable is referred to as such. The dependent variable (y), on the other hand, the dependent variable's value is determined by the values of the independent variable (x), and therefore, it is dependent on the independent variable. The critical correlation types used in the research can be described in Figure 3.10.

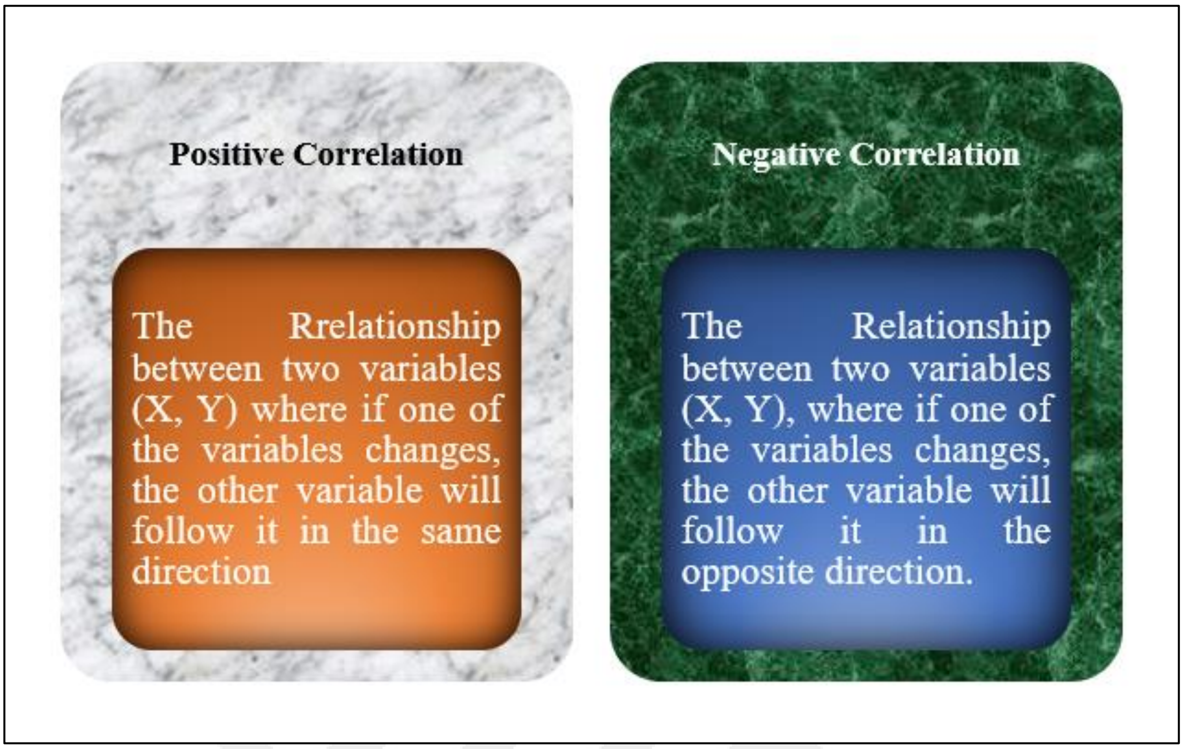

Figure 3.10: The Critical Correlation Types Used in The Research.

3.9.7 Chi-Square Test

A statistical test used to analyze sample distribution and hypotheses is the chi-square test. The nominal data is loaded using the Chi-square test. A nominal scale must be used to categorize and measure variables. It also functions to handle qualitative data that takes the form of iterations of particular groups and to balance the frequency distributions of variables. The salient features of this test are represented in Figure 3.11.

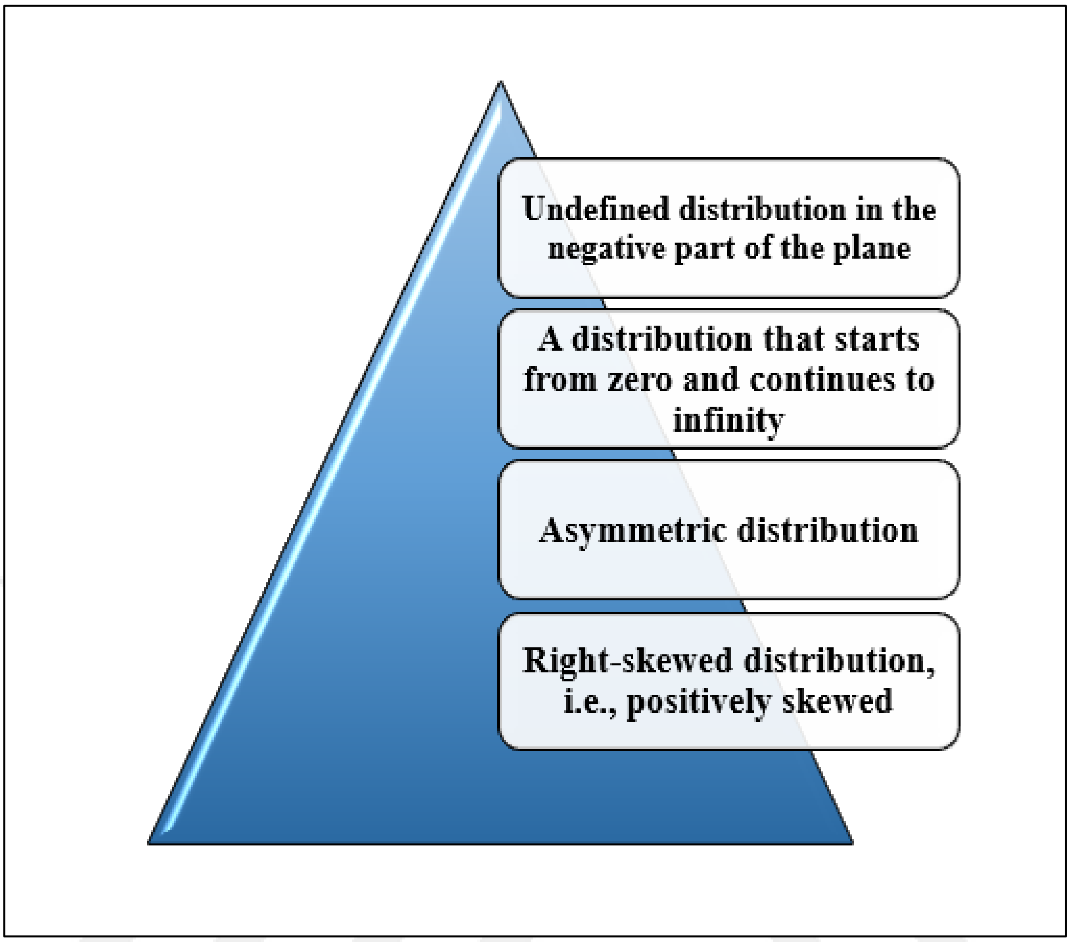

Figure 3.11: Critical Characteristics and Features of Chi-Square Test.

It can be inferred from the information represented in Figure 3.11 that Chi-square test relies on undefined distribution in the negative part of the plane. In addition, it depends on a distribution that starts from a value of zero and continue until infinite quantity.

At the same time, the Chi-square test depends on asymmetric distribution of statistical data. Moreover, this test employes right-skewed distribution or the so-called positively skewed.

4. RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter discusses the various factors that impact the utilization and analysis of modern sustainable methods to enhance construction performance. A questionnaire was utilized to assess these factors and determine their significance levels, which could aid in identifying potential corrective measures, including the incorporation of innovative techniques and tools.

To improve the procedure' accuracy and dependability, the respondents were carefully chosen. The participants have expertise leading civil engineering and construction projects.

4.2 QUESTIONNAIRE ANALYSIS AND FINDINGS

The questionnaire aims to assess the factors that impact the implementation and analysis of state-of-the-art sustainable techniques in improving construction performance. This is done to determine the significance of these factors and their effects on the current state of the construction industry.

4.2.1 Respondents' Demographic SPSS Findings

The survey was administered to eligible participants who were categorized into different levels. Table 4.1 presents the SPSS results associated with the participants' frequency and percentage related to their gender in the cross-sectional study.

Table 4.1: The SPSS Results of The Participants' Frequency and Percentage of Gender.

Gender	Frequency	Percentage (%)
Male	75	75%
Female	25	25%

A graphical illustration of the SPSS analysis results linked to the gender assessment of the respondents can be expressed in Figure 4.1.

