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Influence of Building Information Modeling (BIM) Implementation in High-Rise Buildings towards Sustainability

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Abstract: To secure full benefits without jeopardizing project feasibility, sustainability standards in high-rise building design should be included at all phases of the decision-making process. However, there are limited empirical studies on the influence of building information modeling (BIM) implementation in high-rise buildings. Implementing BIM is a viable technique to improve high-rise building sustainability performance. Therefore, the aim of this research is to explore the influence of BIM implementation in high-rise buildings by integrating the exploratory factor analysis (EFA) and structural equation modeling (SEM) approaches. Following a detailed review of the literature to identify critical success factors (CSFs) for BIM implementation, empirical evidence was gathered through a questionnaire survey with 205 stakeholders in construction projects. The EFA revealed five components, namely, productivity, visualization, coordination, sustainability, and safety improvement, all of which have a significant impact on the long-term construction of high-rise buildings. Moreover, SEM was conducted to develop the model for high-rise buildings. However, it has been revealed that awareness and usage level of BIM technology in high-rise buildings still appears to be limited. This scenario paves the way for future researchers to develop more models in the domain of high-rise buildings in order to improve sustainable development.

Keywords: high-rise buildings; BIM; structural equation modeling; sustainability

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1. Introduction

The construction industry can be seen as one of the most important aspects of environmental sustainability, given the importance of high-rise buildings in terms of finance, sustainability, the environment, and quality of life [1]. High-rise buildings are supposed to be sustainable if their social, economic, and environmental effects on the community are adequately addressed and contribute to the sustainable development of society [2]. Social sustainability refers to the ability of people to stay in line with their needs and the requirements of future generations. Society's long-term interests would be served by addressing the interests of the people who would be affected by the nature of a built environment [3].

Building information modeling (BIM) is a technology for managing construction projects. The BIM concept was introduced in 1970 by Professor Charles M. Eastman, and in the mid-year of 2000, construction industries started to implement BIM in construction projects. In Malaysia, the public works department (PWD) initiated the concept of BIM implementation in 2007. This move resulted in increased government awareness, reduced construction costs, and a reduction in design concerns during the planning process. Furthermore, it has been observed that BIM is a collaborative effort among architects, engineers, project managers, and contractors [4]. In addition, there are two main ways in which BIM has the potential to boost social sustainability. In the first place, BIM offers an improved social living facility design [5]. BIM helps owners to analyze the design and provide information before constructing the facility by evaluating a three-dimensional (3D) building information model. Secondly, the BIM transforms traditional practice into a much more collaborative work which improves working relations between project participants [6].

On the BIM platform, team members must share their point of view of knowledge with other members to provide a clear framework for decision-making on the design of the facility. Moreover, economic sustainability is somewhat harder to quantify, as there are little data to identify where the green economy is developing [7]. However, it has been shown that BIM improves the life-cycle cost savings of the built facility. In the past, high-rise buildings considered sustainable would have cost about 15% more than conventional buildings at the outset [8]. However, some reports now show that the initial cost of high-rise buildings is not higher than that of conventional buildings. These buildings are also attractive resources for facility owners, including the public and commercial sectors [9]. In addition, environmental sustainability reduces emissions of greenhouse gases into the atmosphere, enhancing the quality of life [10]. The concept of environmental sustainability has created positive improvements in the built environment, reducing energy use and natural resource depletion. BIM can improve spatial design, particularly concerning the assessment of airflow and the overall building ecosystem. While it can be used to improve an energy simulation, it can also be used to explore the detrimental effects of the environment in connection with a green assessment [11]. In addition, a high-rise building is described as "a multi-story structure with a height of 35–100 m (115–328 feet) or a building with an unknown height varying from 12–39 floors". Furthermore, the International Conference on Fire Safety in High-Rise Buildings described a high-rise building as "any structure whose height has a significant impact on evacuation" [12].

When BIM and sustainability practices are combined, it is necessary to make use of BIM technologies such as software and plugins, as well as cloud platforms, in order to enable the assessment of the sustainability of infrastructure and building projects [13]. However, most countries have not been consistent in their adoption and implementation of BIM efforts and sustainability, with the United States of America and the United Kingdom leading the way in terms of BIM adoption and sustainability adoption, respectively. Building sustainability is a complicated problem in the construction industry that requires finding a healthy balance between the three pillars of sustainable development: social, economic, and environmental [14]. Bringing technology improvements and raising awareness of sustainability issues into the construction industry has been proposed as the most effective approach of assisting the built environment in achieving its goal towards sustainability [15,16]. BIM is currently being used in sustainability practices such as lifespan cost assessment, sustainable design, renewable resource selection, sewage treatment, power usage and efficiency [17]. Furthermore, a recent study also looked into the possibility of BIM to meet the energy demand and interior environmental quality of construction facilities [18].

Moreover, some studies have been undertaken to investigate BIM implementation in sustainable buildings; however, they have some limitations [19–21]. For instance, Chan et al. [22] undertook a survey to identify BIM implementation barriers, however, they were only able to collect 44 responses. The current analysis, on the other hand, expands the scope of the study by increasing the number of survey respondents (n = 205). Chan et al. [23] conducted another study to investigate BIM implementation critical success factors (CSFs), although they could only discover eleven CSFs. However, the current study added to the body of knowledge by evaluating twenty CSFs. Furthermore, Xa et al. [24] conducted the latest study to highlight the essential techniques for improving BIM implementation, but only collected 116 effective responses.

As a result, in order to explore the influence of BIM implementation in high-rise buildings, the exploratory factor analysis (EFA) and structural equation modeling (SEM) approaches were used. For this reason, the EFA may be employed to simplify and extract information using a small number of dimensions to represent the original data and illustrate the complex interaction between variables. At the same time, SEM is a flexible multivariate statistical technique that accesses the sequence of interdependent correlations between dependent and independent variables in a measurable manner. To fulfill the aim of the study, the research objectives are as follows: (a) to explore the awareness level of BIM technology in high-rise buildings, (b) to highlight the usage of BIM technology in high-rise buildings, (c) to investigate CSFs of BIM implementation in high-rise buildings and (d) to develop the model for high-rise buildings in order to enhance sustainability. This study would explore and generate fresh knowledge gaps, as well as practical requirements for BIM implementation in high-rise buildings towards sustainability. It would also act as a theoretical foundation for boosting sustainable growth in the future for high-rise building projects.

