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Assessment of Building Information Modeling (BIM) as a Time and Cost-Saving Construction Management Tool: Evidence from Two-Story Villas in Jeddah

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Abstract: Building Information Modelling (BIM) is a well-known construction technology for improving management. Its implementation in Saudi Arabia's construction industry is increasing as it adapts to futuristic construction management practices. This quantitative case study examines the factors that led to the success of employing the BIM tool in managing a recent home development project in Jeddah, Saudi Arabia. After a survey of the available literature, 28 success criteria were identified and validated by an expert panel of 18 industry professionals. Exploratory Factor Analysis (EFA) is used to analyze data from a pilot survey of 132 people. A total of three factors are deleted because of factors leading to a value of less than 0.6. Further, there were 212 people who filled out the main survey questionnaire, and the data are analyzed using structural equation modeling (SEM). The findings show that BIM significantly improved the house development project in terms of cost, time, quality, safety, efficiency and environmental effect. Implications for management are highlighted, along with the study's limitations and suggestions for further investigation. Overall, this research offers helpful information for residential building experts who want to make the most of BIM.

Keywords: Building Information Modelling (BIM); construction management tool; two-story villas; Jeddah

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1. Introduction

The construction business is complicated and dynamic, with many variables influencing project timetables, quality, safety and prices. Building Information Modeling (BIM) may help manage building projects more efficiently and effectively [1,2]. BIM is used to manage two-story villas in Jeddah, saving time and money, among other benefits. BIM can solve these issues. BIM lets construction project managers simulate, visualize and evaluate their projects virtually. This platform integrates construction data seamlessly, improving stakeholder engagement and decreasing construction time and costs. BIM is beneficial in the early phases of building project design. Project managers may utilize BIM to construct comprehensive architectural models to spot concerns early on. Early detection helps save expensive redesigns and construction delays. BIM also lets project managers simulate and test design decisions to see how they could affect timelines and budgets [3,4].

BIM helped design the two-story residences in Jeddah by integrating construction data. BIM was used to assess design viability and identify concerns [5]. BIM helped project managers avoid expensive redesigns and delays by testing multiple design possibilities before construction. BIM also tracked the project's progress and identified opportunities for improvement, saving time and money [6]. BIM enhanced stakeholder engagement and communication. BIM enabled real-time cooperation among stakeholders to accomplish goals. BIM helped designers, architects, builders and other stakeholders collaborate on the two-story homes in Jeddah. Collaboration improved project quality and reduced miscommunications [7,8]. BIM also improved project management by centralizing construction data. Project managers could track progress and make modifications by constructing a digital model of the construction project. This sped up construction and cut expenses.

BIM in building projects needs fixing [6,9]. BIM requires particular abilities. BIM requires extensive training for project managers. BIM integration with project management systems might require significant technology and software investments [10,11].

This case study shows how BIM saves time and money while building two-story residences in Jeddah. Two-story residential buildings are very common in the residential communities of all Saudi Arabia [12]. It is the reason that this study only involves two-story buildings, to effectively focus on the application of BIM. This case study uses structural equation modeling (SEM) to explore variable correlations and evaluate BIM implementation. SPSS and Smart PLS 4, popular data analysis tools, are utilized for SEM. SEM research shows that BIM improved the project results, construction time and cost. The results also demonstrate that stakeholder participation and communication were crucial to BIM deployment [13]. The report also emphasizes the necessity for stakeholder participation and project managers with BIM capabilities. SEM is a robust data analysis technique, but it has limits. SEM needs a significant sample size for accurate findings. Some businesses may need more experience and understanding to implement SEM. SEM may help evaluate BIM deployment in building project management despite these limitations. SEM helps construction professionals assess project success elements and improve. Therefore, this case study aims to show how BIM improves project management, construction timetables, quality, safety, the environment, costs and project results. It examines the merits of implementing BIM in building two-story homes in Jeddah. This case study can help construction professionals understand how BIM improves project results. Budget overruns, delays and quality control concerns affect the construction business. This case study shows how BIM saves time and money while building two-story residences in Jeddah. The report also emphasizes stakeholder participation and project managers' BIM proficiency. SEM is used to evaluate BIM deployment and find areas for improvement. Construction professionals may choose the finest tools and tactics for project management by studying the pros and downsides of BIM and SEM.

2. Current Status of BIM in Jeddah

The construction sector has extensively embraced Building Information Modeling (BIM) because it can improve project management and communication, decrease mistakes and rework, and improve project results [14]. BIM is a digital representation of a building or facility's physical and functional qualities that may be utilized for design, construction and operational reasons. BIM has been proven to result in considerable time and cost savings for construction projects, as well as improved overall quality and safety. BIM's capacity to enhance cooperation and communication among project stakeholders, including architects, engineers, contractors and owners, is one of its primary advantages [15,16]. Using a shared digital model, stakeholders may collaborate in real time and make choices based on accurate and current data. This decreases the possibility of mistakes, disputes and the requirement for rework, saving time and money [17,18]. Several studies have examined the advantages of BIM for building projects. In a case study, Lin et al. (2016) showed that the use of BIM on a healthcare project reduced the length of the design phase by 40 percent and the construction expenses by 20 percent [19].

Similarly, D. Liu et al. (2019) showed that the use of BIM on a commercial office building project reduced the number of Requests for Information (RFIs) by 50 percent and modification orders by 60 percent [20]. BIM has been shown to enhance project results in the setting of home buildings. Ahmad and Thaheem (2018) conducted a case study on using BIM to design and construct a single-family home in China [21]. The research concluded that BIM improved project coordination, decreased mistakes and rework, and increased project quality and safety. Another case study by Alothman et al. (2021) evaluated the application of BIM in South Korean affordable housing development and maintenance [22]. According to the report, BIM helped minimize construction waste and expenses and increase the project's efficiency and sustainability. Some more critical relevant studies are shown below in Table 1.

Table 1. Critical findings from the literature.

Serial No.	Title	Project Type	Findings	Methodology	References
1	BIM-based green building evaluation and optimization: A case study	Multi-Story Residential Building	BIM implementation increases the impact of green building initiatives and project management performance.	Case study analysis focusing on green building framework	[19]
2	BIM-enabled computerized design and digital fabrication of industrialized buildings: A case study	Industrial Buildings	BIM-based management can enhance building performance and increase the efficiency of construction.	State-of-the-art review case study	[23]
3	Energy Performance Analysis of Building for Sustainable Design Using BIM: A Case Study on Institute Building	Commercial Sector Multi-Story Buildings	BIM was found to be positively linked with project sustainability and maximized performance.	Case study on a single education building in Egypt	[22]
4	Challenging construction project management institutions: the role and agency of BIM actors	Multi-Story Residential Building	BIM is critically related to improvements in all aspects of project management.	Case study involving semi-structured interviews and observations	[15]
5	Applying digital methods for documenting heritage building in Old Jeddah: A case study of Hazzazi House	Two-Story Single House	BIM implementation was found to be better for increased quality and cost reduction.	Case-study-based surveying of Hazzazi House	[24]
6	BIM in the Saudi Arabian construction industry: state of the art, benefit and barriers	Multi-Story Residential Building	BIM implementation can bring more accuracy and efficiency to construction projects.	State-of-the-art review case study	[25]
7	A BIM-based approach for DfMA in building construction: framework and first results on an Italian case study	Multi-Story Residential Building	BIM is linked with increasing construction sustainability, and projects have become more reliable both in the UK and Singapore.	Case-study-based evaluation of frameworks	[1]

Table 1. *Cont.*

Serial No.	Title	Project Type	Findings	Methodology	References
8	Development of a BIM-Based Data Management System for Structural Health Monitoring with Application to Modular Buildings: Case Study	Modular Multi-Story Buildings	BIM can effectively optimize construction output, reducing performance time.	Case study approach focusing on structural health monitoring of the project's end phase	[18]
9	Building Information Management (BIM), A New Approach to Project Management	Multi-Story Residential Building	BIM can improve project management and bring greater control over project management challenges.	Qualitative case study analysis of the project management of construction projects.	[26]
10	Practices and Processes in BIM Projects: An Exploratory Case Study	Multi-Story Residential Building	BIM can help mitigate gaps in stages of project management.	Exploratory case study analysis	[27]
11	Barriers to implementing Building Information Modeling (BIM) in public projects in Saudi Arabia	Public Sector Multi-Story Building Project	BIM implementation and project management performance improvement barriers were identified.	Case study focusing on Saudi construction projects only	[28]
12	Measurement of Construction BIM Value Based on a Case Study of a Large-Scale Building Project	High-Rise Building Project	Project management value can be enhanced by implementing BIM in large-scale construction projects.	Case study evaluation of large-scale building projects only	[29]
13	From point cloud to Jeddah Heritage BIM Nasif Historical House—case study	Two-Story Single House	BIM was found to be efficient for the maintenance projects of buildings.	Exploratory case study analysis approach	[30]
14	Exploitation and Benefits of BIM in Construction Project Management	Multi-Story Residential Building	BIM has significant benefits if it is implemented with greater control and accuracy.	Case study approach involving a review method	[31]
15	Development of BIM Execution Plan for BIM Model Management during the Pre-Operation Phase: A Case Study	Multi-Story Residential Building	BIM can manage project challenges while improving the ability to optimize costs and time.	Case study only focusing on the operational phase of projects	[19]

In the context of Jeddah, Saudi Arabia, a study on the advantages of BIM for residential development is required. Although BIM has been extensively accepted in other areas of the globe, it is still in its infancy in Saudi Arabia. Thus, the purpose of this case study is to evaluate the use of BIM for the design and construction of two-story villas in Jeddah, with a particular emphasis on its influence on time and cost reductions. The data are analyzed using structural equation modeling using SPSS and Smart PLS 4 to make findings. In doing so, this study intends to add to the expanding body of literature on the advantages of BIM for building projects and to shed light on its potential for the Saudi Arabian construction sector. Table 2 presents the success factors reviewed from the literature and evaluated by experts.