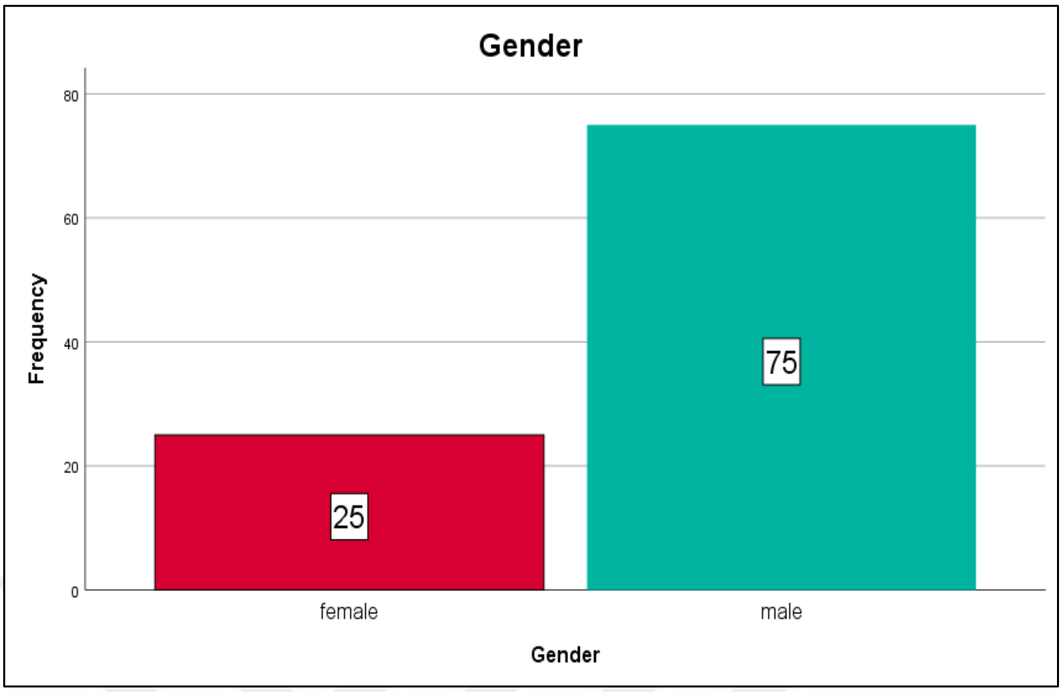

Figure 4.1: A graphical Illustration of the SPSS Analysis Results Linked to Gender Assessment.

It can be indicated from the results shown in Figure 4.1 that the male respondents were about 75%, and the female respondents were about 25%. The obtained results indicate the reliability and high quality of the responses provided. In addition, the SPSS results provided analysis regarding the participants' qualification frequency and percentage. Table 4.2 represents these SPSS research findings.

Table 4.2: The SPSS Results of the Participants' Qualification Frequency and Percentage.

Qualification	Frequency	Percentage (%)
Bachelor	22	22%
Master	73	73%
Doctorate	5	5%

A graphical illustration of the SPSS analysis results linked to the qualification assessment of the respondents can be expressed in Figure 4.2.

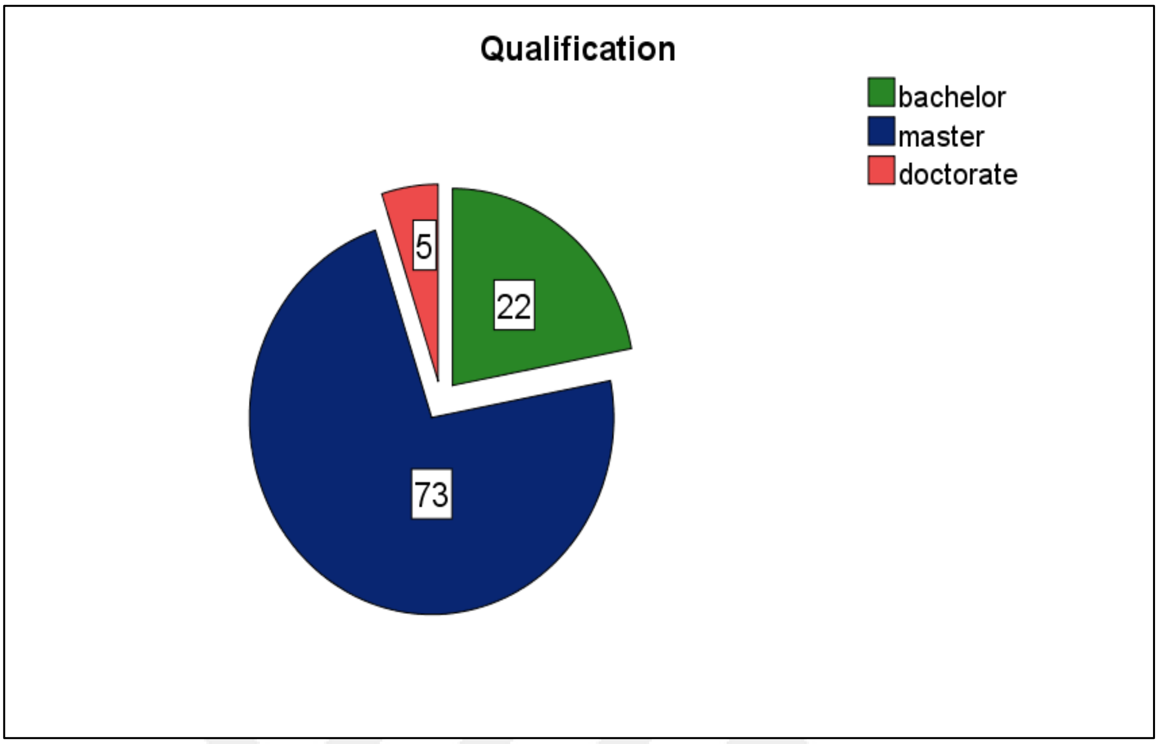

Figure 4.2: A Graphical Illustration of the SPSS Analysis Results Linked To Qualification Assessment.

It can be concluded from the results shown in Figure 4.2 that respondent with a master’s degree about 73%, a bachelor’s degree about 22%, and a doctorate degree about 5%. The obtained results indicate that the responses are reliable and of high quality. Further, the SPSS results provided analysis regarding the participants’ specialty frequency and percentage. Table 4.3 represents these SPSS research findings.

Table 4.3: The SPSS Results of The Participants' Specialty Frequency And Percentage.

The specialty	Frequency	Percentage (%)
Civil Engineering	81	81%
Architectural Engineering	11	11%
Electrical Engineering	2	2%
Mechanical Engineering	6	6%

A graphical illustration of the SPSS analysis results linked to specialty assessment can be represented in Figure 4.3.

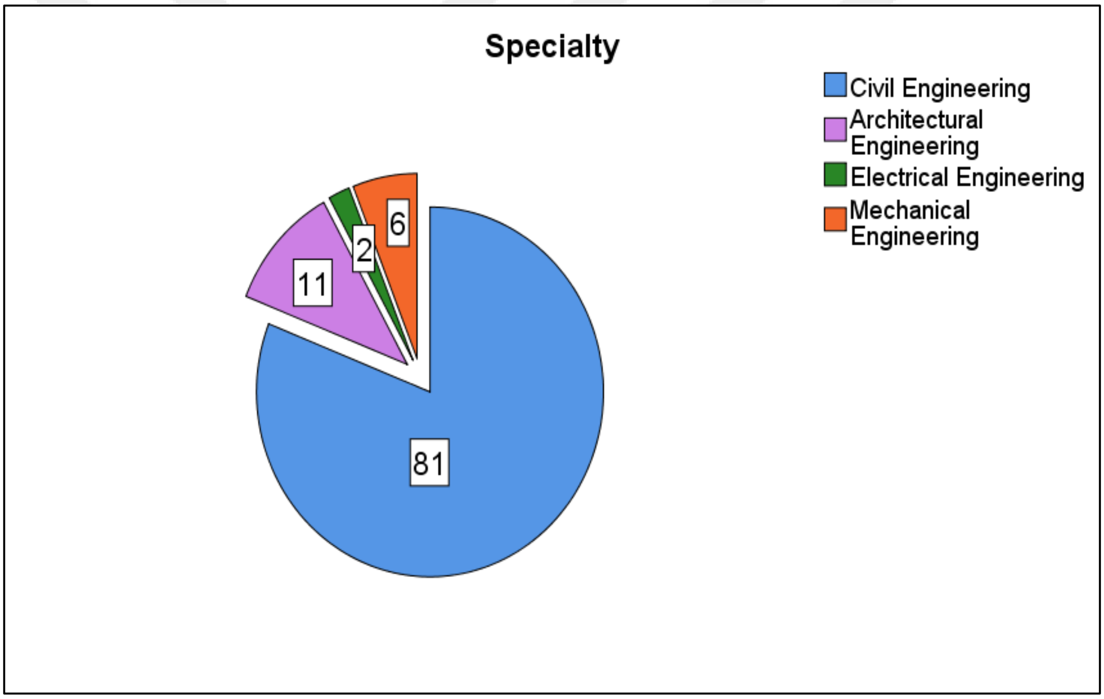

Figure 4.3: A Graphical Illustration of The SPSS Analysis Results Linked to Specialty Assessment.