2. Related Works and Research Gaps

In recent years, the use of technology tools such as BIM for high-rise buildings and project sustainability evaluations have attracted considerable attention from policymakers, academics, government agencies, and key stakeholders in the construction industry [25]. Several recent 6D BIM applications (i.e., BIM and sustainability) provide for the possibility of sustainable material selection in construction projects [26]. Furthermore, to encourage the selection and procurement of low-cost and environmentally sound building materials for different designs, a decision support system has also been developed (DSS) [27]. Likewise, other applications of BIM include: (i) life-cycle cost assessment [28], (ii) simulated building design efficiency [29], (iii) sustainable design [30,31], (iv) building energy analysis [32], (v) indoor environmental quality [33]. In addition to acknowledging the advancements made in the development of building environmental performance evaluation tools, there has also been some criticism that calls for additional research. Along with complexity and geographical variances, the design of a sustainability index has been criticized for being difficult to use during the early stages of a project and for ignoring the economic components of long-term sustainability [34]. The importance of early adoption of sustainability concepts in driving project decisions and design iterations has been well-emphasized during the planning and design stages. In particular, the creation of sustainability appraisal tools to aid experts in making conceptual design selections among various solutions has proven to be a difficult task [35].

Research on Smart Market, McGraw-Hill Construction, provided an in-depth discussion of BIM practices. BIM is considered to achieve sustainability and boost building efficiency objectives [36]. Due to the international push to encourage the use of BIM in project execution, the construction industry is becoming more familiar with the term. Over the years, many BIM literature reviews have been published. Whereas some focus on unique technical aspects of BIM (e.g., potential for rules to be checked to mitigate design errors) [37–40], others are more general [41,42], and some focus on green building and sustainable development [43,44]. Wu and Issa [45] point out the synergy between BIM and green building used to help achieve green objectives and boost sustainable development outcomes. Furthermore, Tran et al. [46] conducted a study on CSFs but limited to sustainable shipping management.

Similarly, a recent study on CSFs was performed, but it was limited to value management [47]. A further study on the impact of procurement processes on sustainable building efficiency was conducted, but it was limited to procurement performance [48]. Furthermore, the investigation of CSFs was accompanied and limited to sustainable, affordable housing [49]. Various research on the barriers to sustainable development was also performed. For example, the barriers to sustainable construction have been identified but are limited to the Ghanaian construction industry [50]. A recent study was conducted by Dalirazar and Sabzi [51] on the strategic analysis of barriers and approaches to the construction of sustainable buildings. Given the above background, it is found that there is a lack of comprehensive study on the influence of BIM implementation in high-rise buildings to boost sustainable development.

Although BIM has become a popular tool in many developed countries to address construction problems in high-rise buildings, similar attention still needs to be paid to most developing nations, including Malaysia. Hence, BIM standards need to be implemented in the Malaysian construction industry due to the significant importance of sustainable environmental policies, numerous standards, and initiatives over the years [52]. In addition, the Malaysian government intends to transform the country into a nation that achieves sustainable growth by the year 2030 [53]. Hence, there is also a need to explore the influence of BIM implementation in high-rise buildings by integrating the EFA and SEM approaches. The CSFs obtained from the current literature are presented in Table 1.

Table 1. Critical success factors of BIM implementation.

Code	Critical Success Factors	References
CSF1	Enhance safety performance parameters	[54–58]
CSF2	Increase productivity and efficiency	[59,60]
CSF3	More efficient communications	[61–63]
CSF4	Better construction planning and monitoring	[63–65]
CSF5	Increase sustainable goals	[66,67]
CSF6	Promote Transparency	[68,69]
CSF7	Improve monitoring and tracking during construction	[70–73]
CSF8	Reduce project duration	[73]
CSF9	Enhance project quality	[74,75]
CSF10	Improve operational and facility management in projects	[76,77]
CSF11	Reduce project cost	[78–80]
CSF12	Improve organizational image	[81–83]
CSF13	Reduced claims and litigation risks	[84–86]
CSF14	Prevent and reduce materials wastage	[87,88]
CSF15	Improve the accuracy of as-built drawings	[89]
CSF16	Reduce clashes in design	[90,91]
CSF17	Support project life cycle data	[92,93]
CSF18	Better cost estimates and control	[94,95]
CSF19	Automated assembly	[96]
CSF20	Enhance collaboration between stakeholders	[97,98]

3. Research Methodology

The research methodology comprises an extensive literature review, questionnaire survey, results, discussion, and model development. Figure 1 provides a detailed picture of the research methodology flowchart. In the first phase of the study, a detailed literature review was conducted to explore the CSFs of BIM implementation. In the second phase of the study, a sampling and questionnaire survey were carried out to fulfill the objectives of the study. In the third phase of the study, results and discussion were conducted to analyze the findings with the aid of analysis of questionnaire respondents, reliability analysis, Spearman's correlation coefficient, the awareness level of BIM technology in high-rise buildings, usage of BIM technology in high-rise buildings, mean score rank technique, and exploratory factor analysis (EFA). In addition, in the third phase of the study, model development was formulated to highlight the influence of BIM implementation on high-rise buildings towards sustainability. In the fourth phase of the study, theoretical implications and conclusion were discussed.

