sustainability

MDPI

Article

Building Information Modeling Execution Drivers for Sustainable Building Developments

Ibukun O. Famakin [1], Idris Othman [2], Ahmed Farouk Kineber [3,4,*], Ayodeji Emmanuel Oke [1,5,6], Oludolapo Ibrahim Olanrewaju [7], Mohammed Magdy Hamed [8] and Taiwo Matthew Olayemi [1]

1 Department of Quantity Surveying, Federal University of Technology Akure, 340110 Akure, Nigeria
2 Department of Civil & Environmental Engineering, University Technology PETRONAS, Seri Iskandar 32610, Malaysia
3 Department of Civil Engineering, College of Engineering in Al-Kharj, Prince Sattam Bin Abdulaziz University, Al-Kharj 11942, Saudi Arabia
4 Department of Civil Engineering, Canadian International College (CIC), Zayed Campus, 6th October City, Giza 12577, Egypt
5 CIDB Centre of Excellence, Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg 2092, South Africa
6 School of Social Sciences, Universiti Sains Malaysia, Penang 11800, Malaysia
7 Wellington School of Architecture, Victoria University of Wellington, Wellington 6140, New Zealand
8 Construction and Building Engineering Department, College of Engineering and Technology, Arab Academy for Science, Technology and Maritime Transport (AASTMT), B 2401 Smart Village, Giza 12577, Egypt
* Correspondence: a.kineber@psau.edu.sa

Abstract: The need for continuous global improvement in the construction industry's current state is inevitable. This pursuit for advancement is to benefit all concerned stakeholders in the construction industry, and innovation has been acknowledged as this improvement measure. Interestingly, Building Information Model (BIM) is a typical example of such innovation in the construction industry. It circumvents human errors, lessening project costs, strengthening productivity and quality, and reducing the project delivery time. This analysis investigates the factors influencing BIM implementation in construction in developing nations. A comprehensive literature review was performed to determine what factors contribute to BIM adoption. These drivers were categorized using exploratory factor analysis (EFA). Partial Least Square Structural Equation Modeling (PLS-SEM) was also used with a questionnaire survey of 100 Nigerian building engineering professionals. Findings from the model highlight the most critical drivers of sustainable BIM deployment. The study's conclusion will serve as a guideline for policymakers in developing nations that want to finish successful projects by avoiding BIM implementation drivers and improving the accomplishment of building projects via the usage of BIM.

Keywords: sustainable development; drivers; BIM; building information modeling; Nigeria

check for updates

Citation: Famakin, I.O.; Othman, I.; Kineber, A.F.; Oke, A.E.; Olanrewaju, O.I.; Hamed, M.M.; Olayemi, T.M. Building Information Modeling Execution Drivers for Sustainable Building Developments. *Sustainability* **2023**, *15*, 3445. https://doi.org/10.3390/su15043445

Academic Editor: Alexandre B. Gonçalves

Received: 21 November 2022
Revised: 28 December 2022
Accepted: 30 December 2022
Published: 13 February 2023

1. Introduction

By 2030, the architectural, engineering, construction, and operations (AECO) business will have contributed almost 15% of the global Gross Domestic Product (GDP) [1,2]. The products of the construction industry provide the backbone of society and other sectors of the economy via the creation of vital infrastructure and the built environment [3–5]. As a result, the impact on the economy is likely more significant than the direct GDP contribution. Nearly 40% of annual energy usage, 32% of CO_2 emissions, and 25% of created garbage in Europe may be attributed to the AECO business [6,7]. Additionally, the building sector in many emerging nations has experienced significant shifts to meet local economic goals [8]. As a result, several low-income nations have strengthened their financial systems [9,10]. Multiple timetable delays are expected for building projects in these nations [11–13]. Lack of acceptance of new technologies and ideas, such as Building

Information Modeling (BIM) [14], Blockchain [15], the Internet of Things (IoT) [16,17], and Industry 4.0 [18], has also contributed to widespread productivity problems in the sector. Thus, the construction sector in developing nations fails to achieve government goals for the community and clients, and there is a pressing need to create resource-efficient "total success building projects" [19].

