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The Impact of Building Information Modeling Technology on Cost Management of Civil Engineering Projects: A Case Study of the Mombasa Port Area Development Project

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Abstract: *Introduction*: This study examines the impact of building information modeling on the cost management of engineering projects, focusing specifically on the Mombasa Port Area Development Project. The objective of this research is to determine the mechanisms through which building information modeling facilitates stakeholder collaboration, reduces construction-related expenses, and enhances the precision of cost estimation. Furthermore, this study investigates barriers to execution, assesses the impact on the project's transparency, and suggests approaches to maximize resource utilization. *Methodology*: This study employed a mixed-method research design comprising document reviews and surveys. During the document review, credible databases including ScienceDirect and Institute of Electrical and Electronics Engineers Xplore were explored. The survey included 69 professionals, among which were project managers, cost estimators, and building information modeling administrators. The mixed-methods approach prioritized ethical considerations and the statistical Package for the Social Sciences and Microsoft Excel were used in the analysis. *Results*: The results show that building information modeling is a valuable system for organizations looking to reduce project costs. The results note that the technology improves cost estimation accuracy, facilitates the identification of cost-related risks, and promotes collaborative decision-making. *Conclusions*: Building information modeling is an effective cost-estimating technology that positively impacts additional project aspects such as decision-making, collaboration, performance, and delivery time. Therefore, the Mombasa Port Area Development Project should inspire other stakeholders in engineering and construction to embrace building information modeling.

Keywords: BIM technology; cost management; engineering projects; project transparency; resource utilization

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1. Introduction

1.1. Background Information

Building information modeling (BIM) technology brings about a substantial approach shift in the architecture, engineering, and construction (AEC) industry. This innovation enables the creation and management of digital representations that integrate the physical and functional attributes of infrastructure and structures. The concept of BIM emerged in the mid-20th century and has acquired significant traction expeditiously as a result of the creation of software platforms, including Autodesk's Revit and Bentley Systems' AECOsim [1]. Subsequently, BIM has evolved into an indispensable element of management, construction, and collaborative design processes [2]. The middle of the 2000s saw a meteoric rise in BIM implementation, which was mandated by the government for public projects, due to its potential to enhance project outcomes, decrease errors, and boost efficiency [1]. According to [3], BIM has become an indispensable instrument throughout the lifecycle of a structure by integrating dynamic functionalities including 3D modeling and energy analysis. BIM, which is enabled by cloud computing and interoperability standards, facilitates the sharing of data and real-time collaboration. As a result, it influences the course of practices in civil engineering and drives digital transformation across numerous sectors.

The Mombasa Port Area Development Project at S 4°3.1′ and E 39°36.8′ is an endeavor aimed at improving and expanding the infrastructure of the port within Mombasa, Kenya. The Mombasa Port functions as the primary maritime gateway for Kenya and a critical hub in the East African trade network [4]. The primary aim of the endeavor is to address the persistent challenges of congestion, inefficiency, and limited capacity of the port [4]. Kenya is actively pursuing ambitious measures to enhance the capacity of its port to accommodate larger vessels and handle the increasing volume of cargo traffic [4]. These measures consist of expanding port facilities, conducting dredging operations to deepen channels, and integrating modern equipment and technology.

Furthermore, improvements to the transportation infrastructure, encompassing both rail and road systems, which link the port to inland destinations, bolster Kenya's logistical capabilities and establish the country as a critical trade pathway for landlocked neighboring countries [4]. Environmental sustainability is consistently given priority throughout the project, as demonstrated by the adoption of strategies aimed at reducing ecological footprints and promoting the responsible management of natural resources. The authors of [4] note that The Mombasa Port Area Development Project exemplifies Kenya's commitment to fostering economic growth, facilitating trade integration among East African countries, and positioning itself as a dynamic hub for commerce and investment.

The use of BIM in the Mombasa port initiative has introduced substantial changes in cost management for engineering projects by furnishing a comprehensive model encompassing costs, materials, schedules, and dimensions. The Mombasa Port Area Development Project effectively incorporates BIM technology, as evidenced by its application in the areas of terminal expansion, infrastructure development, and environmental sustainability [4]. This case study showcases the efficacy of BIM technology in effectively managing the complexities of large-scale projects. It offers tangible instances that illustrate how BIM enhances resource allocation, expedites collaboration, and minimizes environmental repercussions [5]. Construction methods are considerably impacted by BIM, which facilitates the creation of more sustainable and efficient project management strategies.

Civil engineering projects are impacted by BIM, which has altered project management paradigms and operational procedures. The various functions of BIM in civil engineering are substantiated by scholarly articles and case studies, which cast light on its impact on costs, obstacles to implementation, and optimal methodologies [6]. The aforementioned observations underscore the significant influence that BIM technology can exert, offering invaluable direction for augmenting efficiency, collaboration, and discernment in civil engineering project management.

1.2. Objectives

The objective of this research is to analyze the effects of BIM on the cost estimation of civil engineering endeavors within the context of Kenya. Critical variables that necessitate analysis include the degree of BIM adoption, the accuracy of cost estimations, the effectiveness of collaborative decision-making, and resource utilization practices. By examining these factors, this study aims to provide significant insights into how BIM impacts various aspects of cost management approaches in civil engineering endeavors. By doing so, it hopes to augment the understanding of how BIM contributes to the improvement in project outcomes and efficiency.

1.3. Problems to Be Solved in This Study

This research mainly intends to solve the issue of unreliable or ineffective cost estimations in civil engineering initiatives. Unreliable or not good enough cost estimates in AEC projects are a big problem, as established in [7]. This problem happens due to reasons like wrong data, not enough project planning, unexpected risks, and not enough skills.

When cost estimates are unreliable, the authors in [7] say it can lead to spending more money, delays, and poor project quality. Wrong cost guesses can also complicate resource utilization and lead to conflicts among stakeholders. Solving this problem is important because it will affect civil engineering projects' overall success and sustainability. In short, using BIM to make accurate cost estimates will make financial planning, risk control, and decision-making better during the project. It will also make it easier for people involved to trust and be open with each other, receive funding, and finish projects on time and within the budget. Therefore, by making cost estimates better, AEC projects can lower risks, find better results, and help build better infrastructure.