It can be indicated from the results shown in Figure 4.3 that 81% of the respondents were civil engineers, 11% were architects, 2% were electrical engineers, and 6% were mechanical. Figure (4-3) shows the specialization of the respondents. Further, the SPSS results offered an analysis regarding the participants' job position frequency and percentage. Table 4.4 represents these SPSS research findings.

Table 4.4: The SPSS Results of The Participants' Job Position Frequency and Percentage.

Job Position	Frequency	Percentage (%)
Site Engineer	68	68%
Planning Engineer	9	9%
Designer	9	9%
Project Manager	14	14%

Also, Figure 4.4 offers a graphical illustration linked to the SPSS analysis results regarding the job position assessment of respondents.

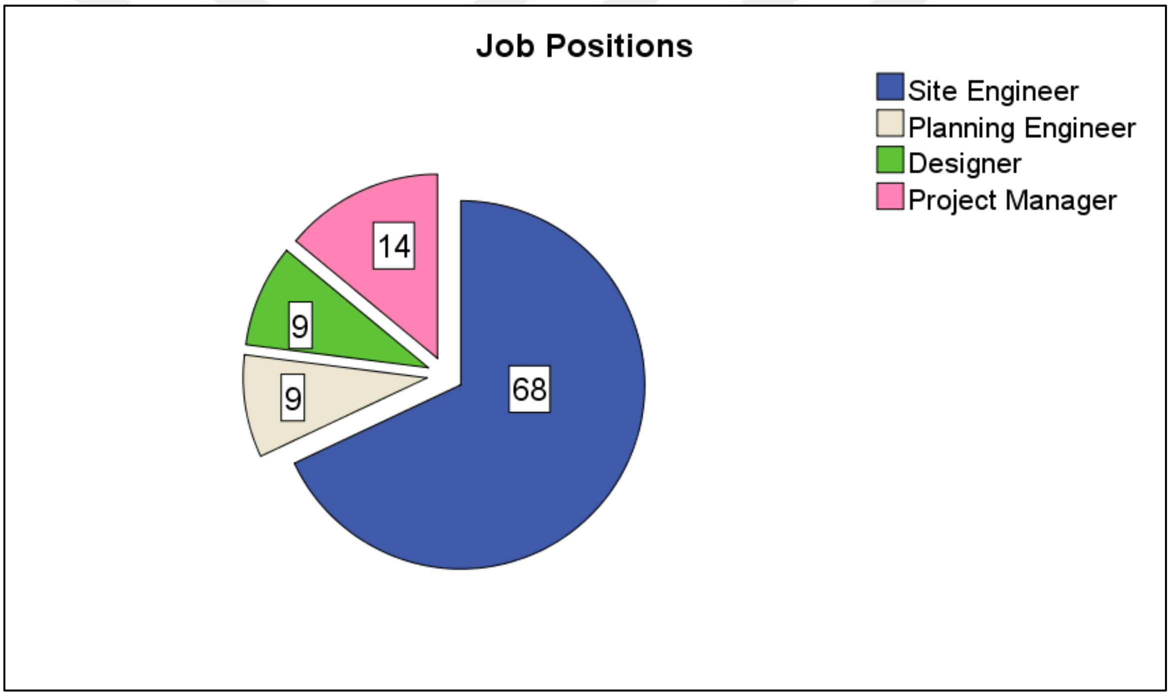

Figure 4.4: A Graphical Illustration of The SPSS Analysis Results Linked to Job Position Assessment.

The results shown in Figure 4.4 can indicate that approximately 68% of the respondents were site engineers, 14% were project managers, 9% were planning engineers, and 9% were designers. Additionally, the SPSS results offered an analysis regarding the participants' experience years frequency and percentage. Table 4.5 represents these SPSS research findings.

Table 4.5: The SPSS Results of The Participants' Experience Years Frequency and Percentage.

Experience Years	Frequency	Percentage (%)
Less than 5 Years	4	4%
5-10 Years	85	85%
11-15 Years	4	4%
16-20 Years	3	3%
More than 20 Years	4	4%

Besides, Figure 4.5 gives a graphical illustration of the SPSS analysis results linked to experience years assessment.

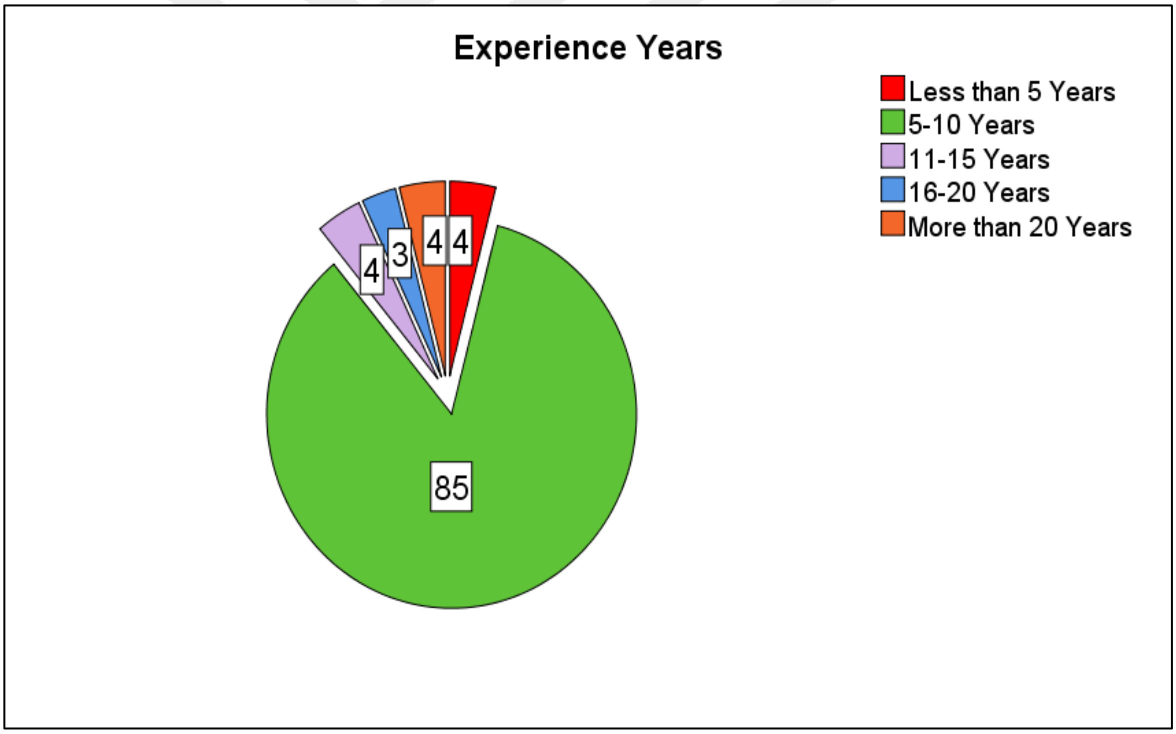

Figure 4.5: A graphical Illustration of The SPSS Analysis Results Linked to Experience Years Assessment.

It can be shown from the results indicated in Figure 4.5 that the respondents were 4% with less than five experience years, 85% with 5-10 years, 4% with 11-15 years, 3% with 16-20 years, and 4% of more than 20 years.

4.2.2 Regression Test

In addition to the demographic data obtained from the SPSS analysis in this research, the questionnaire investigation provides some statistical results related to the regression testing results. Table 4.6 shows these research findings.