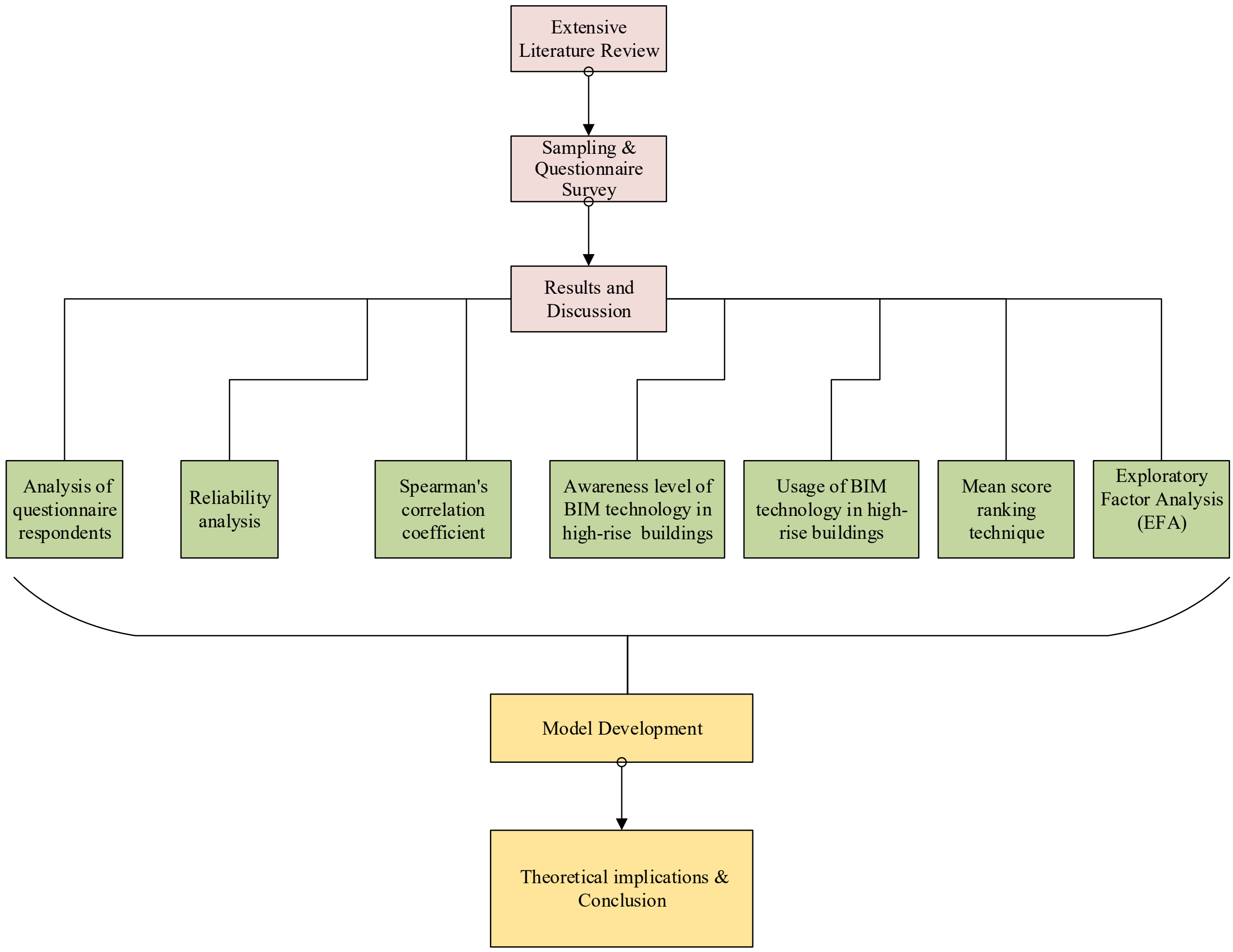

Figure 1. Research flowchart design.

Questionnaire Design and Responses

A pilot survey was undertaken prior to conducting the questionnaire survey to ensure that all necessary information concerning BIM adoption in high-rise buildings could be acquired in order to increase sustainability. The pilot study was conducted to collect feedback from seven participants in order to fine-tune the questions before the final questionnaire survey. The purpose of this pilot study was to test the significance and comprehensiveness of the questionnaire data. The seven participants were three assistant professors, three professors, and one postgraduate student involved in the pilot study.

The final questionnaire consists of four parts: (a) general information of respondents (b) awareness of BIM technology in high-rise buildings, (c) usage of BIM technology in high-rise buildings, and (d) CSFs of BIM implementation in high-rise buildings. In addition, it was proposed that the sample size for the SEM approach be greater than 100 [99]. As this study used the SEM approach, a total of 350 questionnaires were sent out by e-mail, and 205 responses were gathered, resulting in a response rate of 58 percent overall. The respondents were targeted based on their working experiences in high-rise building construction, good knowledge of BIM, and ample experience.

4. Results and Discussion

This section comprises analysis of questionnaire respondents followed by reliability analysis, Spearman's rank correlation coefficient, awareness level of BIM technology in high-rise buildings, usage of BIM technology in high-rise buildings, mean score ranking technique (MS), exploratory factor analysis (EFA), and model development.

4.1. Analysis of Questionnaire Respondents

The respondents involved in the questionnaire survey were classified according to their working experience, organizational role, organization type, education, and position. Figure 2 explains the breakdown of 205 returned questionnaires by the (a) working experience, (b) organizational role, (c) organization type, (d) education, and (e) position.