Table 2. Identified success factors of BIM.

Sr. #	Success Factors	References
1	BIM may assist project teams in managing the project better, improving project quality.	[23]
2	BIM helps project stakeholders work together toward the same objectives. Ensuring that stakeholders agree on project requirements and specifications may increase project value.	[15,32]
3	By providing a virtual 3D model of the project, BIM may assist project teams in more precisely organizing construction operations.	[31,33]
4	BIM can increase energy efficiency by giving precise energy performance data. This may uncover energy savings and improve building systems to minimize energy consumption and greenhouse gas emissions.	[30,34]
5	BIM helps project teams identify project resource needs. This improves resource management and reduces waste.	[35,36]
6	BIM optimizes the design and identifies problems, making it more efficient and effective.	[37,38]
7	BIM lets designers develop a virtual 3D model of the project to discover and fix design faults before construction. This may enhance the design and decrease construction mistakes and rework.	[39,40]
8	BIM helps project teams estimate building costs by providing precise and thorough project information. This reduces cost overruns and delays.	[41,42]
9	BIM may minimize the time required to finish a building project by giving precise and thorough information about the project. This may assist in eliminating construction mistakes, rework and delays, resulting in speedier project completion timeframes.	[43,44]
10	BIM may save construction costs by detecting and fixing flaws before the building starts. This reduces construction mistakes, rework and delays.	[40,45]
11	BIM streamlines design engineers' process and reduces iteration time and expense.	[37,38]
12	BIM provides precise project information to optimize material utilization	[46]
13	BIM enhances construction project sequencing, resulting in productivity improvements.	[41,42]
14	BIM helps improve safety planning by providing accurate and complete project information.	[39,40]
15	BIM's 3D model may prevent construction conflicts.	[43]

Table 2. *Cont.*

Sr. #	Success Factors	References
16	BIM may be used to create virtual training programs for construction personnel to understand project safety measures better.	[44,45]
17	BIM can assist project teams in uncovering value engineering possibilities to increase project value.	[47]
18	BIM may assist in achieving project specs while reducing expenses.	[37,48]
19	BIM's virtual 3D model may assist project teams in discovering dangers before building starts. This reduces construction accidents and injuries.	[38,49]
20	BIM provides accurate project information before construction to ensure that prefabricated components are built to specs and delivered to the building site on schedule.	[50,51]
21	BIM improves construction project data, resulting in efficiency improvement.	[52,53]
22	BIM improves design integration.	[27,54]
23	BIM delivers accurate project information to meet obligations and improves project excellence.	[55]
24	BIM helps project stakeholders work together toward the same ideas, reduces misconceptions and aligns everyone on project needs and specs, improving productivity.	[29,56]
25	BIM's precise energy usage and greenhouse gas emission data help lower the project's carbon impact.	[35]
26	BIM allows parties to operate in a coordinated and collaborative way, streamlining communication and reducing misunderstandings. This may contribute to the timely and cost-effective completion of building projects.	[34]
27	BIM provides better planning, resource management and project stakeholder consultation.	[30,36]
28	BIM may alleviate site congestion by delivering precise project information.	[31,33]

3. Methodology

This study's objective was to learn what makes Building Information Modeling (BIM) effective as a resource for construction management, reducing both the time and money spent on projects. The study used a quantitative methodology to get the job done. There were four primary phases to the process, and they are the following: literature research, expert consultation, a pilot survey and a preliminary questionnaire survey [15,16]. As a construction management tool, BIM was evaluated via a literature study to determine its characteristics of success. At this point, this study involved intensive search of relevant academic publications, books and other resources. The databases that were used in the research were ScienceDirect (9 Articles), MDPI (13 Articles), Springer (16 Articles) and Web of Science (7 Articles). The keywords that were used for searching the databases were Building Information Modelling, Construction Management Tool, Two-Story Villas and Jeddah. Only English language articles with significant relativity to the keywords and goals of the study were included in the analysis. In total, 46 open-access credible research articles were reviewed. What was learned from the literature study shaped the research tools for later phases. The second phase entailed consulting with 18 specialists about BIM and the regional construction sector to validate the confirmed success factors. A structured interview was used for the consultation, and the results were used to improve the research tools [17,20].

During the third phase, 132 two-story Jeddah villas residents were surveyed as part of a pilot project. The validity and trustworthiness of the research tools were evaluated with the aid of the pilot survey. To determine what makes BIM effective as a management tool in construction, this study examined the pilot survey results of 28 factors using Exploratory

Factor Analysis (EFA). In the last phase, 212 residents of Jeddah's two-story villas completed the primary questionnaire survey. The results of the literature study, the contact with experts and the preliminary survey informed the development of the questionnaire.

A model of BIM's success criteria for Jeddah's two-story villas was developed using SEM. Participants' informed permission was acquired to cover any potential ethical issues. The information provided by the participants was kept strictly secret, and participants were ensured of their privacy. This study used a quantitative research approach to determine what makes BIM effective as a resource-conserving construction management tool. This study conducted a literature study, interacted with subject matter experts, conducted a pilot survey and then administered the main questionnaire. EFA and SEM were used to examine the dependability and validity of the study tools. The anonymity and privacy of the study's participants were respected at all times by adhering to strict ethical guidelines. Figure 1 presents the research methodology.

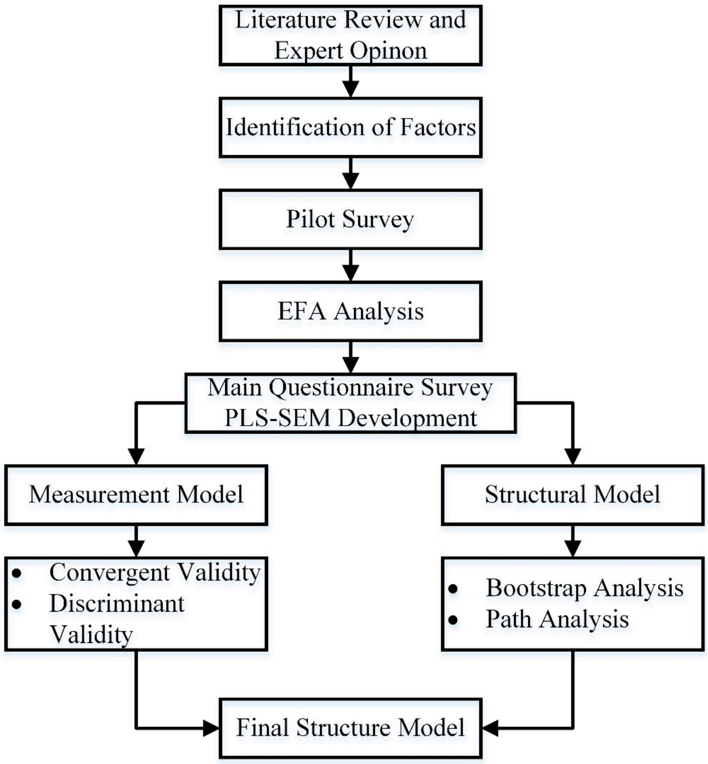

Figure 1. Flow chart of the work.

3.1. Exploratory Factor Analysis

In statistics, EFA refers to a method used to uncover the underlying structure of data collection. Its purpose is to simplify the analysis by eliminating non-essential components and narrowing the focus on those that best explain the data. EFA was applied to the data from the pilot survey of 113 residents of Jeddah's two-story villas. The research team behind this study set out to determine what makes BIM such an effective tool for construction management, saving both time and money [19]. Factors were kept if their eigenvalues were more significant than 1, and the scree plot analysis passed muster. The factor structure was simplified, and the factors' meanings were clarified using a varimax rotational component matrix. Simplifying the factor structure, varimax rotation is an orthogonal rotation that reduces the number of variables with high loadings on each component. The loadings of each variable on each factor after rotation are shown in the varimax rotated component matrix [20]. The most excellent loadings of the variables were used to interpret the factors. The factors were labeled after the variables that contributed the most to their loadings. Using the EFA findings in designing the primary survey questions and the structural equation modeling yielded valuable results.