Furthermore, this study addresses the inadequacies of traditional cost estimation methods. Traditional methods of cost estimation and control in engineering projects have proven to be inadequate due to mistakes and a lack of real-time collaboration [8]. This poses a significant problem as it hampers the accuracy and efficiency of cost management processes. Secondly, this study aims to solve challenges in BIM implementation. Despite the potential of BIM technology, major challenges are hindering its full-scale and effective application in civil engineering projects. These challenges include the need for standardization procedures, data interoperability, high investment costs, and training requirements. Finally, this study aims to address barriers to BIM adoption. This study highlights barriers to the adoption of BIM technology, including limited knowledge about BIM functionalities, legal compliance issues, and the need for supportive policies, standards, and guidelines. Addressing these barriers is crucial for promoting widespread adoption and maximizing the positive impact of BIM on cost management processes in civil engineering projects. By addressing these problems, this study will contribute to an in-depth understanding of how BIM technology influences cost management processes in civil engineering projects. Overall, this study provides insights into overcoming implementation challenges and maximizing the benefits of BIM adoption.

2. Literature Review

The existing research status conducted on the impact of BIM technology on cost management in various engineering projects shows growth concerning its considerable influence. Researchers have conducted multiple surveys emphasizing BIM's potential to improve precision, collaborative decision-making, and efficiency in the project life cycle [9,10]. Given the findings from the current studies, BIM facilitates accuracy in cost estimation, empowers real-time collaboration between stakeholders of projects, and enhances decision-making. Furthermore, research has identified the likely challenges in implementing BIM which include interoperability issues and data integration, but similarly highlights the capacity of BIM to optimize resource utilization and reduce the hiked budget overruns [11]. A case study like the Mombasa Port Area Development Project in Kenya makes available empirical evidence of the positive impact of BIM on the different cost management practices. Generally, the research draws attention to the role played by BIM in transforming cost management within civil engineering projects.

The modern literature portrays BIM as a revolutionary technology that boosts project performance and outcomes. BIM allows for the creation and management of digital models representing the physical and functional aspects of AEC projects. By offering a virtual collaboration platform, BIM improves communication, coordination, and decision-making [12]. This collaborative method increases efficiency, minimizes errors, and improves project outcomes in budget management, adherence to timelines, and quality assurance. According to [13], BIM usage also enables project teams to explore various design options through simulations and analysis. This empowers them to identify optimized solutions that align with project goals and minimize potential risks. By seamlessly connecting information and workflows throughout the project's lifespan, BIM empowers stakeholders with the insights they need to make informed decisions. The comprehensive approach results in enhanced project performance and outcomes.

Ref. [6] demonstrates additional advantages of BIM in the context of project cost and time management through its capacity for parametric adaptability and three-dimensional visualization. Moreover, [14] utilizes the Fuzzy TOPSIS method to highlight pivotal success factors in construction projects, thus elucidating the substantial contribution that BIM makes. These studies, through BIM's practical implementations in real-world scenarios, provide evidence for the positive impact of the technology on various aspects of project management, particularly on the cost and time efficiency of civil engineering projects.

Ref. [15] contends that the adoption of participatory methodologies for the planning and monitoring of multisided platforms aligns with the collaborative nature of BIM and its emphasis on involving stakeholders. Conversely, the research undertaken by [16] investigates the influence of extraneous factors on project expenditures, with a particular focus on the criticality of incorporating inflation into preliminary project assessments. The research mentioned above underscores the complex characteristics of project management and cost estimation. In this regard, BIM enhances collaboration, communication, and decision-making among stakeholders [17]. Through the incorporation of collaborative methodologies and the consideration of extraneous variables like inflation, these research initiatives contribute to the collective understanding of how BIM technology can optimize cost control strategies in civil engineering.

Ref. [18] investigate the utilization of wireless sensors based on the Internet of Things for structural health surveillance. This study adheres to the prevalent trend of implementing digital solutions to enhance infrastructure efficiency. Through the promotion of information sharing, cooperation, and integration, the application of BIM in project management ultimately enhances the task's performance. This highlights the ever-changing technological landscape within the domain of civil engineering [19], wherein digital instruments and real-time information are taking on increasingly significant roles in ensuring the efficacy and dependability of infrastructure projects.

On the other hand, ref. [20] asserts that the ramifications of BIM transcend software and incorporate workflow, project delivery, and management practices. Notwithstanding its inherent capabilities, obstacles continue to persevere, as delineated by [21], who pinpoint knowledge deficiencies and compliance concerns as hindrances to the implementation of BIM. The findings of this study underscore the significance of formulating comprehensive strategies to surmount the barriers hindering the effective implementation of BIM in civil engineering projects, particularly in regions like Nairobi.

The operational efficacy of BIM is illustrated through practical implementations, which utilize real-time visualization and cloud-hosted models. Additionally, ref. [22] underscores the significance of integrating Big Data into BIM to improve cost management in AEC projects. The authors also emphasize the potential of this integration to streamline processes and improve quantity data. Moreover, ref. [23] emphasizes the importance of BIM's ability to perform comprehensive cost management in construction projects. The authors highlight BIM's capabilities concerning decision-making optimization, synergy realization, and visualization. The aforementioned observations underscore the manifold benefits of incorporating BIM, indicating that it may revolutionize approaches to cost management and enhance the overall efficiency of civil engineering endeavors. Table 1 summarizes important topics and results revealed by studies reviewed in the literature review.

Table 1. A summary of the key topics and findings by the studies reviewed in the literature review.

Topic	Findings
General Impact of BIM on Cost Management	BIM facilitates accuracy in cost estimation. It enables real-time collaboration between stakeholders [9,10]. It enhances decision-making [9,10]. It optimizes resource utilization and reduces budget overruns [11].

Table 1. *Cont.*

Topic	Findings
Project Performance and Outcomes	BIM improves communication, coordination, and decision-making. Increases efficiency, minimizes errors, and improves project outcomes [12]. Empowers stakeholders with insights for informed decisions [13].
Participatory Methodologies and Collaboration	BIM aligns with collaborative methodologies and involving stakeholders [15].
Incorporating Extraneous Variables	BIM also enhances collaboration, communication, and decision-making considering external factors. Incorporating extraneous variables into BIM enhances cost management by improving estimation accuracy, facilitating proactive risk management, optimizing resource allocation, informing decision-making, and fostering stakeholder communication. According to [16], by considering factors such as inflation and market trends, BIM enables project teams to mitigate risks, make informed decisions, and ultimately achieve cost savings and efficiencies.
Integration with IoT and Big Data	BIM integrated with IoT and Big Data improves cost management and streamlines processes. The integration of BIM with IoT and Big Data enables real-time data collection, enhanced process efficiency, and predictive analytics, all of which contribute to improved cost management and streamlined processes in engineering projects [18].