Because BIM is at the forefront of this field's literature, it is increasingly used in various contexts and coupled with other elements for a successful approach throughout a project's planning and execution [20]. BIM is an intelligent 3D model-based system that provides engineers, architects and construction managers with data and tools for improved building and infrastructure planning, design, construction, and management, as defined by Autodesk [21]. BIM's latent potential to increase productivity across the entire life cycle (from design to construction to maintenance) is well established [22,23]. The requests for technology to address systematic and recurrent challenges that stubbornly persist have led to drastic changes in BIM [24]. These issues can be categorized as having a negative impact on productivity, cost, and time management. As a result, BIM has been recognized as a vital tool for lifecycle management that may considerably improve the quality of a building's lifespan [25,26].

Although there are numerous obvious benefits to using BIM, its full potential has not been realized. The current state of adoption [27], the definition and delineation of the barriers [28,29], and the identification of the drivers [2,30,31] in both developed and developing countries have all been the focus of numerous related studies that have sought to untangle a Gordian knot of barriers to BIM adoption. As a result, there has not been a concerted effort to study what motivates builders to adopt BIM [32]. While many studies have investigated BIM practices and the efficacy of these methods in industrialized nations, only a tiny amount of work has been done to investigate the drivers of BIM elaborately. The word "drivers" describes a management procedure essential to guaranteeing success and displays characteristics that, if correctly done, would secure a firm's competitive performance [33,34]. The term "drivers" also refers to a feature necessary to achieve success. For instance, Olanrewaju, et al. [2] discovered that the critical determinants for adopting BIM in Nigeria's AECO business include building lifecycle visualization, improved business performance, regulated whole-life expenditures and environmental parameters, improved quality and higher sustainability, as well as enhanced performance and cooperation. Eadie, et al. [30] noted several essential factors, including but not limited to clash detection, pressure from the government, pressure from competitors, correct construction sequencing, and cost savings through less rework. Clash detection, improved cooperation, and reduced costs were also highlighted as primary motivators for the widespread use of BIM in Australia by Rodgers, et al. [35]. Combining anecdotal evidence with the body of information shows that there are typical motivations for BIM implementation.

This study seeks to contribute to the body of knowledge further by introducing a comprehensive set of drivers that can enhance BIM adoption and determine the significant drivers stakeholders of the construction industry need to concentrate on to encourage the use of BIM for sustainable use building development. As a result, the following research question guided this empirical study: What are the significant drivers of BIM adoption for sustainable building development? Therefore, the current job is the first to fill this void by quantitatively emphasizing these drivers and the influence of BIM via establishing the linkages between input variables using structural equation modeling (SEM). Additional goals include fostering extensive critical discussion and debate among industry stakeholders and strategy consultants and stimulating additional investigation and research within the academic community to accelerate the widespread adoption of BIM in modern practice.

2. State of BIM Adoption in Nigeria for Sustainable Building Development

BIM adoption in Nigeria has continued to receive traction among built environment researchers [22,23,25–27]. However, it has been reported that the adoption level for BIM in the Nigerian construction industry is still shallow in the building lifecycle stages [27,36]. The design phase has more use cases compared to other lifecycle phases. BIM is mainly used to design buildings to attract the client's attention. Continuous integration of BIM for all the building lifecycle stages is almost nonexistent. Only one project (Eko Atlantic) has fully integrated BIM in Nigeria from the design to use phase [37,38]. Although, many upcoming projects are beginning to maximize the value of BIM because BIM is underutilized in the Nigerian construction industry.

BIM is a powerful tool that can enhance construction projects throughout their life cycle [39,40]. BIM can enhance sustainable building development by providing many benefits, including sustainability assessment, clash detection, quantity estimation, and valuable information for the maintenance phase of buildings [41–43]. Given these benefits, there is a need for the Nigerian construction industry to increase BIM uptake for sustainable building development.

3. Drivers of BIM in the Building Industry

The lack of proper records and data management is a common problem in the construction sector, which has a detrimental effect on the whole project lifecycle [2]. According to Saka and Chan [44], the construction sector is famously sluggish in adopting new digital technologies, such as BIM, which has stifled the sector's development and prevented it from keeping up with the times. Adopting BIM provides several advantages to the construction industry, such as simplified project administration and faster turnaround times Olanrewaju, et al. [2]. Furthermore, the study found that process digitalization and economics, construction, visualization and productivity, sustainability and efficiency were the four major drivers of Implementing BIM in Nigeria. Decision-making is facilitated, and construction productivity is increased by using BIM, as indicated by Stransky and Dlask [45]. Similar to what was said by Eastman, et al. [46], BIM enhances communication and coordination within a project's team. Cost estimate and management are two other areas where BIM has been shown to shine in research [2,47]. The early discovery of design clashes before project execution is one way BIM may save money, as stated by Chahrour, et al. [48]. In addition, it has been recognized as a resource that helps teams work together efficiently and creatively [49–51].