3.2. Development of SEM Model

Complex interactions between many variables may be analyzed utilizing SEM, a statistical method. Researchers may evaluate the stability and direction of links between observable and latent variables in complicated models. An SEM-based model of the variables contributing to the implementation of BIM in Jeddah's two-story villas was created for this research. A model was created based on responses to the primary survey questions from 202 individuals [21]. The SEM analysis demonstrated that the model matched the data well. It was determined that BIM's effectiveness as a time- and cost-saving construction management tool in Jeddah's two-story villas was significantly influenced by the success criteria discovered in the EFA. The SEM study also made it possible to examine how the success criteria, directly and indirectly, influenced BIM implementation [22,33]. As a result, the most crucial aspects for the practical application of BIM to the building of two-story villas in Jeddah could be isolated and studied in more depth. Overall, SEM created a thorough and precise model of BIM's success elements throughout the building of Jeddah's two-story villas.

The reliability and validity of the measuring equipment used in structural equation modeling may be evaluated using convergent validity (SEM). It is the extent to which different indicators of a construct measure the same underlying notion [37]. The Fornell–Larcker criterion was used to determine convergent validity in this research. This requires checking the levels of correlation between the latent variables and their indicators to see whether they are significant [50,53]. To pass the Fornell–Larcker criterion, the correlation between any two model components must be less than the square root of the average variance extracted (AVE) for that component. The degree of variation in the indicators that can be attributed to the concept is what AVE measures in terms of convergent validity. To what extent one idea is different from the others in the model is what is meant by the term "discriminant validity." There should be no overlap in the concepts being measured by the various constructions [48]. Each construct's AVE must be higher than the squared correlations between that construct and any other construct in the model to satisfy the Fornell–Larcker criterion for discriminant validity.

A statistical technique called the Heterotrait–Monotrait Ratio of Correlations (HTMT) is used in structural equation modeling to assess the model's discriminant validity and convergent validity (SEM). A value of 1 implies complete correlation, whereas a value of 0 indicates no correlation, making it a measure of the degree to which two conceptions are comparable. According to the HTMT criteria, the correlation between two constructs in a model should be lower than the square root of the average variance extracted (AVE) for that construct [44,47]. If the number is less than 0.85, discriminant validity may be an issue; if it is more than 0.9, it is an issue. Convergent validity may also be assessed using an empirical correlation matrix and HTMT statistics. The matrix displays correlation coefficients for all possible combinations of constructs; a strong correlation suggests that the two constructs may be measuring the same underlying notion [40,45]. For testing for convergent validity, it is customary to compare the square roots of the AVEs for each construct to the diagonal values of the matrix. Higher diagonal values suggest that the construct measures more than one underlying notion, which calls into doubt its convergent validity.

It is common research practice to utilize a statistical technique called structure path analysis to probe the connections between different latent variables. Using this method, one may calculate the estimated impacts of external (independent) factors on endogenous (dependent) variables directly and indirectly. In this analysis, SPA was used to create a template for the elements that contribute to the success of Building Information Modeling for two-story villas in Jeddah. Several experiments were conducted to guarantee the SPA model's accuracy. The level of multicollinearity among the model's independent variables may be evaluated using the Variance Inflation Factor (VIF), one of the tests. Multicollinearity, which may cause erroneous coefficient estimations when present when the VIF value is larger than 5, is indicated by a VIF value greater than 5 [39,42]. The predicted relevance analysis is another test used to verify the SPA model. By comparing the model's out-of-sample predictive power to that of a benchmark model, this technique helps to evaluate the model's overall predictive ability.

4. Results

4.1. EFA Analysis

According to the findings of the EFA, the 28 success elements of BIM may be narrowed down to only six different types of constructs, as indicated in Table 3. EFA's six recognized constructs are time, money, quality, safety, efficiency and the environment. A thorough examination of the eigenvalues and factor loadings allowed for the isolation of these concepts. Furthermore, the EFA revealed that the six constructs mentioned above jointly account for 66.23 percent of the total variance in the data. This shows that the six constructs are all-encompassing and may capture a substantial part of the elements that determine the efficacy of BIM in building projects [41]. According to the EFA, BIM has the potential to be a helpful construction management technology that cuts down on costs without sacrificing quality, safety, efficiency or environmental sustainability.

Table 3. Exploratory Factor Analysis output.

Variables	1	2	3	4	5	6
S3	0.863					
S9	0.834					
S26	0.822					
S20	0.811					
S8		0.787				
S10		0.745				
S5		0.743				
S17		0.708				
S18		0.703				
S7			0.732			
S2			0.704			
S23			0.702			
S1			0.684			
S27			0.620			
S19				0.857		
S14				0.808		
S16				0.780		
S15				0.750		
S28				0.701		
S24					0.817	
S13					0.806	
S21					0.741	
S4						0.854
S12						0.802
S25						0.717
Eigenvalue	4.64	4.12	3.45	3.23	2.89	2.83
% Variance						
Extraction	S6, S22, S11					

The construct of time has four success factors assigned to it, namely S3, S9, S26 and S20. These aspects relate to how BIM can aid project teams in precisely organizing construction operations, reducing the time needed to complete a building project, working in a coordinated and collaborative manner and providing accurate project information before construction to guarantee that prefabricated components are built to specs and delivered on time [20,22].

The construct of cost has five success factors assigned to it, namely S8, S10, S5, S17 and S18. These considerations are associated with how BIM can aid project teams in estimating building costs, saving construction costs by detecting and fixing flaws before building starts, determining what resources are required, finding ways to increase the project's value through value engineering and meeting project specifications while keeping costs down [30,31].

The construct of quality has four success factors assigned to it, namely S7, S2, S23 and S1. These aspects concern how BIM can help designers create a 3D virtual model of the project to find and fix design flaws before construction, how it can bring all of the project's stakeholders together to work towards the same goals, how it can provide accurate project information to fulfill obligations and improve project excellence and how it can aid project teams in managing the project more effectively, all of which contribute to the overall quality of the project [55].

The safety construct has five success factors assigned to it, namely S19, S14, S16, S15 and S28. These considerations concern how the virtual 3D model created by BIM can aid project teams in spotting potential dangers before construction begins, in enhancing safety planning through the delivery of accurate and complete project information, in developing virtual training programs for construction personnel to understand project safety measures better, in avoiding construction conflicts and in relieving site congestion through the delivery of accurate project information [44,48].

The efficiency construct had three success factors assigned to it, namely S24, S13 and S21. These considerations are associated with how BIM can bring together project stakeholders to work toward the same ideas and reduce misunderstandings; to improve construction project sequencing, which enhances productivity; and to improve construction project data, which improves efficiency [45].

The environment construct had three success factors assigned to it, namely S4, S12 and S25. Some ways in which BIM may assist in reducing a project's carbon footprint include providing accurate data on energy performance, optimizing material consumption and ensuring that all available resources are used effectively. Table 4 summarizes the constructs and their associated success factors.

Table 4. Barriers along with constructed categories from EFA analysis.

BIM Success Phase	Assigned Code	Description
Time	S3	By providing a virtual 3D model of the project, BIM may assist project teams in more precisely organizing construction operations.
	S9	BIM may minimize the time required to finish a building project by giving precise and thorough information about the project. This may assist in eliminating construction mistakes, rework and delays, resulting in speedier project completion timeframes.
	S26	BIM allows parties to operate in a coordinated and collaborative way, streamlining communication and reducing misunderstandings. This may contribute to the timely and cost-effective completion of building projects.
	S20	BIM provides accurate project information before construction to ensure that prefabricated components are built to specs and delivered to the building site on schedule.

Table 4. *Cont.*

BIM Success Phase	Assigned Code	Description
Cost	S8	BIM helps project teams estimate building costs by providing precise and thorough project information. This reduces cost overruns and delays.
	S10	BIM may save construction costs by detecting and fixing flaws before the building starts. This reduces construction mistakes, rework and delays.
	S5	BIM helps project teams identify project resource needs. This improves resource management and reduces waste.
	S17	BIM can assist project teams in uncovering value engineering possibilities to increase project value.
	S18	BIM may assist in achieving project specs while reducing expenses.
Quality	S7	BIM lets designers develop a virtual 3D model of the project to discover and fix design faults before construction. This may enhance the design and decrease construction mistakes and rework.
	S2	BIM helps project stakeholders work together toward the same objectives. Ensuring that stakeholders agree on project requirements and specifications may increase project value.
	S23	BIM delivers accurate project information to meet obligations and improves project excellence.
	S1	BIM may assist project teams in managing the project better, improving project quality.
	S27	BIM provides better planning, resource management and project stakeholder consultation.
Safety	S19	BIM's virtual 3D model may assist project teams in discovering dangers before building starts. This reduces the number of construction accidents and injuries.
	S14	BIM helps improve safety planning by providing accurate and complete project information.
	S16	BIM may be used to create virtual training programs for construction personnel to understand project safety measures better.
	S15	BIM's 3D model may prevent construction conflicts.
	S28	BIM may alleviate site congestion by delivering precise project information.
Efficiency	S24	BIM helps project stakeholders work together toward the same ideas, reduces misconceptions and aligns everyone on project needs and specs, improving productivity.
	S13	BIM enhances construction project sequencing, resulting in productivity improvements.
	S21	BIM improves construction project data, resulting in efficiency improvements.
Environment	S4	BIM can increase energy efficiency by giving precise energy performance data. This may uncover energy savings and improve building systems to minimize energy consumption and greenhouse gas emissions.
	S12	BIM provides precise project information to optimize material utilization.
	S25	BIM's precise energy usage and greenhouse gas emission data help lower the project's carbon impact.