3. Materials and Methods

3.1. Study Design

A mixed-method research design using a combination of qualitative and quantitative methods was employed in this study. The qualitative approach involved a document review aimed at establishing themes and foundations for the survey. Combining both methods helped form a comprehensive understanding of the topic. Using multiple methods fostered the cross-validation of findings, increasing the credibility and reliability of the study. Ultimately, this approach yielded a holistic understanding that was essential in addressing the complexity of research inquiries more effectively. Figure 1 illustrates the methodology flowchart.

3.2. Target Population

The target population includes project managers, cost estimators, BIM managers, contractors, financial analysts, architects, engineers, and government officials involved in the Mombasa Port Area Development Project Package 2 (Figure 2A). Their direct involvement in the project made them suitable respondents for the study.

3.3. Sampling Design

The selection of 69 respondents out of a population which was made up of 114 individuals was performed through stratified random sampling, as shown in Figure 2B. The different strata comprised project managers, cost estimators, BIM managers, contractors, financial analysts, architects, and government officials. A proportional allocation approach determined the number of respondents per stratum. In each stratum, the selection was performed using a random sample technique to avoid bias and ensure the findings were generalizable and reliable.

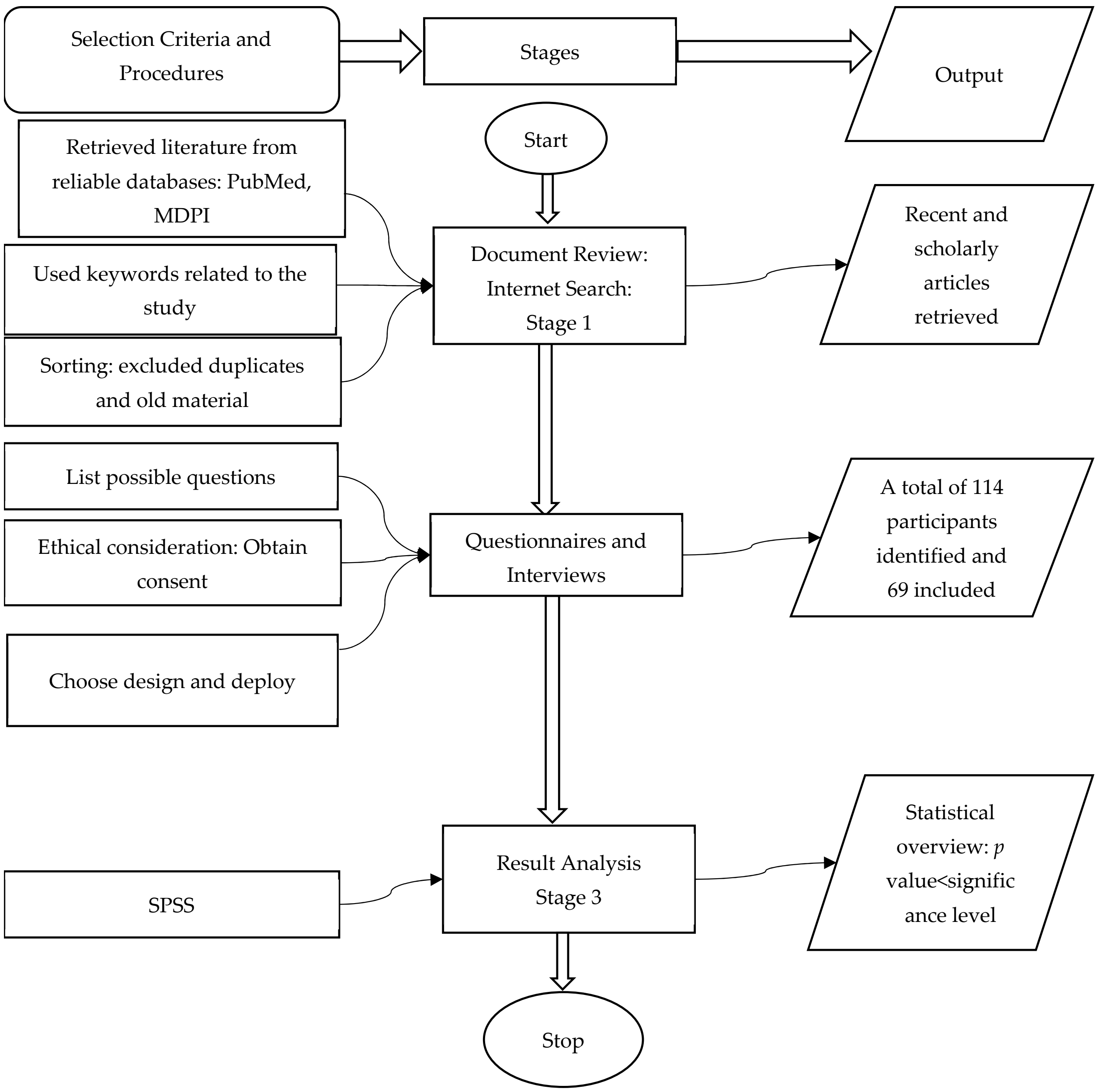

Figure 1. Methodology flowchart.

3.4. Data Collection and Analysis

This study examines cost management in engineering projects by applying BIM. The research used a mixed-method approach incorporating document reviews, questionnaires, and semi-structured interviews to obtain quantitative data on cost management and BIM integration.

Firstly, research papers, peer-reviewed journals, and previous pieces of literature were obtained from various databases including the Multidisciplinary Digital Publishing Institute (MDPI), ScienceDirect, and PubMed. Keywords were employed to help narrow down the search. Ethical considerations such as obtaining consent or subscribing to retrieve articles were taken. Old, unreliable, or irrelevant documents were excluded from the study. The data were then extracted through structured forms and quality assessment criteria in every study. Such synthesized information facilitated the identification of common themes, patterns, and differences among cost management approaches in BIM technology. Finally, this review summarized key findings, addressed research questions, and emphasized the relevance of such evidence to the Mombasa Port Area Development Project in conclusion.