Table 4.6: The SPSS Results Linked to Regression Testing Analysis (Gender and Specialty).

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.096	1	1.096	6.083	0.015[b]
	Residual	17.654	98	0.180		
	Total	18.750	99			
a. Dependent Variable: Gender						
b. Predictors: (Constant), Specialty						

It can be noted from the results expressed in Table 4.6 that are related to the regression test that the factors of gender and specialization had a regression value of 0.015. This value is more significant than 0.05. If this outcome demonstrates that the calculated value (F) is lower than the value listed at degrees of freedom, the null hypothesis is accepted. Additionally, the alternative theory might be disproven.

Also, the SPSS analysis findings indicated the research outcomes linked to the regression testing results of the relation between the dependent variable (Qualification) and the predictor (Job Position), as illustrated in Table 4.7.

Table 4.7: The SPSS Results of Regression Analysis (Between Qualification and Job Position).

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.115	1	1.115	4.752	0.032[b]
	Residual	22.995	98	0.235		
	Total	24.110	99			
a. Dependent Variable: Qualification						
b. Predictors: (Constant), Job Positions						

Table 4.7 displays the results of the regression test conducted on the qualification and job positions factors. The obtained regression value of 0.032 is statistically significant at a significance level of 0.05. To test the null hypothesis, the calculated (F) value should be compared with the tabular value at the given degrees of freedom. If the calculated (F) value is less than the tabular value, the null hypothesis is accepted, and the alternative hypothesis is rejected. Conversely, if the calculated (F) value is greater than the tabular value, the alternative hypothesis is accepted, and the null hypothesis is rejected.

4.2.3 Hypothesis Test

The alternative hypothesis is accepted and the null hypothesis is rejected for items with Z-values greater than (1.96), according to the normal distribution curve illustrated in Figure 4.6, which serves as the basis for the hypothesis tests.

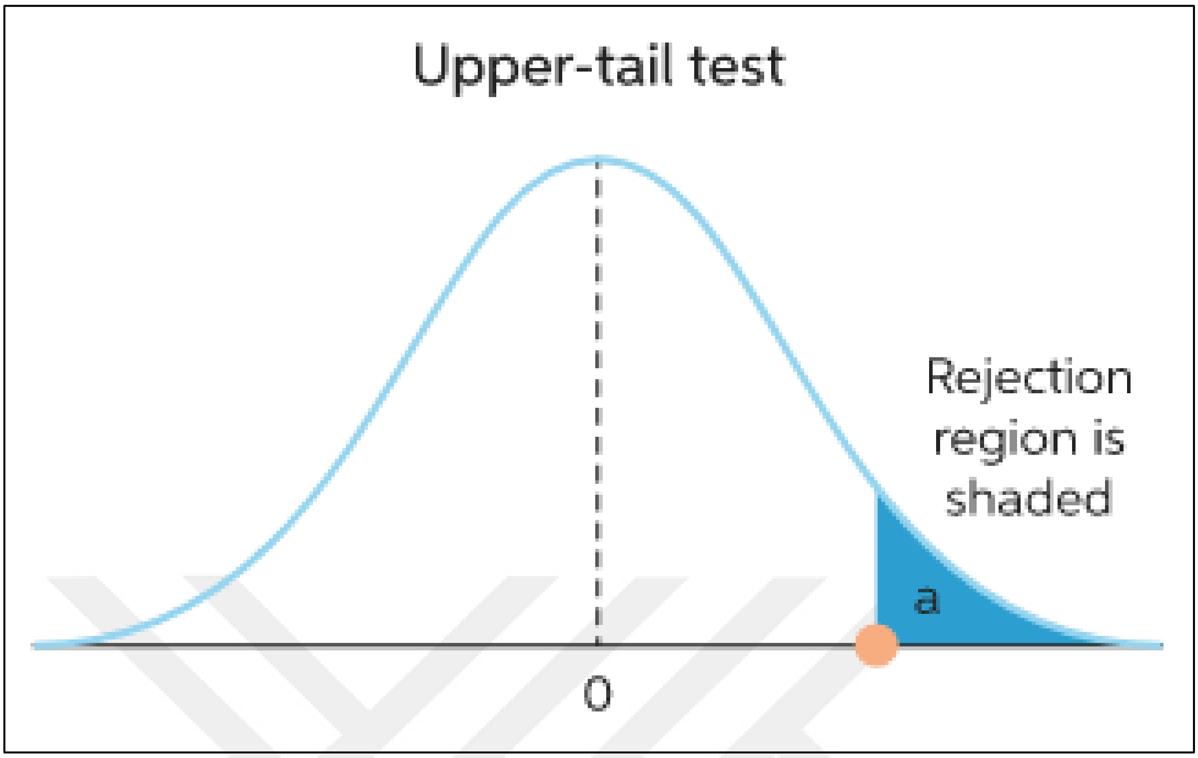

Figure 4.6: The SPSS Research Results Associated With The Normal Distribution.

4.2.4 Data Analysis

Depending on [71], in cases when the P-value is not specified, a specific value can be proposed to solve this problem which is (0.5). Therefore, calculated value can be utilized to determine the sample size needed from the population.

A confidence level of 95% and a significance level of 5% were utilized in this study; in scientific disciplines, the range of acceptable confidence levels is 90-100% and 1–10%, respectively.

A statistical analysis of the study was conducted, where the objective of the analysis was to determine the factors affecting the implementation and analysis of state -of- the art sustainable techniques to improve construction performance.

Table 4.8: SPSS Analysis Results of The Critical Factors Investigated in This Research.

Rank	Factors	Z-value	S. D	Mean
1	Linking the principles of sustainability and design elements	26.407	0.682	4.80
2	Controlling and estimating construction costs	25.215	0.674	4.70
3	Achieving the desired sustainable goals of work	24.706	0.712	4.76
4	Adjust costs for future changes	16.973	0.960	4.63
5	High speed in performance and quantity calculation	12.394	1.210	4.50
6	Project scheduling control	14.357	1.059	4.52
7	Commitment in sustainability standards and indicators to raise building performance	10.803	1.277	4.38
8	Contribute to the development of the sustainable economy of buildings	9.029	1.362	4.23
9	Accuracy of implementation and operation of construction project work	9.157	1.310	4.20
10	Improving and developing the quality of construction	6.142	1.579	3.97
11	Developing the efficiency of material performance and achieving supplier sustainability	4.690	1.706	3.80
12	Monitor and follow up the impact of the building on the surrounding environment	3.955	1.694	3.67

Table 4.8: SPSS Analysis Results of The Critical Factors Investigated in This Research.

“Table Continued”

Rank	Factors	Z-value	S. D	Mean
13	*Increasing the link between the project parties*	4.505	1.554	3.70
14	Ability to solve workflow problems	3.854	1.557	3.60
15	Provide the necessary data to carry out construction work	2.662	1.577	3.42
16	Develop current and future plans in the implementation of construction works	2.219	1.532	3.34
17	Contribute to improving the decision-making process	0.416	1.441	3.06
18	Provide the necessary resources to carry out the project work	-3.067	1.761	2.46
19	Evaluation of staff performance	-2.138	1.403	2.70
20	Controlling the periodic maintenance operations in the long term	-6.471	1.576	1.98
21	Control the time required to do construction work	-9.573	1.368	1.69
22	Reducing waste from building and construction works	-13.127	1.150	1.49

It can be indicated from Table 4.8, The statistical analysis outputs are presented in the table, where the first column displays the rank, standard deviation, and mean of the factors that were identified as potential influencers on the implementation and analysis of advanced sustainable techniques for enhancing construction performance as indicated in the survey questionnaire. In the third column, the arithmetic mean of all items was extracted, then in the fourth column, the standard deviation values for each factor were extracted. At the same time, the last column shows the Z-value amount, which helps test hypotheses. Figure 4.7 represents the SPSS analysis findings related to the means of the questionnaire factors.