4.2. Demographics

The demographics (Figure 2) for the primary questionnaire survey show that the majority of respondents hold a master's degree (55%), followed by those with a Ph.D. (12%). Only a tiny percentage of respondents had a high school education (6%), 18% had a bachelor's degree, and 9% were classified as "Others." In terms of age, the largest group of respondents fell within the 31 to 35 age range (51%), followed by those within the 26 to 30 age range (20%). A small percentage of respondents were above 40 years old (3%). Regarding experience, the largest group of respondents had 11 to 15 years of experience (31%), followed by those with 5–10 years of experience (31%). A smaller percentage of respondents had less than 5 years of experience (22%), 11% had 16 to 20 years of experience, and 5% had more than 20 years of experience. Regarding profession, most respondents were civil engineers (61%), followed by safety managers (11%). Only a tiny percentage of respondents identified as architects (6%), project managers (3%) or "Others" (19%).

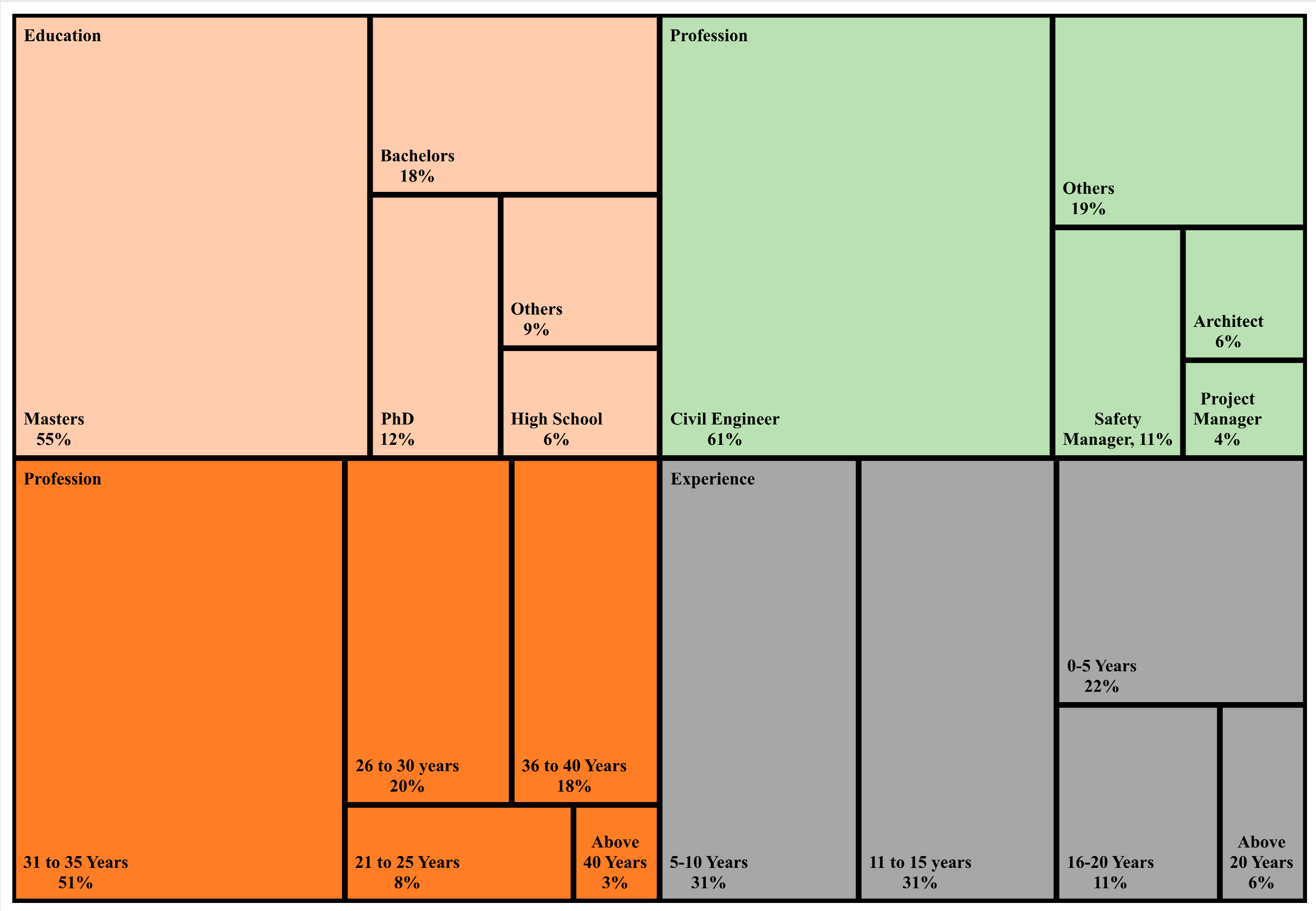

Figure 2. Demographic details.

4.3. Structure Equation Modelling (SEM) and Analysis

The model reliability and validity results for the constructs are shown in Table 5. Validity refers to the extent to which the measurements are accurate and suitable for measuring the targeted construct, whereas reliability refers to the extent to which the measures are consistent and stable. Cronbach's alpha, composite reliability (rho-a), composite reliability (rho-c) and AVE are all included in the table. As a measure of internal consistency, Cronbach's alpha determines how well each item on a scale measures the same construct. A Cronbach's alpha of 0.7 or above is generally accepted as statistically significant. Cronbach's alpha scores for all constructs in this research were more than 0.775, suggesting high levels of internal consistency. A measure of the construct's dependability, composite reliability (rho-a and rho-c) determines how free of error the measurements are. Values closer to 1 for rho-a and rho-c indicate more consistency between observations. This analysis showed strong reliability with composite reliability scores >0.793 for all constructs [49]. To what degree the elements in a construct measure the same underlying dimension is what convergent validity attempts to determine. AVE values may be anything from 0 to 1, with higher values suggesting more convergent validity. This research had strong convergent validity, with all components having AVEs of greater than 0.613. The results of the reliability and validity analyses support the conclusion that the measures that were employed to evaluate the components in this research have high levels of consistency, reliability and validity. This ensures that the study's findings and conclusions may be trusted [38]. The trend of the reliability and validity statistics of the model are indicated in Figure 3. Figure 4 presents the model with relationship significance for all items and constructs. Figure 5 shows the items and constructs' path coefficients and factor loadings.

Table 5. Model reliability and validity findings.

Constructs	Cronbach's Alpha	Composite Reliability (rho-a)	Composite Reliability (rho-c)	Average Variance Extracted (AVE)
Cost	0.876	0.878	0.916	0.733
Efficiency	0.815	0.84	0.891	0.732
Environment	0.775	0.999	0.867	0.69
Quality	0.792	0.793	0.863	0.613
Safety	0.836	0.896	0.9	0.75
Time	0.881	0.894	0.918	0.738