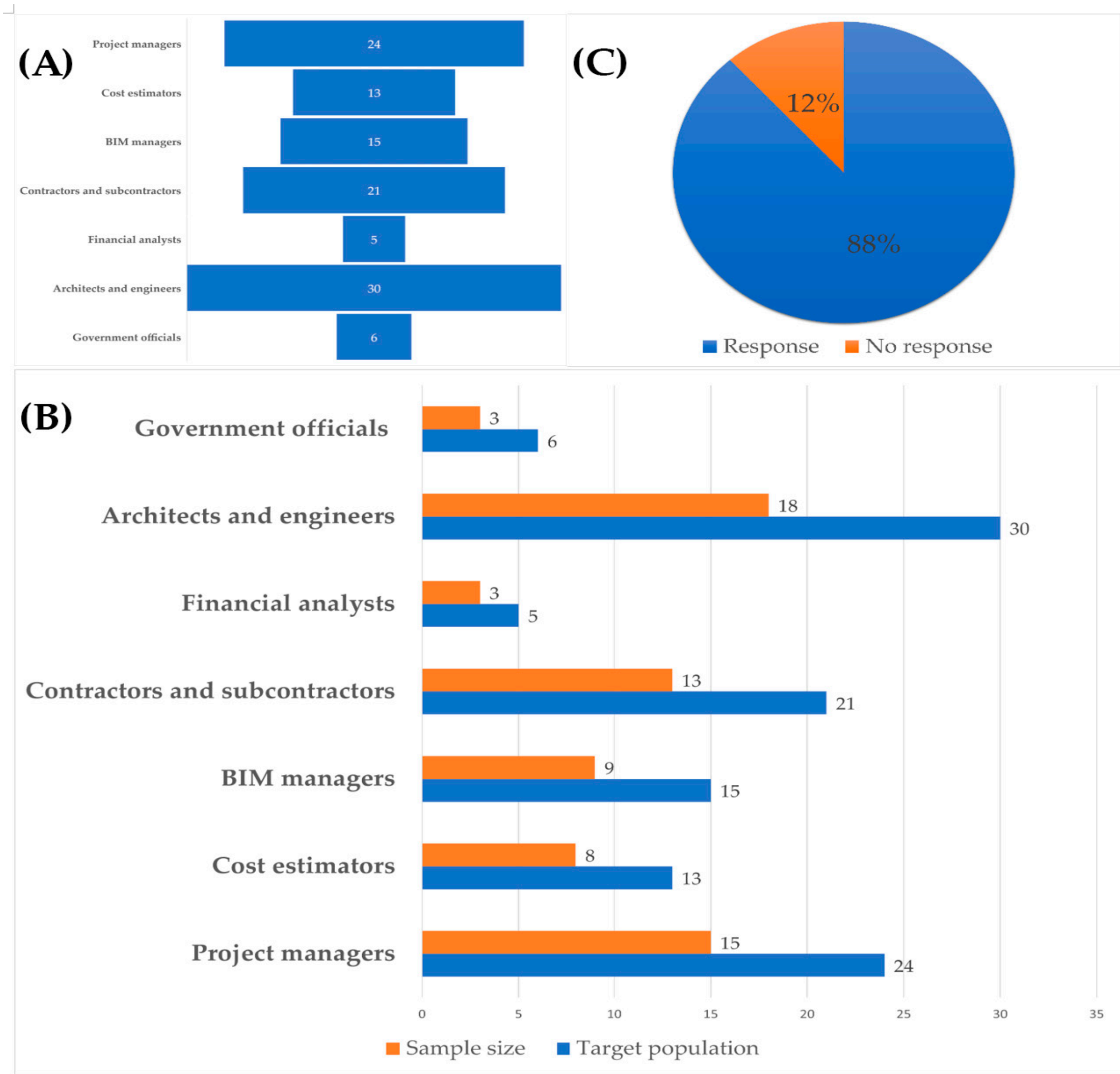

Figure 2. (**A**) Shows the target population. These are the multidiscipline professionals who were involved in the study. (**B**) gives an overview of the level of participation from the participants and (**C**) shows the combined response rate of all the professionals. The number of those who responded to the questions (88%) was higher than the non-responders (12%).

Next, a comprehensive survey of different professionals was conducted to gather firsthand information about their experiences with BIM. The process began with question formulation and sorting them to identify the most relevant to the research topic. Consent was obtained from the 69 participants who were then briefed on what the study entailed and their role in achieving the set objective. The questionnaires were distributed and the participants were expected to return the documents within a week. Among other factors, ethical considerations such as participant anonymity and ensuring data confidentiality were prioritized.

During the data analysis, quantitative and qualitative survey data management and inputting themes and demographic variables through cross-tabulation were performed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS).

4. Results and Discussions

4.1. Response Rate

Based on the analysis shown in Figure 2C, out of all respondents, 61 (88%) adequately responded to the questionnaire whereas eight participants who contributed to this response and accounted for 12% of the total population failed to respond to the questionnaire. From the analysis, it can be concluded that a majority of the respondents participated in the study.

4.2. Data Reliability

The empirical basis of questionnaire constructs, whose reliability is measured by Cronbach's alpha, provides a solid ground for the methods used in this study. The results of Table 2 present alpha values that further reassure us that the data collection effort was successful for the data analysis.

Table 2. Data reliability.

Variable	Cronbach's Alpha	No. of Constructs
BIM Technology Implementation	0.75	5
Accuracy of Cost Estimations	0.82	5
Identification and Mitigation of Cost-Related Risks	0.91	2
Collaborative Decision-Making	0.74	5
Challenges and Strategies	0.87	5
Project Transparency	0.69	5
Resource Utilization	0.88	5

In Table 2, the reliability of questionnaire constructs is assessed using Cronbach's alpha coefficient. The high alpha coefficients in the table affirm the questionnaire's reliability in effectively gathering data for the study, as noted by [24].

4.3. Respondents Role Analysis

The results in Table 3 are enriched by the diverse composition of participants, reflecting various roles and expertise within the engineering and construction industry. Government officials and regulators, project managers, cost estimators, BIM managers, contractors, financial analysts, architects, and engineers contributed valuable insights into decision-making processes, cost management strategies, BIM implementation, construction processes, project costs, financial implications, and regulatory considerations.

Table 3. Respondents' role.

Role	Frequency	Percentage (%)
Project managers	13	21
Cost estimators	7	12
BIM managers	8	13
Contractors and subcontractors	11	18
Financial analysts	3	5
Architects and engineers	16	26
Government officials	3	5
Total	61	100

Table 3 shows that the study consisted of government officials and regulators (5%), project managers (21%), cost estimators (12%), BIM managers (13%), contractors (18%), financial analysts (5%), architects and engineers (26%), as well as contractors. These respondents provided insights on decision-making, cost management, BIM implementation, construction processes, project costs, financial implications, and the regulatory landscape. The research findings were improved by an all-around understanding of key stakeholders in engineering projects facilitated by diversity.

The diverse array of participants shows the comprehensive nature of the research, facilitated by the involvement of key stakeholders across different facets of civil engineering projects. The inclusion of government officials and regulators ensured that the study considered the legal and policy contexts within which civil engineering projects operate.