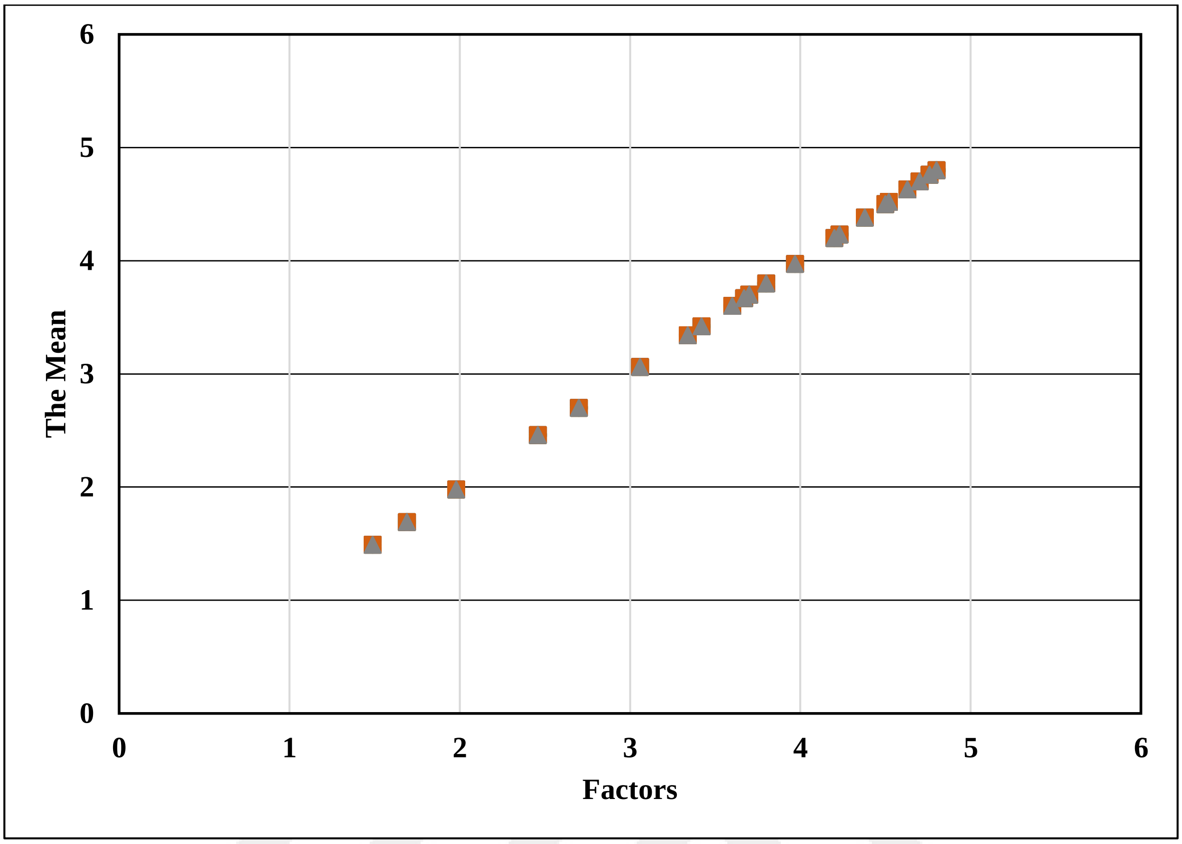

Figure 4.7: The Results Related to The Means of The Questionnaire Factors.

It can be noted from Figure 4.7 that the distribution of the arithmetic mean values for all the elements of the factors have a stimulating effect on the implementation and analysis of state-of-the-art sustainable techniques to improve construction performance.

In addition, it is noted from the figure that these factors are represented in the form of a normal distribution. Table 4.9 illustrates the SPSS analysis results pertain to the overall organization of the factors examined in the study.

Table 4.9: The SPSS Analysis Results Related to The General Arrangement of The Study Factors.

Paragraph	Strongly disagree		Disagree		Neutral		Agree		Strongly agree		Mean	St. Deviation	Rank
	%	F	%	F	%	F	%	F	%	F			
Linking the principles of sustainability and design elements	2	2	1	1	0	0	9	9	88	88	4.80	0.682	1
Achieving the desired sustainable goals of work	1	1	2	2	4	4	6	6	87	87	4.76	0.712	2
Controlling and estimating construction costs	1	1	1	1	3	3	17	17	78	78	4.70	0.674	3
Adjust costs for future changes	2	2	7	7	1	1	6	6	84	84	4.63	0.960	4
Project scheduling control	2	2	9	9	4	4	5	5	80	80	4.52	1.059	5
High speed in performance and quantity calculation	8	8	4	4	0	0	6	6	82	82	4.50	1.210	6
Commitment to sustainability standards and indicators to raise building performance	7	7	8	8	3	3	4	4	78	78	4.38	1.277	7

Table 4.9: The SPSS Analysis Results Related to The General Arrangement of The Study Factors.

"Table Continued"

Paragraph	Strongly disagree		Disagree		Neutral		Agree		Strongly agree		Mean	St. Deviation	Rank
	%	F	%	F	%	F	%	F	%	F			
Contribute to the development of the sustainable economy of buildings	7	7	13	13	2	2	6	6	72	72	4.23	1.362	8
Accuracy of implementation and operation of construction project work	3	3	18	18	5	5	4	4	70	70	4.20	1.310	9
Improving and developing the quality of construction	13	13	15	15	2	2	2	2	68	68	3.97	1.579	10
Developing the efficiency of material performance and achieving supplier sustainability	22	22	6	6	6	6	2	2	64	64	3.80	1.706	11
Increasing the link between the project parties	7	7	32	32	1	1	4	4	56	56	3.70	1.554	12
Monitor and follow up the impact of the building on the surrounding environment	19	19	16	16	2	2	5	5	58	58	3.67	1.694	13
Ability to solve workflow problems	9	9	30	30	4	4	6	6	51	51	3.60	1.557	14

Table 4.9: The SPSS Analysis Results Related to The General Arrangement of The Study Factors. "Table Continued"

Paragraph	Strongly disagree		Disagree		Neutral		Agree		Strongly agree		Mean	St. Deviation	Rank
	%	F	%	F	%	F	%	F	%	F			
Provide the necessary data to carry out construction work	7	7	42	42	1	1	2	2	48	48	3.42	1.577	15
Develop current and future plans in the implementation of construction works	4	4	49	49	0	0	3	3	44	44	3.34	1.532	16
Contribute to improving the decision-making process	4	4	56	56	2	2	6	6	32	32	3.06	1.441	17
Evaluation of staff performance	12	12	57	57	4	4	3	3	24	24	2.70	1.403	18
Provide the necessary resources to carry out the project work	50	50	16	16	1	1	4	4	29	29	2.46	1.761	19
Controlling the periodic maintenance operations in the long term	65	65	12	12	2	2	2	2	19	19	1.98	1.576	20
Control the time required to do construction work	75	75	8	8	1	1	5	5	11	11	1.69	1.368	21
Reducing waste from building and construction works	79	79	10	10	2	2	1	1	8	8	1.49	1.150	22

It can be inferred from the results of the statistical analysis shown in Table 4.9 that linking the principles of sustainability and design elements is the most influential factor in the implementation and analysis of state-of-the-art sustainable techniques to improve construction performance, as the average value was (4.80).

At the second level achieving the desired sustainable goals of work was one of the most prominent factors, where the arithmetic mean value was (4.76). This item shows that the lack of support for the sustainability goals weakens the correct achievement of those goals.

At the third level, controlling and estimating construction costs was among the factors present in abundance, where the arithmetic mean value was (4.70). Thus, the lack of project cost estimation led to problems and delays in project delivery.

At the fourth level, adjusting costs for future changes was one of the essential elements that were present in abundance, as the value of the arithmetic mean was (4.63), which indicates the necessity of estimating and following up on future changes.

At the fifth level, project scheduling control was one of the most common factors in construction projects, as the arithmetic mean of the value was (4.52). This point indicates the importance of adjusting the project schedule to avoid problems in the implementation and delivery processes.

On the other hand, the results showed that reducing waste from building and construction works came in the last rank of the factors, as the value of the arithmetic mean decreased (1.49) and decreased in the area of acceptance of the null hypothesis on the normal distribution curve.

Other points related to controlling the time required to do construction work include the value of the arithmetic mean is 1.69. Besides, controlling the periodic maintenance operations in the long term, which has a mean value of 1.98.

4.2.5 Reliability and Validity Analysis Results

The internal consistency of statistical tests, including questionnaires and other similar measures, is measured by the Cronbach's alpha coefficient. The degree to which a set of things is related to one another as a coherent set is known as internal consistency or reliability.