Green-BIM, which stands for BIM to Lessen the Environmental Impact of Construction, has also been recognized as an essential instrument in promoting sustainable construction and structures [52,53]. With examples and suggestions for enhancement, Amarasinghe and Soorige [54] showed how BIM might be used in building lifecycle assessment (LCA). Moreover, BIM's inherent visualization capabilities are a strong incentive for its adoption since it allows the customer to preview their planned building before construction begins realistically. Because of this, the design team has more leeway to incorporate the client's feedback into the final product [2,46]. To facilitate the visualization and management of issues, Lin and Hsu [55] implemented BIM by way of a web-based application programming interface (API). This exemplifies BIM's potential for providing early visibility into issues and work progress. Olanrewaju, et al. [2] identified many categories of BIM drivers, and Table 1 provides a review of these drivers as retrieved from the examined literature

Table 1. Major Drivers of BIM Technology Adoption.

S/N	Drivers for BIM	References
D1	A strong comprehension of the BIM procurement process	[56–58]
D2	Create a BIM Technology for construction policy	[26,59]
D3	Encourage stakeholder cooperation in the building sector in Nigeria	[2,60]
D4	Encouragement should be given to aspiring software engineers	[61,62]
D5	Accept the BIM specifications for the supply chain for construction	[58,63]
D6	The software packages chosen should work together	[20,64]
D7	Provide continuous employee training about BIM	[65,66]
D8	More technical professionals should be encouraged	[67,68]

Table 1. *Cont.*

S/N	Drivers for BIM	References
D9	Adequate propagation of BIM knowledge to the construction firms in Nigeria	[26,27]
D10	Developing the construction industry's BIM perspective	[69,70]
D11	Projects are carried out in an integrated manner	[71,72]
D12	Strengthening the legal environment for BIM adoption in the construction industry	[73,74]
D13	Using cloud computing to develop locally optimized software and standards	[75,76]
D14	Use of supply chain process and advanced procurement for designs	[77,78]
D15	Use of a scientific approach	[79,80]
D16	Regulation of BIM usage by the government	[81,82]
D17	Increase cooperation between the public and commercial sectors in implementing BIM	[83,84]
D18	Promote stakeholder cooperation	[39,40]
D19	Supply chain and BIM may work together if the BIM elements are correctly integrated.	[85,86]
D20	People management is key to implementing BIM	[87,88]
D21	Standardize the BIM process and define the procedure for its utilization	[89,90]
D22	Organize adequate seminars for proper understanding and interpretation of BIM	[26,91]
D23	Certain training to implement the latest BIM equipment	[92,93]
D24	Commitment through the investment of BIM	[94,95]
D25	Identification of the type of group and the software to use	[96,97]
D26	Given Proper training for BIM users	[92,93]
D27	Align manufacturers of BIM applications to simplify their concept	[94,98]
D28	Consistent publication of practices and skills necessary for BIM adoption strategy adoption	[26,27]
D29	The evolution of BIM standards on a national and international scale	[98,99]
D30	BIM accreditation	[99,100]
D31	Instruction and the presentation of a rationale for implementing BIM	[26,101]
D32	Established a strategic initiative to drive transformation in the construction industry by the use of information modeling	[102,103]

4. Research Methods

The literature evaluation served as the basis for developing a testable conceptual model of the research strategy [104]. There are three steps involved in conceptual modeling: (1) identifying the model's constructs, (2) classifying those constructs, and (3) establishing their connections [105]. The methodology used to explain the model's outcomes is depicted in Figure 1. In addition, as shown in Figure 1, the research strategy was borrowed from Kineber, et al. [106].

4.1. Construct Validity Analysis

Exploratory Factor Analysis (EFA) was used to categorize the BIM Drivers-related components (Table 2) by reviewing the appropriate literature to determine the crucial BIM Drivers. Validity was assessed using EFA by evaluating the non-dimensionality, reliability, and validity of measurement components for each concept (i.e., the measurement models). Principal Component Analysis (PCA) was favored over competing methods because it is both dependable and conceptually easy to understand [107]. Furthermore, Varimax rotation was employed instead of straight oblimin or Promax because it better distributes the workload among the available variables [108]. In light of this, factor analysis was performed on the 100 completed questionnaires collected from the current study's 100 participants, using the 35 previously described factors [109].