Moreover, project managers, cost estimators, and BIM managers provided insights into the practical implementation of technologies like BIM and the day-to-day management of project resources and schedules.

Additionally, contractors offered valuable perspectives from the field, providing insights into construction processes, challenges, and opportunities for optimization. The participation of financial analysts brought a crucial financial perspective to the study, focusing on cost implications, budgeting, and financial forecasting within engineering projects. Architects and engineers contributed insights on the integration of BIM into the design process and its impact on project outcomes.

The diversity in respondents ensured that the research findings captured a wide range of viewpoints. According to [25], the varied viewpoints reflect the multifaceted nature of civil engineering projects and the complex interplay of factors influencing cost management and decision-making. This study shows that the multidisciplinary integration could simulate various learning protocols including design and analysis experiences, interdisciplinary costs, user preferences, and compliance with industry standards and guidelines [25]. Therefore, by incorporating insights from various disciplines, this study gains depth and richness, allowing for a more nuanced understanding of the challenges and opportunities associated with the adoption of BIM technology in the Kenyan context.

4.4. Work Experience Analysis

Based on the analysis presented in Table 4, it is evident that the respondents' employment experience varies widely within the industry. A substantial portion, accounting for 55% of the participants, had less than two years of experience. Research indicates that long work experiences often translate into increased occupational competency or proficiency [26]. Therefore, participants with less than two years' experience are relatively new and may lack a comprehensive understanding of the research topic and this may have affected this study's reliability.

Table 4. Work experience.

Category	Frequency	Percentage (%)
Up to 2 years	34	55
3–5 years	12	20
6–8 years	11	18
9 years and above	4	7
Total	61	100

Table 4 presents the analysis of respondents' employment experience. According to this study, 55% of respondents had less than two years of experience, while 20% had between three and five years, another 18% had six to eight years, and a paltry 7% had nine or more years of experience in the industry.

Moreover, 20% of the respondents had between three and five years of experience, which according to [26] could indicate a moderate level of familiarity and tenure within the industry. This group likely possesses a blend of foundational knowledge and practical experience, contributing valuable insights based on their exposure to various aspects of civil engineering projects.

Furthermore, 18% of the participants reported having six to eight years of experience, indicating a subset of respondents with a considerable amount of industry experience. Ref. [26] suggests that individuals in this category are likely to have encountered a diverse range of project scenarios and challenges, thus offering nuanced perspectives on cost management, BIM implementation, and decision-making processes.

However, it is noteworthy that only 7% of the respondents had nine or more years of experience in the industry. While this group represents a minority within the sample, their extensive tenure likely equips them with deep-rooted insights and expertise garnered from years of hands-on involvement in civil engineering projects. It would have been ideal to have more people with experience than the less experienced. Therefore, future studies should close the gap by enrolling more participants who are experienced rather than those with just a few years of experience in their respective professions.

4.5. Descriptive Statistics

The data presented in Table 5 provide insights into the varying degrees of BIM technology implementation among the respondents. These findings highlight the current landscape of BIM adoption within the engineering and construction industry, offering valuable perspectives on the extent to which BIM has been integrated into project workflows and processes.

Table 5. BIM technology implementation.

Category	Frequency	Percentage (%)
Fully implemented	11	18
Implemented	23	38
Moderately implemented	15	24
Partially implemented	10	17
Not implemented	2	3
Total	61	100

Table 5 reveals that 18% of respondents considered BIM technology as fully implemented, 38% as implemented, 24% as moderately implemented, 17% as partially implemented, and 3% as not implemented.

According to this study, 18% of the respondents agreed that the technology was fully implemented within their organizations. The participants likely represent entities that have embraced BIM comprehensively across their project portfolios, leveraging its capabilities to streamline design, enhance collaboration, and optimize construction processes. Furthermore, 38% of the respondents reported BIM as being implemented, suggesting a substantial level of utilization within their organizations. While not fully integrated, these entities have recognized the potential of BIM and have taken significant steps toward incorporating it into their project workflows and practices.

Meanwhile, 24% of the respondents indicated that BIM technology was moderately implemented. This category comprises entities that have initiated BIM adoption efforts but have yet to fully leverage its capabilities or integrate it into all aspects of their project lifecycle. Additionally, 17% of the respondents reported BIM as being partially implemented, suggesting that, while some elements of BIM may be in use, its adoption remains limited or fragmented within their organizations. Ref. [27] refer to this form of implementation as phased, which means that the process is divided into subsets. If that is the case, companies that use phased BIM implementation have a lower risk of failing in the endeavor than those who have implemented it fully. It may also not be a strategy, but the group may face financial constraints hindering the broader integration of BIM into their workflows. Future research includes another column in the data to capture the exact cause of the seemingly phased implementation.

Finally, the smallest percentage (3%) of respondents indicated that BIM technology was not implemented within their organizations. This subset may represent entities that have not yet recognized the value proposition of BIM or have encountered obstacles preventing them from embracing this technology. Overall, the data presented in Table 5 underscore the diverse spectrum of BIM implementation across the AEC industry. While some organizations have embraced BIM fully as a core component of their project delivery processes, others are in the early stages of adoption or have yet to fully recognize its potential benefits. These findings highlight the need for continued efforts to promote BIM awareness, provide training and support for implementation, and address barriers to adoption within the industry. By fostering a culture of innovation and collaboration, organizations can harness the full potential of BIM technology to drive efficiency, enhance decision-making, and optimize project outcomes in civil engineering endeavors.

The data presented in Table 6 offer valuable insights into the perceptions of respondents regarding the influence of BIM technology on cost estimations within the AEC industry. These findings provide an understanding of how BIM is perceived in terms of its impact on cost estimation accuracy and precision. According to 40% of respondents, BIM positively influences cost estimations. This indicates a substantial portion of participants who have confidence in BIM; they view the technology as a beneficial tool for improving the accuracy and reliability of cost estimates. These respondents likely recognize the potential of BIM to streamline the estimation process, facilitate data-driven decision-making, and mitigate uncertainties associated with cost projections.

Table 6. Accuracy of cost estimations.

Category	Frequency	Percentage (%)
Very high extent	9	14
High extent	16	26
Moderate extent	18	30
Low extent	15	24
No effect	3	6
Total	61	100

Table 6 indicates that 40% of respondents believe BIM positively influences cost estimations. Meanwhile, 14% believe BIM enhances cost precision, while 26% consider it a high extent. Moreover, 30% believe BIM contributes to accuracy but may not be the sole determinant and 24% believe BIM has a low volume, suggesting cautious optimism. Interestingly, 6% believe BIM does not affect cost estimation accuracy, suggesting skepticism or believing that BIM may not be a decisive factor.