Table 4.10 illustrates the fundamental guideline for interpreting Cronbach's alpha scale for questions with Likert scales or dichotomous questions (i.e., questions with two possible answers) [77]:

Table 4.10: Cronbach's Alpha Scale.

Cronbach's Alpha (α)	Internal Consistency
$0.9 \leq \alpha$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Not Acceptable

In addition, the SPSS analysis results indicated the Cronbach Alpha findings and values of all research factors. Table 4.11 shows these research outcomes.

Table 4.11: Cronbach Alpha Results and Values of all Research Factors.

#	Factors	Cronbach Alpha
1	Linking the principles of sustainability and design elements	0.971
2	Controlling and estimating construction costs	0.970
3	Achieving the desired sustainable goals of work	0.970
4	Adjust costs for future changes	0.969
5	High speed in performance and quantity calculation	0.969
6	Project scheduling control	0.969

Table 4.11: Cronbach Alpha Results and Values of All Research Factors. “Tables Continued”

#	Factors	Cronbach Alpha
7	Commitment in sustainability standards and indicators to raise building performance	*0.968*
8	Contribute to the development of the sustainable economy of buildings	0.968
9	Accuracy of implementation and operation of construction project work	0.968
10	Improving and developing the quality of construction	0.968
11	Developing the efficiency of material performance and achieving supplier sustainability	0.968
12	Monitor and follow up on the impact of the building on the surrounding environment	0.967
13	Increasing the link between the project parties	0.968
14	Ability to solve workflow problems	0.967
15	Provide the necessary data to carry out construction work	0.968
16	Develop current and future plans for the implementation of construction works	0.968
17	Contribute to improving the decision-making process	0.968
18	Provide the necessary resources to carry out the project work	0.969
19	Evaluation of staff performance	0.969
20	Controlling the periodic maintenance operations in the long term	0.970
21	Control the time required to do construction work	0.971
22	Reducing waste from building and construction works	0.971

The findings in Table 4.11 suggest that the alpha Cronbach coefficient for the questionnaire is in the range of 0.967 and 0.971. These values can express that the questionnaire articles are excellent and reliable based on the scale represented in Table 4.10.

In addition, Table 4.11 shows that the amounts of Cronbach's alpha coefficient for all components of the questionnaire affected the implementation and analysis of state-of-the-art sustainable techniques to improve construction performance.

Figure 4.8 expresses the values of the Cronbach Alpha related to all questionnaire factors.

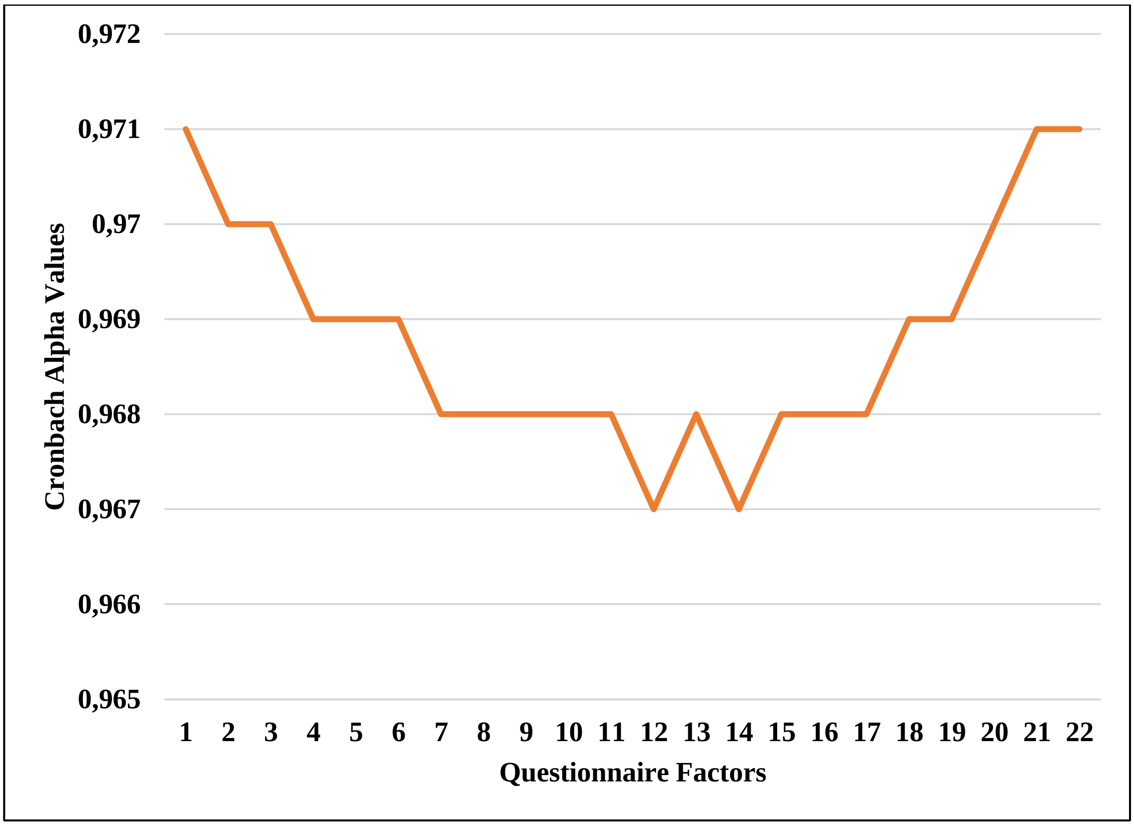

Figure 4.8: The values of the Cronbach Alpha Related to All Questionnaire Factors.

It can be observed from Figure 4.8 that the distribution of Cronbach's alpha coefficient values for all elements of the factors had an influence on the implementation and analysis of the latest sustainable technologies to improve construction performance. Furthermore, it is noted from the figure that they are represented in the form of a normal distribution. Table 4.12 indicates the overall reliability value related to SPSS statistical results related to all questionnaire factors.

Table 4.12: The Overall Reliability Value Related to SPSS Statistical Results Of All Questionnaire Factors.

No. of Items	Cronbach's Alpha
22	0.970

It can be noted from the results of the statistical analysis shown in Table 4.12 that the most influential factors in the implementation and analysis of state-of-the-art sustainable techniques to improve construction performance are:

a. Linking the principles of sustainability and design elements.
b. Control the time required to do construction work.
c. Reducing waste from building and construction works.

Also, the value of Cronbach's coefficient alpha for all articles was (0.971).

Followed in the second level by the following group of elements:

a. Controlling and estimating construction costs.
b. Achieving the desired sustainable goals of work.
c. Controlling the periodic maintenance operations in the long term.

The value of Cronbach's coefficient alpha was (0.970).

From Table 4.12, the reliability coefficient for this research was calculated and reached (0.970), indicating a high-reliability level.

4.2.6 Correlation Coefficient Test

Appendix B presents the results of the correlation coefficient test related to all factors. The results were divided into two groups because there are diverse statistical findings. Hence, the SPSS outcomes can be easily represented. The first group includes Q1 to Q11. At the same time, the second group includes Q12 to Q22.

It can be noted from the results in Tables B.1 and B.2 related to the testing of the correlation coefficient between each element in the factors that "Implementation and Analysis of State -of- The Art Sustainable Techniques to Improve the Construction Performance" This indicates that the correlation coefficients mentioned are statistically significant at a significance level of 0.05, implying that the scale set for the field is valid.

4.2.7 Chi-Square Test

The SPSS analysis procedure also provided analysis findings related to the Chi-Square test. Table 4.13 shows these results.

Table 4.13: The SPSS Results of The Chi-Square Test.

Chi-Square Tests			
Classification	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.819[a]	3	0.050
Likelihood Ratio	12.349	3	0.006
Linear-by-Linear Association	5.786	1	0.016
N of Valid Cases	100	---	---
a. Five cells (62.5%) have an expected count of less than 5. The minimum expected count is 0.50.			

The results presented in Table 4.13 demonstrate that the Chi-Square test score is 0.050, indicating acceptance of the alternative hypothesis as the sample falls within the acceptance range. Simultaneously, based on the degrees of freedom, the null hypothesis is rejected.