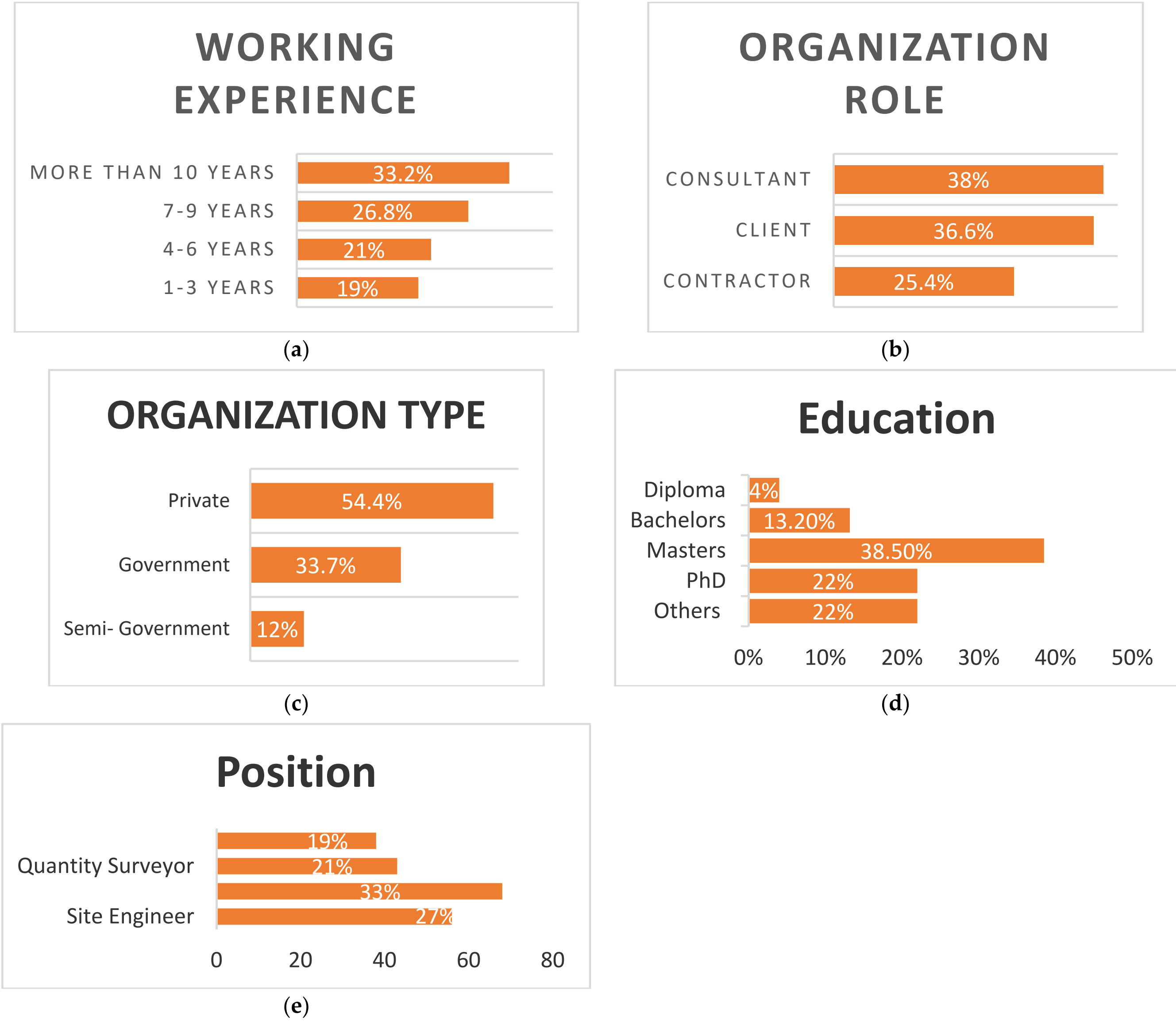

Figure 2. Breakdown of 205 returned questionnaires by the working experience, organizational role, organization type education, position (**a**–**e**).

4.2. Reliability Analysis

Cronbach's coefficient alpha is used to determine the reliability of respondents. The reliability coefficient of Cronbach's alpha is measured in the range of 0 to +1, with higher values indicating greater reliability [100]. The Cronbach's coefficient alpha was the most commonly used metric for determining internal consistency. While the Cronbach's alpha score in this research study was 0.957, it is regarded as reliable and suitable for additional research.

4.3. Spearman's Correlation Coefficient

The Spearman's correlation coefficient (r_s) is computed by the following equation:

$$r_s = 1 - \left[6 \sum_{n=1}^{5} \frac{\left(d^2\right)}{n(n^2 - 1)} \right]$$

Utilizing the Spearman's correlation coefficient serves the purpose of demonstrating a relationship between the perspectives of clients and consultants, as well as the opinions of contractors. The correlation coefficients between all parties were calculated using the Spearman's rank correlation coefficients. The coefficient value between the consultants and contractors is 0.899. The value of correlation between clients and consultants is 0.818, whereas between clients and contractors it is 0.849. This means that there is a strong correlation between consultants and contractors, clients and consultants, as well as clients and contractors.

4.4. Awareness Level of BIM Technology in High-Rise Buildings

The knowledge of BIM in high-rise buildings in Malaysia still appears to be limited. Five levels of awareness of participants were evaluated, as shown in Figure 3. However, level three was considered an appropriate level of awareness (moderately aware). Though 6% were in level one (not at all aware), 33% were in level two (slightly aware), 19% were in level four (somewhat aware), and 7% were in level five (extremely aware).

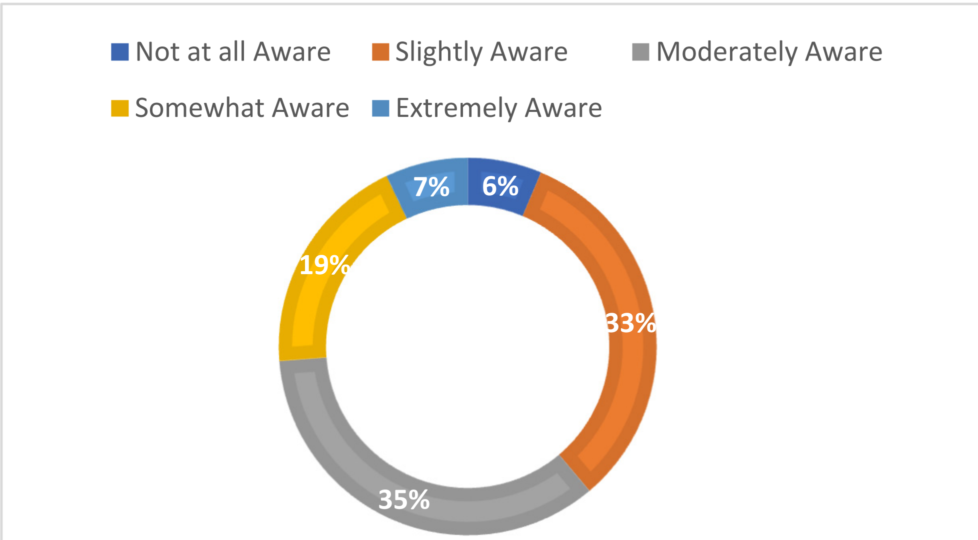

Figure 3. Awareness level of BIM technology in high-rise buildings.