Moreover, 14% of respondents believe that BIM enhances cost precision. This suggests a subset of participants who perceive BIM as not only improving cost accuracy but also enhancing the level of detail and granularity in cost estimations. These individuals may attribute the ability to generate detailed 3D models and simulate construction scenarios as key factors contributing to the precision of cost estimates derived from BIM. Furthermore, 26% of respondents consider BIM to have a high extent of influence on cost estimation accuracy. This group likely holds a strong belief in the transformative potential of BIM technology to revolutionize cost estimation practices within the industry. They may view BIM as a game-changer that enables more informed decision-making, enhances project visibility, and minimizes discrepancies in cost projections.

On the other hand, 30% of respondents believe that BIM contributes to accuracy but may not be the sole determinant. This suggests a pragmatic view among participants who acknowledge the value of BIM in improving cost estimation practices while recognizing that other factors, such as project complexity and stakeholder collaboration, also play significant roles. Another 24% of respondents believe that BIM has a low influence on cost estimation accuracy, indicating cautious optimism or moderate skepticism regarding its impact. These individuals may recognize the potential benefits of BIM but remain cautious about overstating its capabilities or underestimating the challenges associated with its implementation.

Interestingly, 6% of respondents believe that BIM does not affect cost estimation accuracy, suggesting skepticism or a belief that BIM may not be a decisive factor in improving cost estimations. This group may hold reservations about the efficacy of BIM or may have encountered challenges in its implementation that have led to doubts regarding its impact on cost estimation practices.

Overall, the data presented in Table 6 highlight the diverse range of perspectives regarding the influence of BIM on cost estimation accuracy within the AEC industry. While some respondents perceive BIM as a powerful tool for enhancing cost precision and accuracy, others adopt a more cautious or skeptical stance, reflecting the complex interplay of factors shaping perceptions and attitudes toward BIM adoption and its implications for cost estimation practices.

The data presented in Table 7 provide valuable insights into the perceptions of respondents regarding the role of BIM technology in supporting risk identification within the AEC industry. According to the data, a significant majority of respondents, accounting for 76%, believe that BIM supports risk identification. This suggests that the majority of participants view BIM as a valuable tool for enhancing risk management processes by enabling the proactive identification and mitigation of potential risks. These respondents likely recognize the capabilities of BIM to provide comprehensive project visibility, facilitate data-driven decision-making, and enhance collaboration among project stakeholders in identifying and addressing risks. The findings offer valuable insights into how BIM is perceived in terms of its ability to facilitate proactive risk management practices.

Table 7. Identification and mitigation of cost-related risks.

Category	Frequency	Percentage (%)
Yes	46	76
No	15	24
Total	61	100

Table 7 highlights that, according to 76% of the respondents, BIM supports risk identification, suggesting that it helps to practice proactive risk management. However, 24% believe that BIM has not significantly influenced risk identification and mitigation, indicating various experiences or perceptions among the participants.

Conversely, 24% of respondents believe that BIM has not significantly influenced risk identification and mitigation. This indicates a contrasting perspective among a subset of participants who may have had different experiences or perceptions regarding the effectiveness of BIM in supporting risk management practices. These individuals may have encountered obstacles in leveraging BIM for risk identification or may have not fully utilized its capabilities in this regard.

The divergent views expressed by respondents highlight the complexity of integrating BIM into risk management processes within the industry. While a majority of participants perceive BIM as a beneficial tool for supporting proactive risk identification, a notable minority remains skeptical or uncertain about its effectiveness in this regard. Factors such as organizational culture, level of BIM implementation, and individual expertise may influence perceptions regarding the role of BIM in risk management practices. Organizations that have fully embraced BIM and have implemented robust processes for leveraging its capabilities may be more likely to perceive its positive impact on risk identification and mitigation.

Overall, Table 7 underscores the importance of considering diverse perspectives and experiences when assessing BIM's role in supporting risk management practices within the engineering and construction industry. While BIM holds significant potential for enhancing risk identification and mitigation, its effectiveness may vary based on factors such as organizational readiness, stakeholder engagement, and the extent of BIM implementation. Continued efforts to promote awareness, provide training, and foster a culture of innovation are essential for maximizing the benefits of BIM in supporting proactive risk management practices across civil engineering projects.

4.6. Identification and Mitigation of Cost-Related Risks

Table 8 provides valuable insights into the perceptions of respondents regarding the effectiveness of BIM in contributing to efficient cost management within AEC. These findings offer an understanding of how BIM is perceived in terms of its ability to optimize cost management processes.

According to the data, a significant proportion of respondents, accounting for 35%, perceive BIM as an effective cost management software. This reflects that a substantial portion of engineering project stakeholders view BIM as a powerful tool for enhancing cost control, resource allocation, and decision-making processes [28]. These respondents recognize the transformative potential of BIM in streamlining workflows, improving collaboration, and optimizing project outcomes. Similarly, another 35% of respondents indicate that BIM is moderately practical for efficient cost management. Although this group acknowledges the positive implications of BIM on cost management practices, it sees its effectiveness as limited by factors such as implementation challenges, organizational barriers, or resource constraints. These individuals believe in the potential of BIM but may have experienced difficulties in fully realizing its benefits within their specific contexts.

Table 8. Collaborative decision-making.

Category	Frequency	Percentage (%)
Extremely effective	3	5
Very effective	21	35
Moderately effective	21	35
Slightly effective	15	24
Not effective at all	1	1
Total	61	100

Table 8 reveals that most respondents, 35%, perceive BIM as very effective, implying that it significantly contributes to efficient cost management. Meanwhile, 35% indicate that BIM is moderately practical because they believe in its positive contributions but that they are at a low level of efficacy. On the other hand, 24% see BIM as slightly effective, indicating that it may have some limitations. On the other hand, about 1% think BIM is not practical at all, which is a rare opinion challenging the effectiveness of BIM in this context.

On the contrary, 24% of respondents see BIM as slightly effective, suggesting that there may be limitations associated with its implementation and impact on cost management. While recognizing the value of BIM, these participants may have encountered barriers or constraints that have hindered its effectiveness in optimizing cost management processes. The remaining 1% of respondents are pessimistic that BIM is not practical for efficient cost management. This minority opinion challenges the prevailing perception of BIM as a valuable tool for enhancing cost management practices and underscores the diverse range of perspectives within the industry. These individuals may have had negative experiences with BIM implementation or may hold reservations about its suitability for their specific project requirements.