4.3 CASE STUDY RESULTS

The case study analysis revealed research findings related to the employment of sustainable and environmentally friendly materials to mitigate the facilities' impact on nature and make them economically feasible. The material used in this case study is timber. The location of the buildings is Kurdistan, Iraq. The research analysis of the timber in buildings constructed in Kurdistan, Iraq, confirmed that using wood in constructing different buildings in Iraq could offer various beneficial impacts on the construction sector, including [78]:

a. The reduction of building energy consumption by 65% compared with concrete-brick materials.
b. The minimization of GHG emissions, mainly carbon dioxide, as timber emissions include roughly 70% of the overall emissions emitted by construction activities when the concrete-brick material is employed.
c. The lower maintenance of timber compared with other construction materials over the lifecycle of the building.
d. A larger construction speed is achieved when timber is used in buildings compared with other materials.
e. The significant level of durability is related to the employment of timber in facilities.
f. The provision of tremendous and beautiful aesthetics for the building.
g. The provision of excellent insulation principles compared with concrete. Concrete has higher thermal conductivity than timber.
h. Non-toxicity of timber. This feature could offer higher safety conditions in construction for the labor force compared with other construction materials.
i. The provision of higher levels of stability, durability, and fire resistance.

Figure 4.9 represents some examples related to the employment of timber in Iraqi Kurdistan buildings.

Figure 4.9: Timber Ceilings and Columns Used in Some Buildings in Iraqi Kurdistan [78].

Using timber in construction can offer a higher rating of sustainable standards and building codes, Examples of sustainable construction techniques include Leadership in Energy and Environmental Design (LEED). LEED certificates are based on collecting points related to the employment and utilization of sustainable materials in the facility. When a high number of points are achieved in the building, then the building can be significantly considered sustainable and can obtain the LEED platinum rating compared with the (green) LEED-certified facility that has a lower number of points.

Figure 4.10: The Ratings and Types of The LEED Certification [79].

Thus, utilizing wood in construction can increase the points of LEED rating in the facility and helps make the building more sustainable.

4.4 DISCUSSION

The results of this work from the cross-sectional study and case study revealed that using sustainable methods, intelligent energy-efficient techniques, and green building principles play a critical role in improving building sustainability and achieving various essential benefits in terms of better economic feasibility, lower maintenance, and operation costs, indoor environment quality, and reducing GHG emissions and negative impact on the environment. In addition, it was found that employing state-of-the-art materials in buildings, such as modern insulation materials and insulation approaches, could mitigate a significant amount of power consumption in buildings, and reduce the cooling and heating electrical bills monthly required in summer and winter, respectively. Also, the results of the case study and the questionnaire analysis confirmed that implementing sustainability principles in construction could minimize the quantity of waste and control the construction phases to alleviate the impact of construction activities on the environment. Also, the results indicated that the commitment to several construction standards associated with sustainability principles could help enhance the facilities' performance and energy management. These results are consistent with the research findings of and [54]–[63] and [42], [46], [47], who carried out research examining the critical role of sustainability and green building principles for construction purposes and found that employing sustainability and green construction standards could contribute to remarkable enhancements in the buildings' resilience, reliability, performance, thermal equilibrium, power consumption, and energy stability.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter provides a summary of the conclusions and recommendations resulting from the research conducted on the significance of implementing and analyzing state-of-the-art sustainable techniques for enhancing construction performance. The study focuses on the identification and classification of factors that influence the importance of implementation and analysis of state -of- the art sustainable techniques to improve construction performance.

5.2 CONCLUSIONS

The researcher utilized statistical analysis in collecting and analyzing data to identify the significant factors that impact construction. One hundred engineers having experience in civil engineering were asked, and the researcher reached several conclusions:

a. The study concluded the importance of linking the principles of sustainability and design elements in order to implement and analyze the latest sustainable technologies to improve building performance.

b. In the study, the researcher focused on the importance of controlling and estimating construction costs in order to achieve effective sustainability that contributes to improving construction performance.

c. The researcher emphasized the achievement of the desired sustainable work goals that would increase the quality of the performance of construction projects.

d. The study concluded the importance of controlling costs in the event of future changes in order to avoid problems in construction and weaken the performance of the project.

e. In the study, the researcher focused on achieving high-performance speed in calculating quantities to ensure the application of effective techniques that increase the sustainability and performance of construction projects.

f. The study focused on the importance of monitoring project scheduling for its vital role in improving construction performance and not causing delays in project delivery.

5.3 RECOMMENDATIONS

The researcher suggests several recommendations to address the issues, which include:

a. The researcher emphasized the bug of the need to remove waste from building and construction works in a way that ensures that the performance of the construction project is not diminished.

b. Preparing more studies on the topic of sustainable technologies that contribute to improving building performance.

c. Preparing and developing programs that increase the sustainability of buildings and improve the performance of construction projects.

d. The necessity of controlling the time required to carry out construction work in order to ensure the sustainability of the buildings.

e. The importance of controlling long-term periodic maintenance operations in order to achieve effective sustainability standards in construction projects.

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APPENDIX A

THE QUESTIONNAIRE DIMENSIONS AND ARTICLES OF THE CROSS-SECTIONAL STUDY IN THIS WORK

This thesis has a title: “Implementation and Analysis of State-of-the-Art Sustainable Techniques to Improve the Construction Performance: An Iraqi Case Study.”

A survey questionnaire is executed through a cross-sectional quantitative descriptive study to predict Iraqi construction experts' and engineering professionals' points of view regarding active and practical practices of sustainable methods and energy-saving techniques for buildings.

The following aspects represent a list of the significant factors that affect the Engineering Management of Sewage and Rainwater Infrastructure in Iraq. Rank on a scale of 1-5 the importance of the listed factors below in your opinion.

a. Strongly disagree
b. Disagree
c. Neutral
d. Agree
e. Strongly agree

Table A.1 represents the dimensions, articles, and statements used to collect primary data necessary for research purposes from high-knowledge professionals and chief engineers.

Table A.1: The Thesis Questionnaire.

No	Dimension/ Article	Effects Degree				
		1	2	3	4	5
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	Develop current and future plans in the implementation of construction works					
2	Control the time required to do construction work					
3	Achieving the desired sustainable goals of work					
4	Provide the necessary resources to carry out the project work					
5	Increasing the link between the project parties					
6	Ability to solve workflow problems					
7	Provide the necessary data to carry out construction work					
8	Contribute to improving the decision-making process					
9	Evaluation of staff performance					
10	Improving and developing the quality of construction					
11	Developing the efficiency of material performance and achieving supplier sustainability					
12	Controlling the periodic maintenance operations in the long term					
13	Monitor and follow up the impact of the building on the surrounding environment					
14	Linking the principles of sustainability and design elements					
15	Controlling and estimating construction costs					
16	Contribute to the development of the sustainable economy of buildings					
17	Reducing waste from building and construction works					
18	Accuracy of implementation and operation of construction project work					

Table A.1: The Thesis Questionnaire. “Tables Continued”

19	Adjust costs for future changes					
20	High speed in performance and quantity calculation					
21	Project scheduling control					
22	Commitment in sustainability standards and indicators to raise building performance					

APPENDIX B

CORRELATION COEFFICIENT TEST RESULTS RELATED TO THE QUESTIONNAIRE FACTORS

Table B.1: Correlation Coefficient Test Results of The First Group of Factors (Q1 to Q11).

Category		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Linking the principles of sustainability and design elements	Pearson Correlation	1	.857**	.940**	.858**	.808**	.803**	.726**	.648**	.622**	.487**	.487**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Controlling and estimating construction costs	Pearson Correlation	.857**	1	.879**	.856**	.829**	.886**	.884**	.879**	.846**	.738**	.738**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Achieving the desired sustainable goals of work	Pearson Correlation	.940**	.879**	1	.932**	.902**	.877**	.834**	.744**	.680**	.559**	.559**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.1: Correlation Coefficient Test Results Related To The First Group Of Factors (Q1 To Q11). "Tables Continued"

Adjust costs for future changes	Pearson Correlation	.858**	.856**	.932**	1	.960**	.946**	.906**	.815**	.742**	.639**	.639**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
High speed in performance and quantity calculation	Pearson Correlation	.808**	.829**	.902**	.960**	1	.962**	.941**	.855**	.777**	.685**	.685**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Project scheduling control	Pearson Correlation	.803**	.886**	.877**	.946**	.962**	1	.973**	.911**	.849**	.752**	.752**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Commitment in sustainability standards and indicators to raise building performance	Pearson Correlation	.726**	.884**	.834**	.906**	.941**	.973**	1	.953**	.889**	.805**	.805**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Contribute to the development of the sustainable economy of buildings	Pearson Correlation	.648**	.879**	.744**	.815**	.855**	.911**	.953**	1	.970**	.911**	.911**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.1: Correlation Coefficient Test Results Related To The First Group of Factors (Q1 To Q11). "Tables Continued"