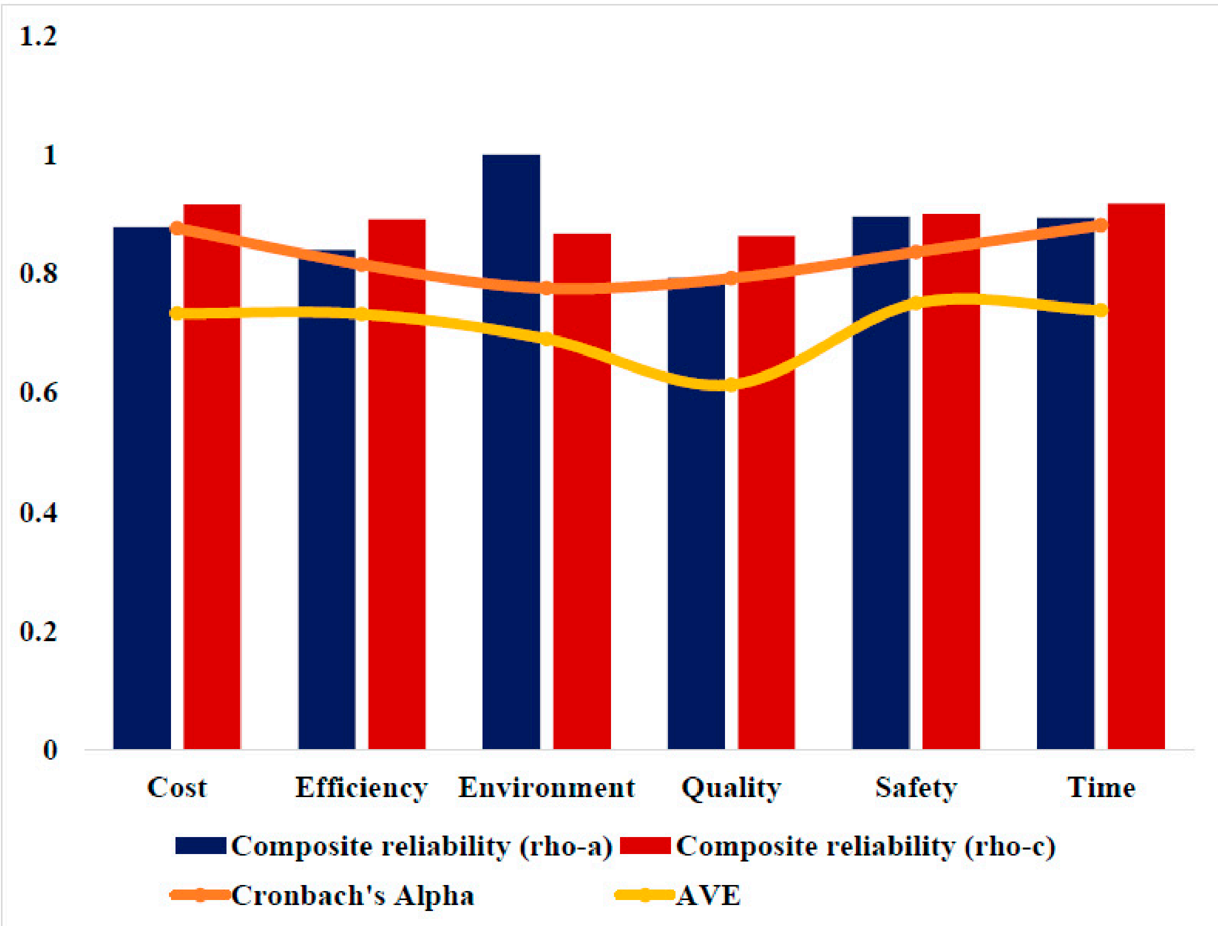

Figure 3. Trend of reliability statistics.

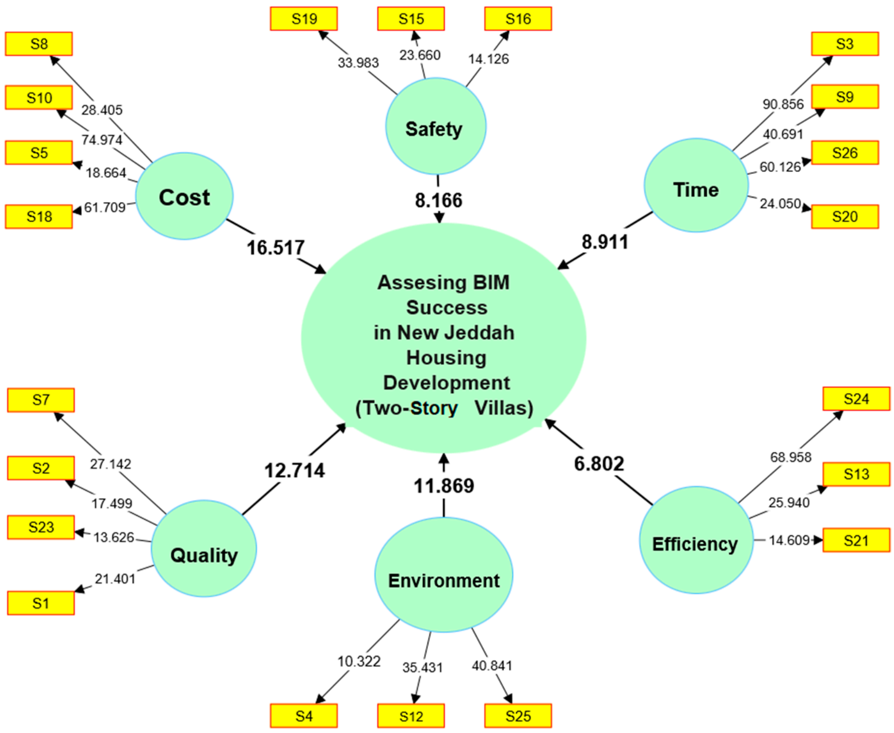

Figure 4. Structure model indicating relationship significance of success factors.

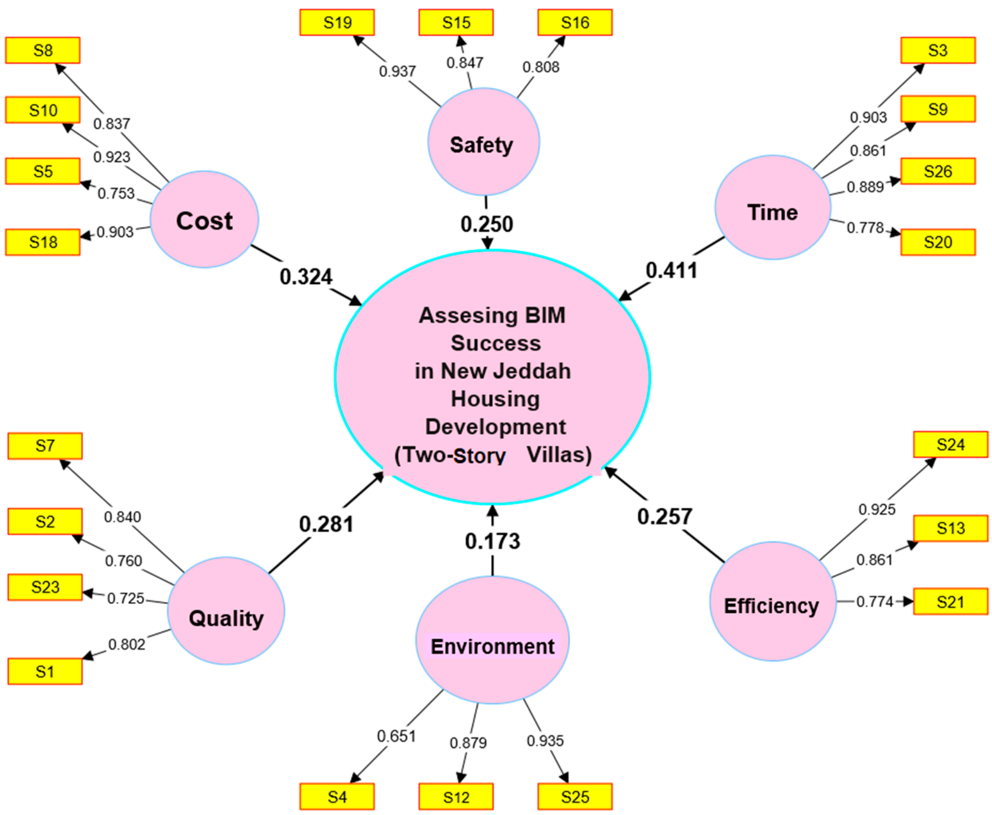

Figure 5. Model with items, item loadings and path coefficients.

Each cell in Table 6 of the empirical correlation matrix displays a pairwise correlation coefficient. A correlation coefficient statistic may quantify the strength and direction of a linear link between two variables. The correlation coefficient may take on any value between −1 and 1, where −1 indicates absolutely zero connection, 0 indicates no correlation and

1 indicates a perfect positive correlation [47,48]. For instance, the 0.104 coefficient between S1 and S10 in the correlation matrix indicates a moderately weak positive connection. Similarly, there is a minor negative connection between S1 and S12 (r = −0.153).

4.3.1. Second-Order Analysis

Results for the Fornell–Larcker criterion's six dimensions (time, quality, safety, cost, environment and efficiency) are shown in Table 7. According to the Fornell–Larcker criterion, how well each construct's indicators reflect the construct's variation can be stated. The AVE is compared to the square of the correlation between each concept and its indicators. Calculating the amount of a construct's variation that can be attributed to its indicators yields the AVE. Table 6 shows that the diagonal values (representing the AVE for each construct) are superior to the off-diagonal ones (i.e., the correlations between constructs). This means that the indicators for each concept explain more variation for that construct than they do for the others, a sign of strong convergent validity [39,40].

Most importantly, the constructions seem relatively well-defined and separate because the diagonal values span from 0.105 (Safety) to 0.398 (Time). The strongest association between the dimensions was found between time and quality (0.43), followed by efficiency and time (0.274). These correlations are concerning but not too high to raise concerns about discriminant validity [45,51]. Overall, Table 6's Fornell–Larcker criterion findings imply that the measurement model for these constructs has strong convergent and discriminant validity, giving confidence in the fact of the constructs and their indicators.

The HTMT analysis is shown in Table 8; it is a typical method for evaluating discriminant validity in SEM. The diagonal components in this table represent the construct's connection with itself, which are all set to 1. The off-diagonal features suggest that the notions have some discriminant validity. In particular, there is little overlap between the constructs, as seen by the fact that all HTMT values are below the suggested threshold of 0.9. Regardless, there are a few pairs of constructs with relatively high HTMT values. For instance, the HTMT value between efficiency and cost is 0.154, which is close to the cutoff point of 0.9. This provides evidence of a connection or overlap between these concepts. The negative HTMT score (−0.023) between quality and environment is also surprising and may point to problems with the model's measurement or overall design [37,47]. There may be some difficulties with some construct combinations that need additional investigation, but overall, the HTMT findings show that the measurement model for the constructs in the research is usually valid.