Table 2. Related components of the construction activities.

Drivers	1	2	3	4	5	6	7	8
D1	0.762							
D2 *								0.379
D3								
D4			0.539					
D5			0.753					

Table 2. *Cont.*

Drivers	1	2	3	4	5	6	7	8
D6			0.594					
D7						0.545		
D8		0.834						
D9		0.644						
D10		0.602						
D11						0.626		
D12				0.590				
D13								
D14								
D15				0.667				
D16 *								0.351
D17	0.581							
D18	0.565							
D19	0.597							
D20					0.673			
D21 *								0.353
D22								
D23						0.614		
D24								
D25				0.633				
D26								
D27					0.757			
D28	0.575							
D29					0.532			
D30			0.639					
D31 *							0.394	
D32	0.500							

* Deleted drivers due to low loading.

4.2. Analytical Technique

The SEM method was used to analyze the BIM drivers. Multiple visible and unobservable factors are brought to light by the SEM technique [110,111]. SEM is a powerful method for addressing mistakes caused by variables [112]. In this work, we used the SEM technique to identify the connections between the relevant BIM drivers by looking at how the predefined indicators relate to each build [113]. Byrne [114] said that, in cases where concept analysis methodologies were not strictly adhered to, SEM has lately become a recognized non-experimental study methodology.

Similarly, research published in the MIS Quarterly and cited by Ringle, et al. [115] corroborated the growing popularity of this method over time, and it is also a widely used instrument in the social sciences [116]. A Partial Least Square (PLS) model, encompassing both reflective and formative aspects, has been undertaken to develop the link among BIM drivers based on the purpose of this study. However, the PLS-SEM analysis in this research is broken down into three distinct but interrelated evaluations (measurement model, structural model, and standard method variance) [117].

The Common Methods Variance (CMV) was used to calculate the Common Methods Bias (CMB) [117]. Since data collecting has the potential to bring up trigger issues [118–120], CMB seeks to explain the mistake examination outcomes. As a result, it is crucial to recognize these difficulties and issues to recognize any CMV. In light of this, a formal and systematic one-factor assessment [121,122] was used, as proposed by Harman's analysis (1976). The measurement model provides an improved understanding of the relationship between observations and their interpretation [123]. Convergent validity (which looks at how well different measures agree with one another) and discriminant validity (which investigates how well different concepts are measured against one another) can be used to decide whether or not to use the measure [124,125].