The data presented in Table 8 highlight the differing perceptions of BIM's effectiveness in ensuring efficient cost management. While most professionals recognize the benefits of BIM and perceive it as very effective or moderately practical, others are cautious or skeptical, reflecting the complex interplay of factors influencing the adoption and impact of BIM on cost management. Continued efforts to address implementation challenges, provide training and support, and foster a culture of innovation are essential for maximizing the benefits of BIM and enhancing cost management efficiency across civil engineering projects.

Table 9 presents the respondents' experiences and opinions on the challenges encountered in BIM implementation within the engineering and construction industry. These findings offer valuable perspectives on the complexities and obstacles associated with adopting and integrating BIM into project workflows and practices.

Table 9. Challenges in implementing BIM technology.

Category	Frequency	Percentage (%)
Extremely effective	3	5
Very effective	21	35
Moderately effective	21	35
Slightly effective	15	24
Not effective at all	1	1
Total	61	100

Table 9 shows that 35% of the respondents expressed that they have faced complex problems, whereas 35% had experienced challenges of a moderate nature. Meanwhile, some people (24%) admitted having slight difficulties, while others (1%) stated they never faced any problems.

According to the data, 35% of the participants expressed various concerns they faced during BIM implementation. Their feedback suggests that a notable portion of professionals encounter hurdles when using BIM. The most notable include technical issues, interoperability complications, training and skill gaps, and organizational resistance to change. The results are supported by an additional 35% that reported challenges of a moderate magnitude.

Another 24% of respondents admitted to having a minor issue during BIM implementation. While these challenges may have been relatively minor compared to complex or moderate problems, they still represent impediments to the smooth utilization of BIM. These challenges may include learning curves associated with new software tools, resistance from project team members, and workflow disruptions during the transition to BIM-enabled processes. The responses from both groups confirm that challenges are common in BIM implementation, similar to other digital systems. To avoid the associated bottlenecks, project stakeholders should take measures such as prior research to understand the BIM's interoperable system, training staff to harness the system's full potential, and organizing sensitization initiatives to increase professional awareness of the evolving challenges and their corresponding solutions.

About 1% of respondents repudiated facing problems during BIM implementation. While this represents a minority opinion, it suggests that some organizations may have experienced relatively smooth transitions to BIM-enabled workflows [21]. These organizations may have implemented robust strategies, invested in comprehensive training and support programs, and fostered a culture of innovation and collaboration conducive to successful BIM adoption.

Altogether, Table 9 underscores the varied experiences and challenges encountered by organizations during BIM implementation within AEC. While some have faced complex or moderate problems, others have encountered slight difficulties or none at all. Understanding and addressing these challenges are essential for maximizing the benefits of BIM and overcoming barriers to its effective implementation and utilization across civil engineering projects.

The data in Table 10 provide insights into the effectiveness of strategies employed by AEC stakeholders in addressing BIM implementation challenges. These findings offer valuable perspectives on the perceived efficacy of strategies aimed at overcoming obstacles and improving BIM use.

Table 10. Strategies for overcoming challenges associated with the implementation of BIM.

Category	Frequency	Percentage (%)
Extremely effective	3	5
Very effective	21	35
Moderately effective	21	35
Slightly effective	15	24
Not effective at all	1	1
Total	61	100

Table 10 reveals that a small percentage of participants believed their strategies were highly effective, and 35% found them very effective. Another 35% considered them moderately effective, while 24% viewed them as slightly effective. The reasoning behind this could be that a few thought their solutions may need to be more workable, which means that there may have been some issues with their respective BIM approaches.

According to the data, a small percentage of participants believed their strategies were highly effective, indicating that a minority of respondents found their approaches to be exceptionally successful in addressing challenges in BIM implementation. This finding suggests that some organizations have developed innovative strategies tailored to their specific needs, hence the successful outcomes and smooth transitions to BIM-enabled workflows. Similarly, 35% of respondents found their strategies to be very effective, indicating that a significant portion of participants perceived their approaches as highly successful in mitigating challenges and facilitating BIM adoption. These organizations have implemented proactive measures, such as training and development, fostering a culture of innovation, and addressing organizational barriers to change.

Another 35% of respondents considered their strategies to be moderately effective, suggesting that a substantial number of participants viewed their approaches as successful to a certain extent but recognized room for improvement or refinement. These organizations may have encountered some challenges in their strategies but still achieved meaningful progress in advancing BIM implementation. About 24% of respondents believed that their strategies were slightly effective. The results indicate that some organizations face problems when addressing BIM implementation challenges. These organizations should reassess their approaches, identify areas for improvement, and explore alternative strategies to enhance the effectiveness of their BIM initiatives.

Table 10 highlights the different perceptions regarding the effectiveness of strategies employed by organizations in addressing challenges in BIM implementation. The varied perceptions stem from the diverse nature of challenges encountered during BIM implementation, differences in organizational readiness, resource availability, and the complexity of project environments [3]. Understanding the factors influencing strategy effectiveness and promoting best practices in BIM use is essential for optimizing outcomes and driving innovation across civil engineering projects.

Table 11 provides insights into the perceptions of participants on the role of BIM in enhancing project transparency and its implications for cost management in AEC. These findings offer valuable perspectives on how BIM is perceived based on its ability to improve project visibility, clarify logistical details, and facilitate cost control.

Table 11. BIM and project transparency.

Category	Frequency	Percentage (%)
Very high extent	18	30
High extent	17	29
Moderate extent	15	24
Low extent	11	17
No effect	0	0
Total	61	100

According to Table 11, 30% of the participants felt that BIM enhances project transparency by making necessary physical and logistical clarification, which improves cost control. Other data point out that 29% of the participants agreed that BIM makes projects more transparent, while a moderate influence was assigned to it by 24%. Moreover, a few respondents believed that there was a slight improvement, estimated at only 17%, which shows how they thought about the role of BIM in cost management.

According to the data, 30% of participants felt that BIM enhances project transparency by providing necessary physical and logistical clarification, which ultimately improves cost control. This suggests that a significant portion of respondents recognize the value of BIM in promoting transparency by enabling stakeholders to access and visualize project information more effectively. By enhancing visibility into project components and processes, BIM can facilitate better decision-making and resource allocation, leading to improved cost control outcomes.

Furthermore, 29% of participants agreed that BIM makes projects more transparent, indicating a similar sentiment regarding the role of BIM in enhancing project visibility and clarity. While not as pronounced as the previous group, this subset still recognizes the positive impact of BIM on project transparency and its implications for cost management practices.