Accuracy of implementation and operation of construction project work	Pearson Correlation	.622**	.846**	.680**	.742**	.777**	.849**	.889**	.970**	1	.949**	.949**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Improving and developing the quality of construction	Pearson Correlation	.557**	.760**	.640**	.712**	.758**	.807**	.842**	.928**	.964**	.969**	.969**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Developing the efficiency of material performance and achieving supplier sustainability	Pearson Correlation	.487**	.738**	.559**	.639**	.685**	.752**	.805**	.911**	.949**	1	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		---
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.1: Correlation coefficient test results related to the first group of factors (Q1 to Q11). "tables continued"

Monitor and follow up the	Pearson Correlation	.467**	.682**	.536**	.613**	.658**	.716**	.759**	.843**	.881**	.963**	.963**

impact of the building on the surrounding environment	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Increasing the link between the project parties	Pearson Correlation	.467**	.636**	.537**	.581**	.607**	.642**	.679**	.758**	.794**	.884**	.884**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Ability to solve workflow problems	Pearson Correlation	.466**	.625**	.532**	.596**	.616**	.648**	.676**	.749**	.782**	.867**	.867**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.1: Correlation Coefficient Test Results Related To The First Group of Factors (Q1 To Q11). "Tables Continued"

Provide the necessary data to carry out construction work	Pearson Correlation	.408**	.547**	.468**	.504**	.524**	.551**	.582**	.646**	.672**	.745**	.745**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Develop current and future plans in the implementation 0of construction works	Pearson Correlation	.375**	.501**	.409**	.436**	.452**	.488**	.511**	.577**	.615**	.683**	.683**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Contribute to improving the decision-making process	Pearson Correlation	.341**	.445**	.368**	.388**	.400**	.430**	.448**	.502**	.534**	.588**	.588**
	Sig. (2-tailed)	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.1: Correlation Coefficient Test Results Related To The First Group Of Factors (Q1 To Q11). "Tables Continued"

Provide the necessary resources to carry out the project work	Pearson Correlation	.246*	.373**	.282**	.323**	.346**	.380**	.407**	.474**	.511**	.589**	.589**
	Sig. (2-tailed)	.014	0.000	.004	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Evaluation of staff performance	Pearson Correlation	.359**	.438**	.402**	.441**	.470**	.480**	.487**	.512**	.522**	.557**	.557**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Controlling the periodic maintenance operations in the long term	Pearson Correlation	.184	.279**	.212*	.242*	.259**	.285**	.305**	.355**	.383**	.442**	.442**
	Sig. (2-tailed)	.066	.005	.035	.015	.009	.004	.002	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.1: Correlation Coefficient Test Results Related To The First Group Of Factors (Q1 To Q11). "Tables Continued"

Control the time required to do construction work	Pearson Correlation	.149	.227*	.172	.196	.210*	.231*	.247*	.288**	.311**	.358**	.358**
	Sig. (2-tailed)	.138	.023	.088	.050	.036	.021	.013	.004	.002	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Reducing waste from building and construction works	Pearson Correlation	.126	.191	.145	.166	.178	.195	.209*	.243*	.263**	.303**	.303**
	Sig. (2-tailed)	.211	.056	.150	.099	.077	.052	.037	.015	.008	.002	.002
	N	100	100	100	100	100	100	100	100	100	100	100
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

Table B.2: Correlation Coefficient Test Results of The Second Group of Factors (Q12 To Q22).

Category		Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22
Linking the principles of sustainability and design elements	Pearson Correlation	.467**	.467**	.466**	.408**	.375**	.341**	.246*	.359**	.184	.149	.126
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	.001	.014	0.000	.066	.138	.211
	N	100	100	100	100	100	100	100	100	100	100	100
Controlling and estimating construction costs	Pearson Correlation	.682**	.636**	.625**	.547**	.501**	.445**	.373**	.438**	.279**	.227*	.191
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.005	.023	.056
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group of Factors (Q12 To Q22). "Tables Continued"

Achieving the desired sustainable goals of work	Pearson Correlation	.536**	.537**	.532**	.468**	.409**	.368**	.282**	.402**	.212*	.172	.145
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	.004	0.000	.035	.088	.150
	N	100	100	100	100	100	100	100	100	100	100	100
Adjust costs for future changes	Pearson Correlation	.613**	.581**	.596**	.504**	.436**	.388**	.323**	.441**	.242*	.196	.166
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	.015	.050	.099
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

High speed in performance and quantity calculation	Pearson Correlation	.658**	.607**	.616**	.524**	.452**	.400**	.346**	.470**	.259**	.210*	.178
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.009	.036	.077
	N	100	100	100	100	100	100	100	100	100	100	100
Project scheduling control	Pearson Correlation	.716**	.642**	.648**	.551**	.488**	.430**	.380**	.480**	.285**	.231*	.195
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.004	.021	.052
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Commitment in sustainability standards and indicators to raise building performance	Pearson Correlation	.759**	.679**	.676**	.582**	.511**	.448**	.407**	.487**	.305**	.247*	.209*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	.013	.037
	N	100	100	100	100	100	100	100	100	100	100	100
Contribute to the development of the sustainable economy of buildings	Pearson Correlation	.843**	.758**	.749**	.646**	.577**	.502**	.474**	.512**	.355**	.288**	.243*
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.004	.015
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Accuracy of implementation and operation of construction project work	Pearson Correlation	.881**	.794**	.782**	.672**	.615**	.534**	.511**	.522**	.383**	.311**	.263**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	.008
	N	100	100	100	100	100	100	100	100	100	100	100
Improving and developing the quality of construction	Pearson Correlation	.914**	.836**	.825**	.707**	.643**	.556**	.546**	.547**	.410**	.332**	.281**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	.005
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Developing the efficiency of material performance and achieving supplier sustainability	Pearson Correlation	.963**	.884**	.867**	.745**	.683**	.588**	.589**	.557**	.442**	.358**	.303**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002
	N	100	100	100	100	100	100	100	100	100	100	100
Monitor and follow up the impact of the building on the surrounding environment	Pearson Correlation	1	.956**	.941**	.820**	.756**	.649**	.658**	.599**	.493**	.400**	.338**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Increasing the link between the project parties	Pearson Correlation	.956**	1	.981**	.876**	.807**	.694**	.701**	.621**	.525**	.426**	.360**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Ability to solve workflow problems	Pearson Correlation	.941**	.981**	1	.933**	.862**	.740**	.753**	.661**	.565**	.458**	.387**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Provide the necessary data to carry out construction work	Pearson Correlation	.820**	.876**	.933**	1	.952**	.815**	.832**	.701**	.629**	.510**	.431**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Develop current and future plans in the implementation 0of construction works	Pearson Correlation	.756**	.807**	.862**	.952**	1	.878**	.863**	.734**	.680**	.552**	.466**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Contribute to improving the decision-making process	Pearson Correlation	.649**	.694**	.740**	.815**	.878**	1	.956**	.878**	.832**	.686**	.579**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Provide the necessary resources to carry out the project work	Pearson Correlation	.658**	.701**	.753**	.832**	.863**	.956**	1	.915**	.873**	.735**	.621**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Evaluation of staff performance	Pearson Correlation	.599**	.621**	.661**	.701**	.734**	.878**	.915**	1	.924**	.829**	.705**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Controlling the periodic maintenance operations in the long term	Pearson Correlation	.493**	.525**	.565**	.629**	.680**	.832**	.873**	.924**	1	.920**	.813**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000
	N	100	100	100	100	100	100	100	100	100	100	100

Table B.2: Correlation Coefficient Test Results Related To The Second Group Of Factors (Q12 To Q22). "Tables Continued"

Control the time required to do construction work	Pearson Correlation	.400**	.426**	.458**	.510**	.552**	.686**	.735**	.829**	.920**	1	.919**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000
	N	100	100	100	100	100	100	100	100	100	100	100
Reducing waste from building and construction works	Pearson Correlation	.338**	.360**	.387**	.431**	.466**	.579**	.621**	.705**	.813**	.919**	1
	Sig. (2-tailed)	.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	100	100	100	100	100	100	100	100	100	100	100
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												