Each item's connection to the related construct is shown in the cross-loadings in Table 9. In this scenario, time, money, quality, security and the environment are concerned. The high quality of the cross-loadings suggests that the items successfully assess the targeted constructs. Most items have high loadings (0.753 and 0.935) for their target build. A few items, however, have very low loadings for their target build, indicating that they may not be the greatest indicators of that construct [40,43]. To illustrate, item S8's loading for the cost construct is lower than its loading for the efficiency construct, at 0.837. (0.117). Items S21 and S22 have high loadings for the efficiency build and low loadings for the environment construct (0.774). Very high cross-loadings may also point to issues with the measurement model, because this indicates that a single item may be measuring many constructs. The measurement model seems sufficient, with no obviously excessive cross-loadings.

Table 6. Empirical correlation matrix.

Variabl	S1	S10	S12	S13	S15	S16	S18	S19	S2	S20	S21	S23	S24	S25	S26	S3	S4	S5	S7	S8	S9
S1	1	0.104	−0.153	−0.012	0.094	−0.111	0.123	−0.048	0.378	0.23	0.04	0.37	0.074	−0.099	0.126	0.127	0.097	0.22	0.904	0.131	0.152
S10	0.104	1	0.09	0.152	0.203	0.11	0.94	0.229	0.165	0.211	0.126	0.02	0.145	0.097	0.248	0.268	0.035	0.522	0.048	0.692	0.275
S12	−0.153	0.09	1	0.036	−0.017	−0.04	0.081	−0.071	−0.156	−0.075	−0.066	−0.088	−0.014	0.805	0.062	0.252	0.425	0.041	−0.115	0.031	0.065
S13	−0.012	0.152	0.036	1	0.179	0.064	0.13	0.12	0.158	0.023	0.458	0.229	0.73	0.147	0.158	0.144	0.064	0.078	−0.023	0.066	0.202
S15	0.094	0.203	−0.017	0.179	1	0.483	0.18	0.659	0.12	−0.04	0.054	0.162	0.186	0.057	0.129	0.225	−0.065	0.225	0.109	0.171	0.134
S16	−0.111	0.11	−0.04	0.064	0.483	1	0.062	0.745	0.052	0.021	0.052	0.024	0.016	0.001	0.135	0.193	−0.101	0.015	−0.151	0.033	0.086
S18	0.123	0.94	0.081	0.13	0.18	0.062	1	0.184	0.163	0.186	0.114	0.033	0.095	0.081	0.177	0.231	0.008	0.48	0.06	0.671	0.236
S19	−0.048	0.229	−0.071	0.12	0.659	0.745	0.184	1	0.146	0.186	0.067	0.147	0.144	0.095	0.315	0.366	−0.1	0.223	−0.092	0.163	0.298
S2	0.378	0.165	−0.156	0.158	0.12	0.052	0.163	0.146	1	0.332	0.085	0.426	0.158	0.02	0.387	0.389	0.055	0.072	0.429	0.051	0.388
S20	0.23	0.211	−0.075	0.023	−0.04	0.021	0.186	0.186	0.332	1	0.08	0.195	0.136	0.11	0.547	0.521	0.048	0.338	0.244	0.193	0.701
S21	0.04	0.126	−0.066	0.458	0.054	0.052	0.114	0.067	0.085	0.08	1	0.123	0.596	−0.002	0.179	0.205	−0.009	0.086	0.061	0.116	0.206
S23	0.37	0.02	−0.088	0.229	0.162	0.024	0.033	0.147	0.426	0.195	0.123	1	0.229	0.041	0.243	0.255	−0.005	0.242	0.419	0.022	0.223
S24	0.074	0.145	−0.014	0.73	0.186	0.016	0.095	0.144	0.158	0.136	0.596	0.229	1	0.127	0.253	0.197	0.1	0.12	0.079	0.12	0.263
S25	−0.099	0.097	0.805	0.147	0.057	0.001	0.081	0.095	0.02	0.11	−0.002	0.041	0.127	1	0.373	0.445	0.373	0.141	−0.029	0.06	0.24
S26	0.126	0.248	0.062	0.158	0.129	0.135	0.177	0.315	0.387	0.547	0.179	0.243	0.253	0.373	1	0.859	0.053	0.352	0.189	0.188	0.608
S3	0.127	0.268	0.252	0.144	0.225	0.193	0.231	0.366	0.389	0.521	0.205	0.255	0.197	0.445	0.859	1	0.1	0.37	0.193	0.206	0.662
S4	0.097	0.035	0.425	0.064	−0.065	−0.101	0.008	−0.1	0.055	0.048	−0.009	−0.005	0.1	0.373	0.053	0.1	1	0.133	0.123	0.248	0.046
S5	0.22	0.522	0.041	0.078	0.225	0.015	0.48	0.223	0.072	0.338	0.086	0.242	0.12	0.141	0.352	0.37	0.133	1	0.181	0.528	0.355
S7	0.904	0.048	−0.115	−0.023	0.109	−0.151	0.06	−0.092	0.429	0.244	0.061	0.419	0.079	−0.029	0.189	0.193	0.123	0.181	1	0.131	0.2
S8	0.131	0.692	0.031	0.066	0.171	0.033	0.671	0.163	0.051	0.193	0.116	0.022	0.12	0.06	0.188	0.206	0.248	0.528	0.131	1	0.264
S9	0.152	0.275	0.065	0.202	0.134	0.086	0.236	0.298	0.388	0.701	0.206	0.223	0.263	0.24	0.608	0.662	0.046	0.355	0.2	0.264	1

Table 7. Fornell–Larker criterion results.

	Cost	Efficiency	Environment	Quality	Safety	Time
Cost						
Efficiency	0.182					
Environment	0.149	0.111				
Quality	0.198	0.197	0.16			
Safety	0.236	0.16	0.105	0.189		
Time	0.398	0.274	0.264	0.43	0.277	

Table 8. HTMT analysis results.

	Cost	Efficiency	Environment	Quality	Safety	Time
Cost	0.856					
Efficiency	0.154	0.856				
Environment	0.126	0.087	0.831			
Quality	0.167	0.165	−0.023	0.783		
Safety	0.224	0.145	−0.002	0.086	0.866	
Time	0.355	0.24	0.267	0.377	0.257	0.859

Table 9. Cross-loadings of items.

Variables	Cost	Efficiency	Environment	Quality	Safety	Time
S8	0.837	0.117	0.123	0.1	0.156	0.247
S10	0.923	0.165	0.094	0.113	0.221	0.293
S5	0.753	0.112	0.139	0.221	0.203	0.411
S18	0.903	0.13	0.073	0.125	0.177	0.242
S24	0.141	0.925	0.107	0.182	0.149	0.251
S13	0.126	0.861	0.12	0.13	0.147	0.16
S21	0.129	0.774	−0.02	0.103	0.067	0.201
S4	0.122	0.066	0.651	0.081	−0.1	0.073
S12	0.072	−0.014	0.879	−0.165	−0.051	0.102
S25	0.113	0.113	0.935	−0.013	0.069	0.354
S7	0.124	0.047	−0.008	0.84	−0.038	0.236
S23	0.098	0.231	0.002	0.725	0.143	0.268
S2	0.133	0.159	−0.008	0.76	0.132	0.437
S1	0.171	0.042	−0.069	0.802	−0.013	0.179
S19	0.237	0.133	0.009	0.067	0.937	0.346
S15	0.23	0.17	0.011	0.158	0.847	0.142
S16	0.065	0.049	−0.041	−0.045	0.808	0.134
S3	0.319	0.211	0.369	0.328	0.316	0.903
S20	0.276	0.096	0.064	0.328	0.078	0.778
S26	0.288	0.233	0.263	0.322	0.238	0.889
S9	0.334	0.263	0.179	0.325	0.219	0.861

The variables that were removed from the study are listed in Table 10. Due to factors such as low factor loadings or strong cross-loadings, these variables were not included in the final model. According to the data in the table, variables S6, S11 and S22 were removed from consideration during the EFA pilot phase, and variables S14, S17, S27 and S28 were removed from consideration during the SEM major analysis phase. The choice to exclude these variables was made only on the basis of statistical criteria, not on any theoretical or philosophical considerations. Their omission from the final model suggests that they made little to no contribution to the elucidation of the hidden constructs [41,42]. Thus, the final measurement model is composed of a reduced set of the original variables that were judged to be superior in their ability to assess the target constructs.

Table 10. Summary of deleted factors.

Variables	Stage	Status
S6	EFA (Pilot)	Deleted
S22	EFA (Pilot)	Deleted
S11	EFA (Pilot)	Deleted
S17	SEM (Main)	Deleted
S27	SEM (Main)	Deleted
S14	SEM (Main)	Deleted
S28	SEM (Main)	Deleted

The factors' group impact rank, VIF and outer weights are all shown in Table 11. The outer weights represent how strongly one concept is related to another. An increase in the VIF score suggests increased multicollinearity. Finally, the group impact rank illustrates the weight of each component of the model. Time (composed of S26, S20, S3 and S9) has the greatest influence on the model as a whole, followed by cost (S5, S8, S10 and 18), quality (S1, S2, S23 and 7), efficiency (S13, S21 and 24), safety (S15, S16 and 19) and environment (S15, S16 and 19). It is important to keep in mind that the greatest outer weights do not always correspond to the highest group impact rank. For instance, despite S23's larger outer weight compared to those of S7 and S15, it ranks lower for group impact because it belongs to the auality construct, which has less overall influence compared to that of the time, cost and safety constructs. Table 10 shows that all aspects of manufacturing need consideration when assessing its worth. However, time itself seems to be the most significant factor regarding outcomes.