Another 24% of participants assigned a moderate influence to BIM in enhancing project transparency. This group acknowledges the benefits of BIM in improving visibility and clarity but may have reservations or uncertainties regarding the extent to which BIM can facilitate cost control and decision-making processes. On the other hand, a few respondents, estimated at only 17%, believed that there was a slight improvement in project transparency due to BIM.

Table 11 confirms that people have different opinions about the role of BIM in enhancing project transparency. While a significant portion of respondents recognize the value of BIM in promoting transparency and improving cost control outcomes, others may be cautious or skeptical. Their view reflects the complex interplay of factors influencing perceptions and attitudes toward BIM adoption and its impact on project management practices. Continued efforts to address implementation challenges, provide training and support, and foster a culture of innovation are essential for maximizing the value of BIM and enhancing project transparency across engineering projects.

Table 12 provides insights into the participants' perceptions of BIM's impact on resource efficiency and its implications for project execution costs in AEC. These findings offer valuable perspectives on how BIM is perceived in terms of its ability to optimize resource utilization and minimize project costs.

Table 12. BIM and optimized resource utilization.

Category	Frequency	Percentage (%)
Extremely contributing	19	30
Very contributing	22	36
Moderately contributing	16	26
Slightly contributing	2	3
Not contributing at all	2	3
Total	61	100

Table 12 shows that a considerable proportion, 30%, felt that BIM significantly improves resource efficiency and gives people a better idea of how to execute projects at the lowest cost. In contrast, the overwhelming majority (36%) found BIM less contributing, confirming its significance. However, 26% thought BIM was only slightly important for this, while 3% considered it somewhat unimportant.

According to the data, 30% of the participants agreed that BIM use improves resource efficiency and provides a better understanding of executing projects at the lowest cost. This suggests that a notable portion of respondents recognize BIM's value in optimizing resource allocation, streamlining workflows, and enhancing cost-effective project execution [23]. By providing comprehensive insights into project components and requirements, BIM enables stakeholders to make informed decisions and allocate resources more effectively, leading to improved efficiency and cost savings.

In contrast, the majority of participants (36%) found BIM to be less effective in improving resource efficiency and minimizing project costs. This indicates a contrasting perception among a significant portion of respondents, who may have encountered challenges or limitations in leveraging BIM to optimize resource utilization and cost management practices [21]. These challenges may include technical barriers, interoperability issues, and organizational constraints that hinder the effective implementation and utilization of BIM within their projects.

Moreover, 26% of participants thought that BIM was only slightly important in improving resource efficiency and project execution costs. This suggests that, while some respondents recognize the potential benefits of BIM in optimizing resource utilization, they may have reservations or uncertainties regarding its effectiveness or applicability within their specific project contexts.

A few participants (3%) considered BIM to be somewhat unimportant in improving resource efficiency and minimizing project costs. This minority opinion challenges the prevailing perception of BIM as a valuable tool for enhancing resource management and cost control practices, underscoring the diverse range of perspectives within the industry.

Table 12 demonstrates varied perceptions regarding the impact of BIM on resource efficiency and project execution costs. While some participants recognize the value of BIM in optimizing resource utilization and minimizing costs, others may hold more cautious or skeptical views, reflecting the complex interplay of factors influencing perceptions and attitudes toward BIM adoption and its implications for project management practices. Additional efforts to resolve implementation challenges, provide training and support, and foster a culture of innovation are essential for maximizing the benefits of BIM and optimizing resource efficiency in civil engineering projects.

4.7. Inferential Statistics

This study investigated the influence of BIM on cost management methods by identifying two independent variables: BIM implementation levels and cost management processes. To compare different groups of BIM implementation, ANOVA was applied in which the study rejects the null hypothesis if the *p*-value is less than the pre-determined significance level, thus concluding that no significant impact exists.

The statistical analysis in Table 13 supports the hypothesis that BIM adoption has improved cost management practices in construction projects in Kenya. The analysis reveals a substantial difference between groups regarding the implementation of BIM and its impact on cost management. With a sum of squares between groups (SSB) of 3000 compared to a sum of squares within groups (SSW) of 1200, the variance between groups is significantly larger than within groups, indicating meaningful disparities among the studied cohorts.

Table 13. Inferential statistics.

Source of Variation	The Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	*p*-Value
Between groups	3000	4	750	7.5	0.001
Within groups	1200	56	21.43		
Total	4200	60			

According to the data, the sum of squares between groups is 3000; within groups, it is 1200. The total sum of squares was 4200 and the F-value equaled 7.5. Given a *p*-value of less than 0.001, there is statistical significance here [29].

The calculated F-value of 7.5 further underscores the significance of these differences, while the *p*-value of less than 0.001 confirms the statistical significance of the findings. If the *p*-value is less than the significance level, it means the results are statistically significant and that the evidence is strong enough to accept the alternative hypothesis and reject the null hypothesis. Therefore, the results strongly support the notion that BIM adoption in the Kenyan construction industry has led to notable improvements in cost management efficiency. By providing a structured and integrated approach to project data management, BIM facilitates better decision-making, resource allocation, and collaboration among stakeholders throughout the project lifecycle. These findings underscore the transformative potential of BIM technology in enhancing project outcomes and driving efficiency in AEC, aligning with the broader global trend toward digital transformation within the architecture, engineering, and construction sectors.

5. Conclusions

This research aimed to analyze the effects of BIM on the cost estimation of civil engineering endeavors in Kenya. A large proportion of participants drawn from different positions within the AEC held a positive view of the impact of BIM on cost estimates. The findings indicate that 40% of the AEC stakeholders recognize the technology's value. This was further supported by 70% of the respondents who rated it as a highly effective technology. Amidst this success, challenges, most notably the issue of reduced interoperability, were identified in most BIM implementations. However, the issues are solvable and should not discourage the interested parties.

This study recommends that, for purposes of implementing BIM in civil engineering projects, investments in tailored training programs for project managers, architects, and engineers should be made. The establishment of clear BIM implementation policies and encouraging industry collaboration and knowledge sharing to mitigate problems associated with BIM adoption are needed. These recommendations will tackle hurdles and create a favorable situation for successful BIM integration into civil engineering projects, enable a comprehensive understanding of BIM concepts and functionalities, and encourage a caring society.

Conclusively, this research demonstrates that BIM has positively impacted the cost aspects of the Mombasa Port Expansion Project. The technology has great potential to improve AEC projects in developing countries that have not embraced the technology fully. However, the research has two gaps that should be addressed to increase the chances of success. Firstly, future studies should recruit people with many years of experience for the survey. Lastly, opinions such as those given on the challenges encountered in BIM implementation should be filtered out of the research to avoid bias and improve the study's reliability.

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