4.5. Usage of BIM Technology in High-RFIGUise Buildings

Similarly, since there is a low level of knowledge of BIM technology in high-rise buildings, the use of BIM technology in high-rise buildings is also limited. It is illustrated in Figure 4 that 46% of stakeholders had an experience of using BIM technology in the last 1–2 years, while 42% had an experience of using BIM technology in the last 3–5 years. However, 8% of stakeholders had used BIM technology in the previous 6–10 years, and 4% had used BIM technology in the previous 11 years. As a result of the above situation and data review, there is a need to increase the usage of BIM in high-rise buildings to boost sustainable growth.

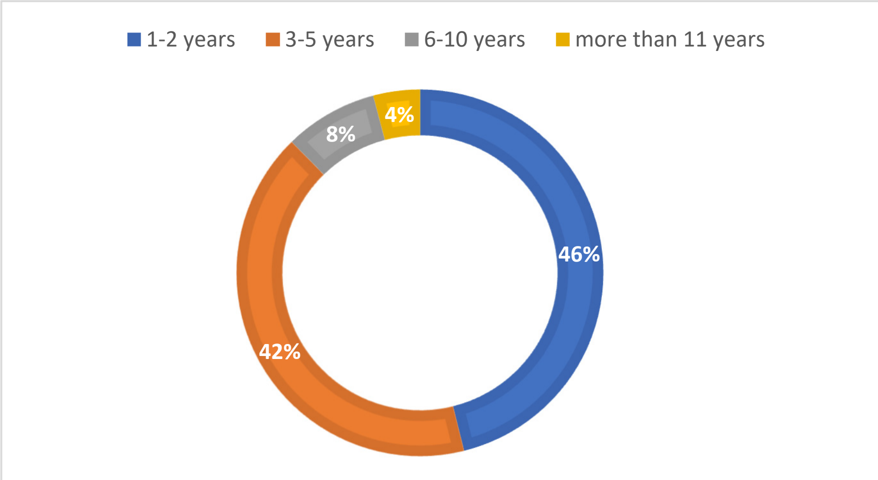

Figure 4. Usage of BIM technology in high-rise buildings.

4.6. Mean Score Ranking Technique

The mean score ranking technique (MS) is used to rank the relative relevance of factors in a quantitative study in order of importance/criticality [101]. The MS technique has also been used in a number of previous studies [102–105]. The ranking of CSFs for BIM implementation is divided into four categories based on the results of the data analysis using the mean value: (a) overall ranking, (b) ranking from the perspective of contractors, (c) ranking from the perspective of consultants, and (d) ranking from the perspective of clients. Table 2 depicts a more complete image of the MS technique in greater depth.

Table 2. Ranking of CSFs of BIM implementation.

Code	Critical Success Factors	Overall Respondents		Contractors' Perspective		Consultants' Perspective		Client's Perspective	
		Mean Value	Rank	Mean Value	Rank	Mean Value	Rank	Mean Value	Rank
CSF1	Enhance safety performance parameters	4.19	1	4.01	2	4.09	2	4.41	1
CSF20	Enhance collaboration between stakeholders	3.89	2	4.05	1	4.10	1	3.60	3
CSF2	Increase stability and efficiency	3.83	3	4.00	3	3.77	4	3.77	2
CSF4	Better construction planning and monitoring	3.82	4	3.98	4	3.90	3	2.64	12
CSF3	More efficient communications	3.64	5	3.75	6	3.70	5	3.50	4
CSF7	Improve monitoring and tracking during construction	3.63	6	3.84	5	3.64	6	3.49	5
CSF5	Increase sustainable goals.	3.07	7	3.13	7	3.20	7	2.90	6
CSF6	Promote transparency.	2.96	8	2.94	16	3.03	10	2.87	7
CSF19	Automated assembly	2.92	9	3.11	8	3.05	9	2.68	10
CSF18	Better cost estimates and control	2.89	10	3.01	13	3.14	8	2.56	13
CSF10	Improve operational and facility management in projects	2.86	11	3.07	10	2.89	14	2.70	9
CSF8	Reduce project duration	2.85	12	3.09	9	2.80	16	2.74	8
CSF12	Improve organizational image	2.84	13	2.90	17	2.98	13	2.65	11
CSF17	Support project life cycle data	2.82	14	3.03	12	3.00	12	2.52	16

Table 2. *Cont.*

Code	Critical Success Factors	Overall Respondents		Contractors' Perspective		Consultants' Perspective		Client's Perspective	
		Mean Value	Rank	Mean Value	Rank	Mean Value	Rank	Mean Value	Rank
CSF16	Reduce clashes in design	2.80	15	3.05	11	3.02	11	2.50	17
CSF15	Improve the accuracy of as-built drawings	2.73	16	2.92	15	2.87	15	2.48	18
CSF9	Enhance project quality	2.76	17	2.98	14	2.79	17	2.58	14
CSF14	Prevent and reduce materials wastage	2.66	18	2.78	18	2.77	18	2.46	19
CSF11	Reduce project cost	2.64	19	2.75	19	2.66	20	2.56	15
CSF13	Reduced claims and litigation risks	2.56	20	2.63	20	2.76	19	2.30	20