Table 11. Outer weights and group impact rank.

Variables	Outer Weights	VIF	Group Impact Rank
S1 ← Quality	0.802	2.488	Rank 3
S2 ← Quality	0.76	1.347	
S23 ← Quality	0.725	1.334	
S7 ← Quality	0.84	1.898	
S15 ← Safety	0.847	1.77	Rank 5
S16 ← Safety	0.808	2.252	
S19 ← Safety	0.937	3.055	
S26 ← Time	0.889	2.031	Rank 1
S20 ← Time	0.778	2.079	
S3 ← Time	0.903	2.373	
S9 ← Time	0.861	2.584	

Table 11. *Cont.*

Variables	Outer Weights	VIF	Group Impact Rank
S4 ← Environment	0.651	1.225	Rank 6
S25 ← Environment	0.935	2.847	
S12 ← Environment	0.879	2.992	
S5 ← Cost	0.753	1.489	Rank 2
S8 ← Cost	0.837	2.09	
S10 ← Cost	0.923	2.328	
S18 ← Cost	0.903	2.627	
S13 ← Efficiency	0.861	2.145	Rank 4
S21 ← Efficiency	0.774	1.555	
S24 ← Efficiency	0.925	2.629	

4.3.2. Path Analysis

Formative construct route analyses are shown in Table 12. Each path's coefficient (β), standard error (SE), t-value (t), *p*-value (*p*) and variance inflation factor (VIF) are listed in the table below. According to the findings, BIM implementation in the New Jeddah Housing Development project benefited from the attention paid to the six formative constructs (cost, efficiency, environment, quality, safety and time). The route coefficients represent the strength of the connections between the formative structures and the overall effectiveness of BIM implementation. To what extent the cost of implementing BIM affects its overall performance is shown by its path coefficient of 0.324. Similarly, positive path coefficients of 0.257, 0.173, 0.281 and 0.250 for the efficiency, environment, quality and safety constructs, respectively, show that they are also significant variables in BIM success. Time has the greatest influence on the BIM success of any of the formative components, as seen by its path coefficient of 0.411. This might be because timely construction project completion is vital for customer satisfaction, budget management and income production [31,34]. There is no major multicollinearity problem among the predictors because the VIF values for all the formative components are less than 5 [29,56]. Overall, the findings of the path analysis are helpful for project managers and decision makers in the construction sector because they provide light on the elements that impact the effectiveness of BIM within the context of the New Jeddah Housing Development project. Figure 6 presents the model with the results of the bootstrapping analysis. The significance of each construct and item is indicated in the model, which confirms the relationship of all constructs with latent variables.

Table 12. Path analysis results of formative constructs.

Path	β	SE	t-Values	*p*-Values	VIF
Cost → Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	0.324	0.026	16.517	<0.001	1.077
Efficiency → Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	0.257	0.025	6.802	<0.001	1.2
Environment → Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	0.173	0.026	11.869	<0.001	1.519

Table 12. *Cont.*

Path	β	SE	t-Values	*p*-Values	VIF
Quality → Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	0.281	0.029	12.714	<0.001	1.153
Safety → Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	0.250	0.026	8.166	<0.001	1.222
Time → Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	0.411	0.03	8.911	<0.001	1.106

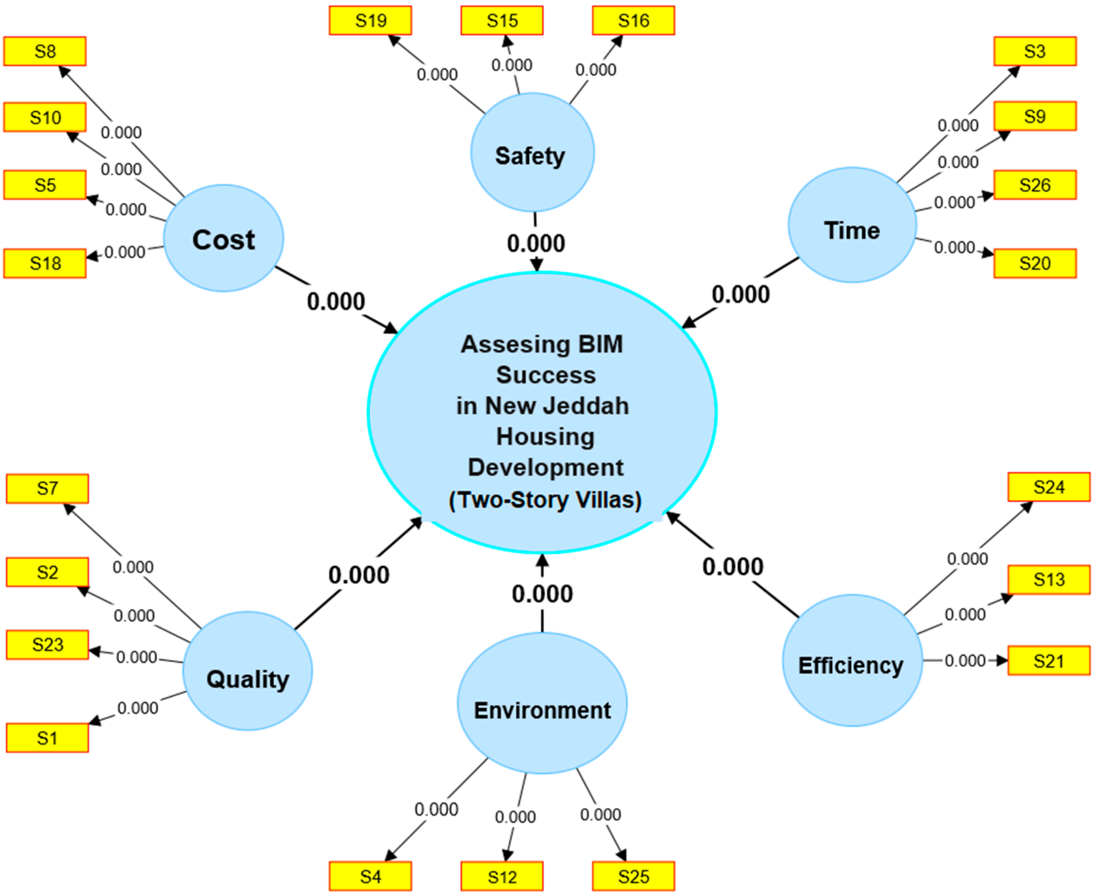

Figure 6. Path significance results after bootstrapping analysis.

Results of the model's predictive relevance analysis are presented in Table 13, which includes the Q^2 value for the endogenous latent variable "Assessing BIM success in New Jeddah Housing Construction (Two-Story Villas)." The amount of variation in the endogenous construct that can be anticipated by the exogenous variables in the model is quantified by Q^2, a measure of the model's predictive accuracy. The Q^2 value of 0.131 in this table indicates a reasonable level of prediction accuracy for applying the model to evaluate the performance of BIM in the New Jeddah Housing Development. This means that the endogenous construct is only partially explained by the exogenous variables included in the model (by roughly 13.1%) [27,55]. Although this is not a very high threshold, it does provide some insight into the model's ability to correctly forecast the endogenous construct. Quantiles of Q^2 greater than 0 suggest that the model has some prognostic value. However, improved prediction accuracy is associated with a more considerable Q^2 value [29,54]. The model has some predictive capacity for evaluating BIM performance in the new Jeddah housing construction, even if the Q^2 value of 0.131 is not exceptionally high [52,54]. While attempting to make sense of these findings, it is also crucial to think about their potential application and the degree to which they match the model as a whole.

Table 13. Endogenous latent variable Q^2.

Predictive Relevance Analysis of Model	SSO	SSE	Q^2 (=1 − SSO/SSE)
Assessing BIM success in New Jeddah Housing Development (Two-Story Villas)	14,980.000	13,011.495	0.131

5. Discussion

The time formative construct includes S3, "By providing a virtual 3D model of the project, BIM may assist project teams in more precisely organizing construction operations"; S9, "BIM may minimize the amount of time required to finish a building project by giving precise and thorough information about the project. This may assist in eliminating construction mistakes, rework and delays, resulting in speedier project completion timeframes"; S26, "BIM allows parties to operate in a coordinated and collaborative way, streamlining communication and reducing misunderstandings. This may contribute to the timely and cost-effective completion of building projects"; and S20, "BIM provides accurate project information before construction to ensure that prefabricated components are built to specs and delivered on schedule to the building site." Many aspects that might affect BIM's performance in the new Jeddah housing construction are included in the time-formative build. Improved collaboration and resource management may shorten the time it takes to finish a project [39,43]. Building errors, rework and delays may be avoided with its help, which would shorten the project's duration. It may help in finishing construction jobs quickly and cheaply. Successful project completion on schedule and within budget may be the result. BIM may aid in expediting the building process and staying on budget by enhancing collaboration, communication and resource management.