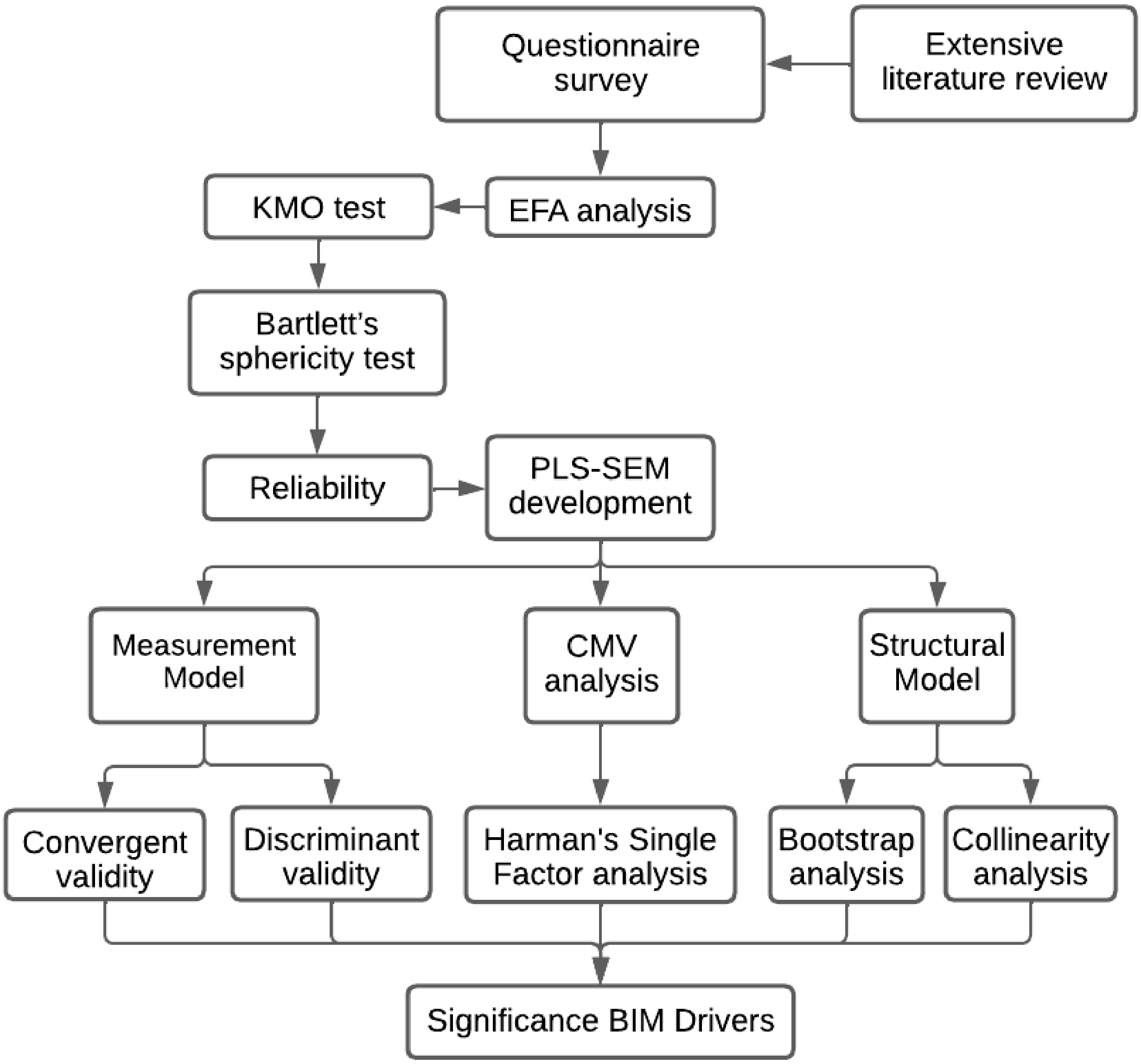

Figure 1. Research design.

4.3. Questionnaire Design and Data Collection

The questionnaire survey was designed on a five-point Likert scale to obtain data from professionals knowledgeable about BIM in the Nigerian construction industry.

4.3.1. Target Population

Due to the limited schedule, financial constraints, familiarity with the area and ease of data collection, this research focused on the Ondo State construction industry. The target population will comprise professionals in the construction industry, viz, Quantity Surveyor, Architect, Engineers, and Project Manager. For the uniqueness of this study in terms of numbers, the census method was adopted. The census method was appropriate for this study because the total number of all proposed respondents is manageable.

4.3.2. Sample Frame

This is the primary material or device from which a sample is drawn. It lists all population members who can be sampled and may include individuals, householders or institutions (Wikipedia). The sample frame in this research is the professionals in the construction industry working within Ondo state.

4.3.3. Sampling Techniques

Sampling techniques involve the selection of a section of a population in order to define the characteristics of the entire population. There are two sampling techniques: non-random sampling (also known as non-probability sampling) and random sampling (also known as probability sampling). In the non-random sampling method, the samples are gathered in a manner that does not afford all the members of the population equal opportunity of being included in the sample, while in the random sampling method, all the members of the population have an equal opportunity of being included in the sample. This study adopted non-random sampling techniques. The reason for choosing this method is that respondents are picked based on convenience concerning their availability, accessibility, proximity and by other means decided by the researcher.

5. Results

5.1. EFA Analysis

Factor analysis was also used to analyze the significant drivers of the acceptance of BIM knowledge in Nigeria's building industry. This analysis explored and detected the relationship among variables and categorized the factors concisely and comprehensively. The data obtained passed Bartlett's Test of Sphericity for enough correlation between the variables, and the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy indicated that the data might be used for factor analysis. Bartlett's Test of Sphericity will provide a positive result if the data or the sampling is suitable for factor analysis. KMO was used to conduct the sampling adequacy test, and the findings suggested that 81.6% of the data gathered met the criteria for factor analysis.