According to Table 2, the MS value for 'enhance safety performance parameters' is 4.19 and it ranks first among all respondents. The 'enhance collaboration between stakeholders' factor has MS value of 3.89 and is ranked second. The MS value for 'increase stability and efficiency' is 3.83, and it is ranked third. However, based on contractors' feedback, 'enhance safety performance parameters' has MS value of 4.01 and is ranked second. 'Improve collaboration between stakeholders' has MS value of 4.05 and is ranked first. The MS value for 'increase stability and efficiency' is 4.00 and is ranked third. Furthermore, according to consultants' feedback, 'enhance safety performance parameters' remained second, with MS value of 4.09. 'Improve collaboration between stakeholders' is also ranked first, with MS value of 4.10. However, with MS value of 3.77, 'increase stability and efficiency' is ranked fourth. Furthermore, based on clients' feedback, 'enhance safety performance parameters' has MS value of 4.41 and is ranked first. 'Improve collaboration between stakeholders' has MS value of 3.60 and is ranked third. The MS value for 'increase stability and efficiency' is 3.77, and it is ranked second. According to the findings, the common CSFs among all respondents are to 'enhance safety performance parameters', 'enhance collaboration between stakeholders', and 'increase stability and efficiency'. Perhaps the most unexpected aspect of the results is the comparatively low rank of 'reduced claims and litigation risks', which has MS value of 2.56. In fact, there is growing evidence that 'reduced claims and litigation risks' are of major importance in implementing BIM and sustainability practices in the built environment [106].

4.7. Exploratory Factor Analysis (EFA)

The purpose of EFA is to simplify and extract the information data with the aid of a small number of dimensions for representation and interpretation of original data structure. Therefore, the two tests were carried out to know the adequacy of the data (a) Kaiser–Meyer–Olkin (KMO) test and (b) Bartlett test. To confirm that the initial factors have strong correlations, the KMO test and the Bartlett test must be performed. The KMO test essentially focuses on the properly distributed values on the factor analysis measurement sample, which needs a minimum KMO coefficient of 0.8 [107]. In this study, the value of the KMO test was 0.945, which means that the results are suitable for further analysis. In addition, the significance of the Bartlett test was 0.000, which was less than 0.01, indicating that the findings were sufficient for more exploratory factor analysis. Table 3 summarizes the results of EFA after varimax rotation. The three CSFs with eigenvalues greater than 1 were extracted, having a variance of 74.235%.

Table 3. Interpretation of total variance in the exploratory factor analysis.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
CSF18	11.728	58.640	58.640	11.728	58.640	58.640	8.178	40.890	40.890
CSF11	2.118	10.588	69.228	2.118	10.588	69.228	3.119	15.596	56.486
CSF17	1.002	5.008	74.235	1.002	5.008	74.235	2.053	10.264	66.750
CSF3	0.762	3.811	78.047	0.762	3.811	78.047	1.678	8.391	75.142
CSF7	0.630	3.148	81.194	0.630	3.148	81.194	1.211	6.053	81.194
CSF4	0.563	2.815	84.010						
CSF16	0.408	2.038	86.047						
CSF20	0.401	2.007	88.054						
CSF9	0.359	1.794	89.848						
CSF1	0.310	1.552	91.400						
CSF13	0.281	1.403	92.803						
CSF12	0.255	1.273	94.076						
CSF2	0.220	1.098	95.174						
CSF14	0.205	1.026	96.200						
CSF15	0.181	0.907	97.106						
CSF19	0.150	0.751	97.858						
CSF5	0.138	0.692	98.550						
CSF8	0.103	0.516	99.065						
CSF10	0.099	0.494	99.560						
CSF6	0.088	0.440	100.000						

Extraction method: principal component analysis.

A detailed picture of the factor load matrix after rotation is shown in Table 4, along with the extraction of five groups. Variables with a load factor above or near 0.50 are suggested to be kept because they significantly contribute to the analysis of the group of factors [108,109]. In addition, the variable CSF19 (automated assembly) was excluded due to cross-loading.

Table 4. Factor loading after rotation in exploratory factor analysis.

Code	Component Loading				
	1	2	3	4	5
Group 1—Productivity					
CSF13	0.868	-	-	-	-
CSF14	0.843	-	-	-	-
CSF9	0.831	-	-	-	-
CSF12	0.793	-	-	-	-
CSF15	0.788	-	-	-	-
CSF16	0.710	-	-	-	-
CSF16 *	0.648	-	0.510	-	-
Group 2—Visualization					
CSF3	-	0.808	-	-	-
CSF4	-	0.779	-	-	-
CSF7	-	0.744	-	-	-
CSF2	-	0.620	-	-	-
Group 3—Coordination					
CSF20	-	-	0.778	-	-
CSF8	-	-	0.665	-	-
Group 4—Sustainability					
CSF5	-	-	-	0.747	-
CSF6	-	-	-	0.646	-
Group 5—Safety Improvement					
CSF1	-	-	-	-	0.589
CSF10	-	-	-	-	0.521

Extraction method: principal component analysis. * Excluded due to cross-loading.

As shown in Table 4, the remaining seventeen independent variables are divided into five significant groups with six variables of group 1, four variables of group 2, two variables of group 3, two variables of group 4, and two variables of group 5. To encourage further discussion, it is important to rename the five extracted groups based on the results of the analysis. The five underlying groups can therefore be named as follows:

- Group 1—Productivity
- Group 2—Visualization
- Group 3—Coordination
- Group 4—Sustainability
- Group 5—Safety Improvement

Despite an excessive emphasis on BIM in construction in many developed countries, its presence in developing countries is minimal. Malaysia has experienced difficulties and discrepancies in the building standards, as have many other developing countries. This shows that these challenges need to be addressed by BIM principles. Practitioners would significantly increase the decision of senior management to recognize BIM as an integrated platform/feature for their high-rise building projects by implementing BIM. As the analysis results clearly shown that Malaysia has at level three (moderately aware) for awareness of BIM. It is an alarming situation because, with more emphasis on the usage of BIM, the construction of high-rise buildings will become more economical and increase sustainable development. The following section discusses the five groups derived from EFA and validated by SEM.