The cost formative construct includes S8, "BIM helps project teams estimate building costs by providing precise and thorough project information. This reduces cost overruns and delays"; S10, "BIM may save construction costs by detecting and fixing flaws before building starts. This reduces construction mistakes, rework and delays"; S5, "BIM helps project teams identify project resource needs. This improves resource management and reduces waste"; and S18, "BIM may assist achieve project specs while reducing expenses". Using BIM may result in cost reductions and effective resource management, as shown by the influence of the cost formative build on BIM success in the new Jeddah housing construction (two-story villas). The route analysis findings show that a 1-unit increase in the cost construct is associated with a 0.324-unit increase in BIM success. This indicates that the New Jeddah Housing Development may benefit significantly from BIM's capacity to assist project teams with cost estimation, defect detection and correction prior to construction, resource identification and attaining project specifications at lower prices [23,57].

The quality formative construct includes S7, "BIM lets designers develop a virtual 3D model of the project to discover and fix design faults before construction. This may enhance the design and decrease construction mistakes and rework"; S2, "BIM helps project stakeholders work together toward the same objectives. Ensuring that stakeholders agree on project requirements and specifications may increase project value"; S23, "BIM delivers accurate project information to meet obligations and improves project excellence"; and S1, "BIM may assist project teams in managing the project better, improving project quality." Four potential aspects that might affect the effectiveness of BIM in the new Jeddah housing construction are included in the quality formative build. This might benefit the endeavor as a whole. Second, if the project successfully satisfies all the stakeholders' requirements, the value of the project might rise. Project teams may have better judgment and prevent mistakes that lower quality if they can access accurate and thorough information about the project [26,58]. By giving teams access to real-time data, BIM improves project results by helping teams see and fix problems before they escalate. The quality formative construct concludes that BIM contributes positively to the quality of the New Jeddah Housing Development by facilitating improved design, stakeholder cooperation, information management and project management.

The safety formative construct includes S19, "BIM's virtual 3D model may assist project teams in discovering dangers before building starts. This reduces the number of construction accidents and injuries"; S16, "BIM may be used to create virtual training programs for construction personnel to understand project safety measures better"; and S15, "BIM's 3D model may prevent construction conflicts". The success of BIM implementation in the New Jeddah Housing Development project largely depended on the safety formative construct, consisting of S15, S16 and S19. Better safety policies and procedures may be implemented as a result of the use of BIM on the project, making the workplace safer for everyone involved. By educating employees on proper safety procedures, these programs may help cut down on workplace mishaps and injuries. Unsafe situations in the workplace may be avoided if the team takes the time to anticipate and resolve possible disputes before they arise [32,59]. In conclusion, the safety construct and its associated aspects may significantly contribute to the overall success of BIM implementation in the New Jeddah Housing Development project by improving safety standards, lowering the number of accidents and injuries and preventing disputes.

The efficiency formative construct includes S24, "BIM helps project stakeholders work together toward the same ideas, reduces misconceptions and aligns everyone on project needs and specs, improving productivity"; S13, "BIM enhances construction project sequencing, resulting in productivity improvement"; and S21, "BIM improves construction project data, resulting in efficiency improvements." The efficiency formative construct analyzes how several elements influence the project team's output and performance. BIM may improve productivity on the New Jeddah Housing Development project. BIM may help groups organize construction activities and determine the necessary sequence of tasks more precisely because it provides a 3D representation of the project. More effective and timely completion of the project may result from this. Increased efficiency and production may be the outcome [15,16]. When this occurs, resources may be used more effectively and efficiently, leading to more production with fewer expenditures. BIM implementation in the New Jeddah Housing Development project may benefit from the efficiency construct and its elements, leading to greater efficiency, productivity and cost-effectiveness.

The environment formative construct includes S4, "BIM can increase energy efficiency by giving precise energy performance data. This may uncover energy savings and improve building systems to minimize energy consumption and greenhouse gas emissions"; S12, "BIM provides precise project information to optimize material utilization"; and S25, "BIM's precise energy usage and greenhouse gas emission data help lower the project's carbon impact." This not only follows the current fashion for eco-friendly construction methods, but it also has the potential to save money in the long term by cutting down on energy use and carbon tax obligations. The project's effect on the environment and natural resources may be lessened by cutting down on waste and increasing the efficiency with which materials are used [18]. As a whole, the environment construct stresses the significance of taking environmental considerations into account during construction, and BIM can play a pivotal role in facilitating this by providing reliable information for use in making informed decisions and improving the efficiency of the built environment.

5.1. Empirical and Theoretical Contributions

The results show that BIM has the ability to improve several facets of building projects, such as timeline, budget, quality, safety, efficiency and environmental impact. In addition, the findings give concrete case studies of how BIM may be utilized in building a new Jeddah housing complex (two-story villas), demonstrating the methodology's relevance in the actual world. The findings add to our knowledge of BIM's function in building projects, especially its ability to boost project outcomes in many ways. The results illustrate the potential advantages of BIM as a digital technology in enhancing project performance, and they add to the more considerable theoretical debate on technology acceptance and implementation in the construction sector. The findings provide light on how Building Information Modeling (BIM) was used in the New Jeddah Housing Development (Two-Story Villas), illustrating the significance of contextual elements in determining the utility of BIM in any given project scenario.

5.2. Managerial Suggestions

BIM may increase efficiency and effectiveness by facilitating better interaction and coordination among all parties involved in a project. Stakeholders in a project may reap the software's full advantages if they have received proper training on how to use it. BIM may aid in detecting design flaws and disputes, resulting in a more streamlined and successful design process. Prioritizing BIM deployment during the design phase may help teams avoid making expensive adjustments or redoing work during the building phase. Building Information Modeling (BIM) helps reduce a project's carbon footprint by providing accurate information on energy efficiency, optimizing the use of materials, and more. Costs may be cut, and sustainable development practices can be more closely aligned using BIM to improve energy efficiency and environmental sustainability. Building Information Modeling (BIM) may be used to design virtual training programs for construction staff to help them learn about and practice the project's safety procedures and spot possible safety concerns before they start building. To guarantee a safer and healthier workplace, project teams may include BIM in safety training and processes. Project teams should regularly monitor and evaluate its implementation to ensure that BIM is being utilized to its maximum potential. Results from BIM implementation should be tracked so that teams may change their approaches based on things such as money saved, time saved and increased quality and safety.

5.3. Limitations and Future Implications

The use of EFA and structural equation modeling is one of the drawbacks of SEM. These statistical techniques are frequently used in the academic world, but they are not without their caveats and may only sometimes provide the same findings when applied to other data sets or circumstances. Moreover, the results may not be transferable to other projects or cases because this research only examines how BIM affected one construction project's performance. The effect of BIM on the completion of particular building types, such as skyscrapers, hospitals or bridges, can be the subject of future study. Future research can also examine how project management techniques and stakeholder involvement affect the success of BIM-based building projects. Last, future studies can investigate how BIM affects project performance in other areas, taking into account cultural and regulatory issues that can affect BIM's deployment and efficacy.

There is an increasing trend toward villas in the Saudi Arabian residential construction sector. Further, because of significant economic growth in recent years, Jeddah's local government and urban authorities are focusing on improving the performance of construction in affordable residential villas. The outcomes of this study are specifically differentiating the success outcomes of BIM in villas. Previously, for two-story villas, studies have not focused on the perspective of BIM. It is known, however, that BIM application and its success outcomes are completely different for every structure. In two-story villas, there is a limited scope, cost and elements of the project where BIM functions can be easily implemented with minimal risk. This study uniquely indicates the success outcomes of BIM while relating to the limited structural constraints and requirements of two-story villas.

6. Conclusions

BIM has been shown to improve the efficiency and accuracy of building projects significantly, and this study sheds light on the many aspects that contribute to this improvement. This research found many formative dimensions that affect BIM performance, including quality, time, cost, safety, efficiency and the environment, via a comprehensive quantitative case study examination of newly constructed housing developments in Jeddah, Saudi Arabia. The practical ramifications of this study's empirical results for construction project managers and stakeholders are substantial. Researchers found that BIM helped them locate and solve design flaws before construction began, boosted communication and cooperation among project participants and ensured that everyone had the knowledge they needed to fulfill their responsibilities. By simplifying communication, optimizing resource management and finding and repairing defects before construction begins, BIM may help cut down on project time and expenses. By facilitating the early identification of possible threats and the development of virtual training programs for construction staff, BIM may help cut down on construction accidents and injuries. BIM may boost efficiency through better project sequencing, enhanced construction project data and a unified consensus on project requirements and specifications. This research concludes that BIM has the potential to benefit the environment by reducing the project's carbon footprint via increased energy efficiency, optimized material usage and reduced waste.

Nevertheless, this research has certain caveats, such as the case study analytic approach, which might make it hard to generalize the findings. This investigation of BIM success determinants in building projects uncovers important theoretical and practical implications for project managers and stakeholders. This research shows that BIM adoption is crucial for the construction industry's quality, timeliness, cost-effectiveness and efficiency and for fostering sustainability. The results of this study may be used to educate best practices for using BIM on construction projects and to guide future research on the elements that contribute to the effectiveness of Building Information Modeling.

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