Group 1—Productivity

"Productivity" comprises six variables (CSF13, CSF14, CSF9, CSF12, CSF15, CSF16,), i.e., reduced claims and litigation risks (CSF13), prevent and reduce materials wastage (CSF14), enhance project quality (CSF9), improve the organizational image (CSF12), improve the accuracy of as-built drawings (CSF15), reduce clashes in design (CSF16). Government bodies such as the Building and Industrial Authorities as well as regulators will be of vital importance in helping to promote sustainable products and technologies. More government bodies will be expected to incorporate BIM at the design stage, where it currently finds that the application will be needed to promote the practice of sustainability. [110]. It can be achieved if authorities collaborate with the customer and senior executive to clarify the expense of the project and shorten the project time to strengthen the reputation of the organization. Improvements in the BIM implementation towards sustainability procedures in high-rise buildings will therefore be recorded. In addition, productivity is an essential component of encouraging sustainable growth in high-rise building projects in order to foster the image of the enterprise.

Group 2—Visualization

"Visualization" consists of four variables (CSF3, CSF4, CSF7, CSF2), i.e., more efficient communications (CSF3), better construction planning and monitoring (CSF4), improve monitoring and tracking during construction (CSF7), and increase stability and efficiency (CSF2). Visualization technologies have enhanced construction safety by enabling stakeholders to visually access construction worksites and recognize construction hazards prior to the construction phase [111]. Visualization is one of the most important features of BIM implementation in the direction of sustainability due to the increase in construction safety in high-rise buildings [112]. The knowledge on the safety of the project is combined with the visualization in order to support the construction workers and to create coordination. In construction education, therefore, BIM is used for an efficient approach to visualization teaching [113].

Group 3—Coordination

"Coordination" consists of two variables (CSF20 and CSF8), i.e., enhance collaboration between stakeholders (CSF20) and reduce project duration (CSF8). There has been a significant rise in the need for high-rise buildings in the building industry [114]. Firms and governments are becoming more mindful of the maintenance costs of greener construction solutions over time, and they all are preparing to take advantage of the lifecycle financial benefits [115]. Therefore, the appointment of an appropriate design and construction team at the early stage of the project could ensure the successful completion of high-rise building projects [105]. In addition, according to [116], the breakthrough prospects in high-rise buildings usually lie at the very early stage of the project. As a result, engaging stakeholders from the outset would ensure collaboration and creativity in the process. At the same time, designers are often supposed to be able to possess the knowledge and creative capacity, and flexibility. However, collaboration is an integration level where stakeholders share similar responsibilities and collaborate to achieve the expected target [117]. To foster such an atmosphere, best practices would recommend that all team members be required to form a team early in the project [118]. This team should be well aware of green construction standards, and procurement focused on professional accreditation [118].

Group 4—Sustainability

“Sustainability” consists of two variables (CSF5 and CSF6), i.e., increase sustainable goals (CSF5) and promote transparency (CSF6). Sustainability is defined as “building design and construction using methods and materials that are resource-efficient and that will not compromise the health of the environment or the associated health and well-being of the building’s occupants, construction workers, the general public, or future generations” [119]. Green BIM is considered an instrument using sustainable design and building strategies for informed decision-making at an early stage in the design process and allowing greater impact on building project effectiveness and efficiency [120]. The use of ‘green BIM’ should not be limited solely to the building sustainability analysis and management, but also to the entire building life cycle, including (commissioning and occupation), the repair, maintenance, and demolition phases [34]. Therefore, to achieve sustainable goals and enhance transparency, the integration of BIM should be made essential in the production of the building industry.

Group 5—Safety Improvement

“Safety improvement” comprises two variables (CSF1 and CSF10), i.e., enhance safety performance parameters (CSF1) and improve operational and facility management in projects (CSF10). In essence, sustainable development is a holistic approach that takes account of the impact of the built environment on the natural environment. This strategy requires a balance between the needs of the present and those of the future. The overall objective of sustainable development is to balance the resulting effects of existing development projects and to conserve future generations’ social and environmental resources. In order to fulfill the increasing challenges of safety, the building projects are accomplished to meet the safety demand. For this purpose, BIM is the most promising and ever-lasting technology. By taking a positive approach to workers’ safety and health, the sustainability and green building movement could be distinguished. Sustainability will be made more global and the mechanism would rise because of the adequacy of the safety and health of construction workers in those projects which met the sustainability criteria. The redesign of sustainable manufacturing construction processes should include the setting of the production design criteria for health and safety, environmental safety, as well as workplace safety in the design and evaluation of building processes. During construction, several accidents occurred due to insufficient coordination among construction workers, which is why visualization technology provides a forum for successful safety training [121,122].

4.8. Model Development

Based on the findings, it is shown in Figure 5 that visualization has the highest influence on BIM implementation, with a factor load of 0.89. However, coordination has the least influence on BIM implementation, with a factor load of 0.62. This highlights the need for obtaining particular information from stakeholders throughout the project assessment. Sustainability, on the other hand, has a factor load of 0.74, followed by safety improvement. Figure 5 shows that all pathways are statistically relevant at 0.01. Furthermore, since BIM implementation in Malaysia is still in its early stages, 3D drawings can be made quickly and easily. There is an urgent need to encourage simulation techniques such as virtual and augmented reality in Malaysian construction projects. BIM-enabled collaboration within the project team is made possible by modern technical ways of working. The advanced features of personal protective equipment (PPE), safety sensors, and drone technology has made it easier to the improve safety performance of construction projects. Unfortunately, in Malaysia, there is still a demand for these advanced techniques to enhance safety performance [123].

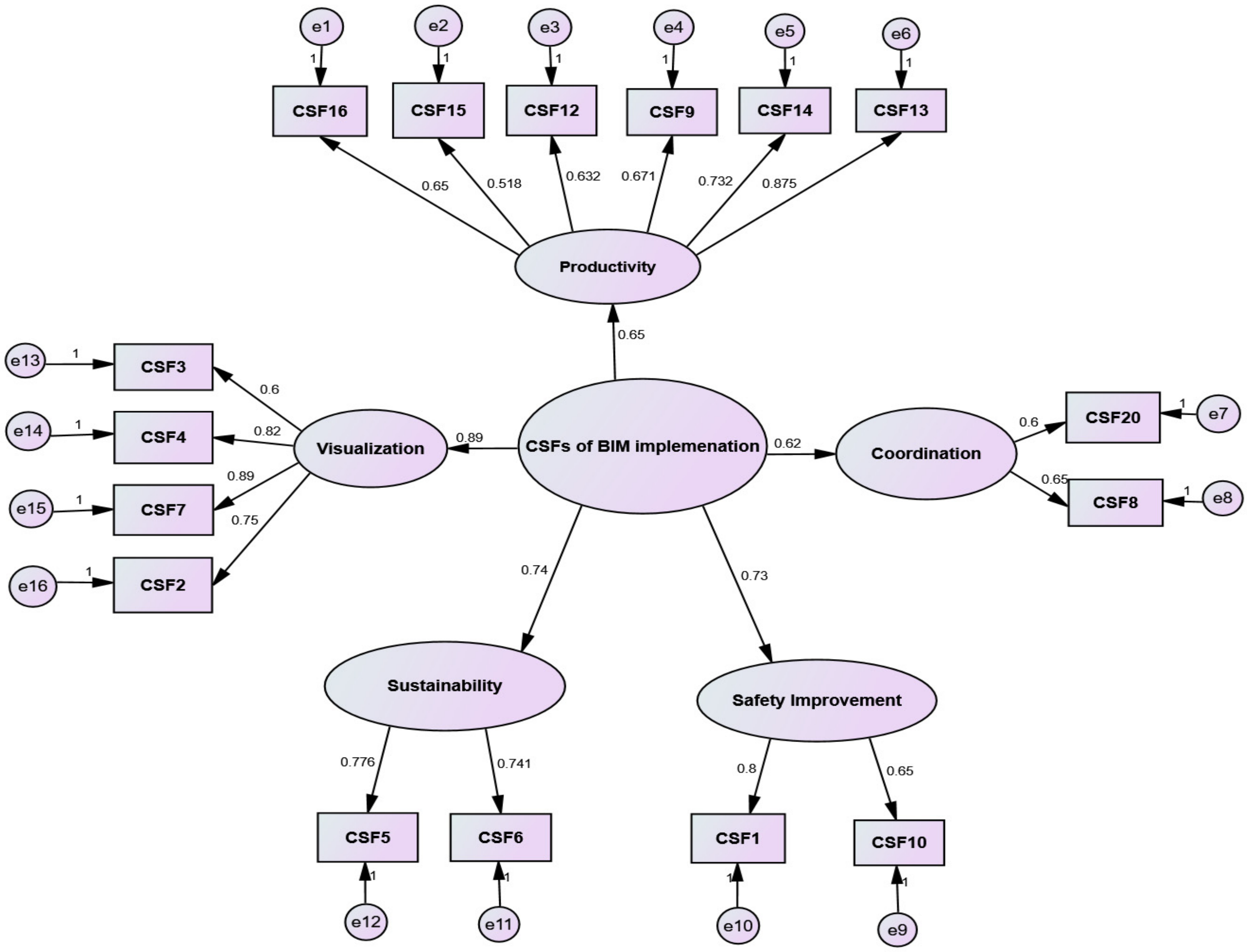

Figure 5. Model development for BIM implementation.

5. Theoretical Implications

The principle of sustainable development has been integral to many companies. The proposed model prescribes BIM implementation, particularly in the area of high-rise buildings. The CSFs are useful for successful implementation in the Malaysian building industry in overcoming current barriers to utilize BIM. As a result, this study will decrease the gap between BIM practice and theory. However, to our best knowledge, there has been no research carried out in the Malaysian building sector to explore the influence of BIM implementation specifically focused on high-rise buildings in order to enhance sustainability. Furthermore, knowledge of awareness of BIM level and usage of BIM technology also laid a strong foundation for policymakers in the field of sustainability of high-rise buildings. The findings provide a starting point for scholars who are interested in further investigating the impact of BIM in developing nations, particularly those working in the domain of construction engineering and management. This study will lay the foundation for applying computer simulation techniques to CSFs in Malaysia and other developing countries by providing a mathematical model for identifying CSFs that can be used effectively. From a theoretical perspective, this study provides a mathematical basis for identifying CSFs of BIM that can be used effectively in Malaysia and other developing countries. Therefore, this study provides a mechanism that can impartially incorporate BIM to policymakers who are interns.

6. Conclusions and Future Directions

To execute sustainability in high-rise buildings, the influence of implementing BIM has gained a high degree of global attention in recent times. In the present work, EFA and

SEM were proposed to explore the influence of implementing BIM in high-rise buildings in order to boost sustainable growth. It was found that the awareness and usage level of BIM technology in high-rise buildings in Malaysia still appears to be limited. The EFA was carried out to extract components and to reduce the data dimension. The SEM was then applied to access the relationships between factors to execute the model. It was revealed that five components were identified by EFA; i.e., productivity, visualization, coordination, sustainability, and safety improvement have a significant influence on the progress of BIM in high-rise buildings. This study fills the knowledge gap on high-rise buildings in developing countries and offers valuable information for policymakers and practitioners concerned with sustainable development. In addition, this study will be valuable and helpful in ultimately achieving more sustainable growth for international organizations and stakeholders interested in promoting sustainability in Malaysia. Therefore, in the future, there is a need to implement and develop a more detailed comprehensive analysis in different countries with different cultural backgrounds and then compare their findings to achieve sustainability effectively. It is anticipated that a more complex BIM model would necessitate more data for building sustainability management and performance tracking, resulting in increased total building data storage space. Green BIM usage is expected to increase in the near future, as the tool is used in the construction development process in many countries. As time goes on, it appears that the reality of implementing BIM for high-rise buildings is becoming more evident to everyone. Aside from the incentives provided by the construction industry, there has been an increase in the amount of research conducted on various aspects of BIM implementation.

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