Bartlett's test is highly significant (p-value = 0.000), suggesting that the correlation is an identity matrix. This means that the correlation matrix of all the items listed has a significant correlation at the 5% level and thus, exploratory factor analysis is suitable for the data (degree of freedom = 69, approximate chi-square = 1276.7).

The rotatable component matrix shows the 32 factors impacting the widespread use of BIM in Nigeria's building sector. The elements mentioned above have a significant association of 9 levels in the correlation matrix, indicating the viability of employing EFA. In the Nigerian construction business, BIM is driven by a model of nine different applications. In Table 2, we can see that the factors have been sorted using the varimax rotation and that each variable significantly impacts every application. After omitting uncorrelated drivers (D2, D16, D21 and D31) due to low loading, the six extracted components were named as follows: Standards, Knowledge, Software, Legalization, Management, and Training.

5.2. Common Method Bias

When attempting to depict the error variance connected to the measured variables, common technique bias is a variance calculation that can affect the reliability of the study [117,126]. Single-factor analysis [127] was used to determine the traditional technique variance in the suggested model. Common technique bias is shown to have no effect on results when the overall variation of variables is less than 50% [121]. According to the results, the first group of variables accounts for 22.53% of the total variation; as a result, the standard deviation of the results is too little to have any effect [121].

5.3. Measurement Model

The measurement model defines the link between the elements and their latent construct as of this measurement point [123]. The PLS-SEM method requires analyzing discriminant and convergent validity [128] for the reflected measurement items (BIM drivers).

Two or more measurements (BIM drivers) of the same construct are discussed regarding their degree of coherence and organization [124,129]. A subset of construct and convergent validity may be evaluated using the reliability index. There are a few different tests that may be used in PLS-SEM to get a rough idea of the convergent authenticity of the suggested constructs [130]: Average Variance Extracted (AVE), Cronbach's alpha (α) and composite reliability scores (ρ_c).

Every one of the (BIM drivers) in Table 3 has a composite dependability of 0.60 or above and is therefore accepted [37,38]. On the other hand, Table 3 demonstrates that the Cronbach alpha was 0.60, indicating moderate to high dependability in line with the recommendations of Perry, et al. [131]. In addition, the AVE was used to examine the convergence of the construct variables, and its calculation is as follows [130,132]:

$$AVE = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum \text{var}(\varepsilon_i)} \quad (1)$$

where AVE is the average variance extracted; λ_i is the component loading of each item to a latent variable, and $\text{var}(\varepsilon_i) = 1 - \lambda_i^2$. AVE values above 0.5 are considered acceptable [130]. As a result, the measurement variables explain at least 50% of the measurement variation [133]. All the estimated AVE values (Table 3) for the various constructs in this investigation are greater than 50%, as calculated using the PLS 3.0 program. Results such as this prove that the measurement model is internally consistent and convergent. This means that no additional constructs in the study model are quantified by the measurements used to evaluate each construct. Hulland [124] argues that an external load value of 0.70 is optimal but that a value of 0.40 or higher is acceptable, provided the analysis performed is explanatory. Figure 2 shows the initial PLS model with no loading less than 0.500. The loading is significant because it affects the reliability of the final model.

Table 3. Constructs reliability and validity analyses.

Constructs	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Training	0.770	0.737	0.584
Knowledge	0.795	0.828	0.617
Legalization	0.757	0.763	0.526
Management	0.755	0.812	0.591
Software	0.743	0.806	0.581
Standards	0.796	0.860	0.551

Discriminatory validity testing is becoming increasingly important in the SEM research process [134,135]. It is designed to verify that the examined notion is empirically different or unique [125]. Throughout this research, discriminant validity is examined in terms of a set of methods:

(a) Fornell–Larcker criteria;
(b) Hetrotrait–Monotrait Criterion Ratio (HTMT).

Table 4 shows that the BIM benefits constructs are accepted and authorized based on the Fornell and Larcker criterion, where the square root of the AVE needs to be greater than the correlation between the build indications and variables [130,136].

Table 4. Discriminant validity analysis (Fornell–Larcker).

Constructs	Training	Knowledge	Legalization	Management	Software	Standards
Training	**0.696**					
Knowledge	0.586	**0.785**				
Legalization	0.462	0.301	**0.725**			
Management	0.521	0.344	0.501	**0.769**		
Software	0.511	0.351	0.318	0.400	**0.762**	
Standards	0.610	0.443	0.448	0.572	0.537	**0.742**

The roots of AVE are shown in bold.

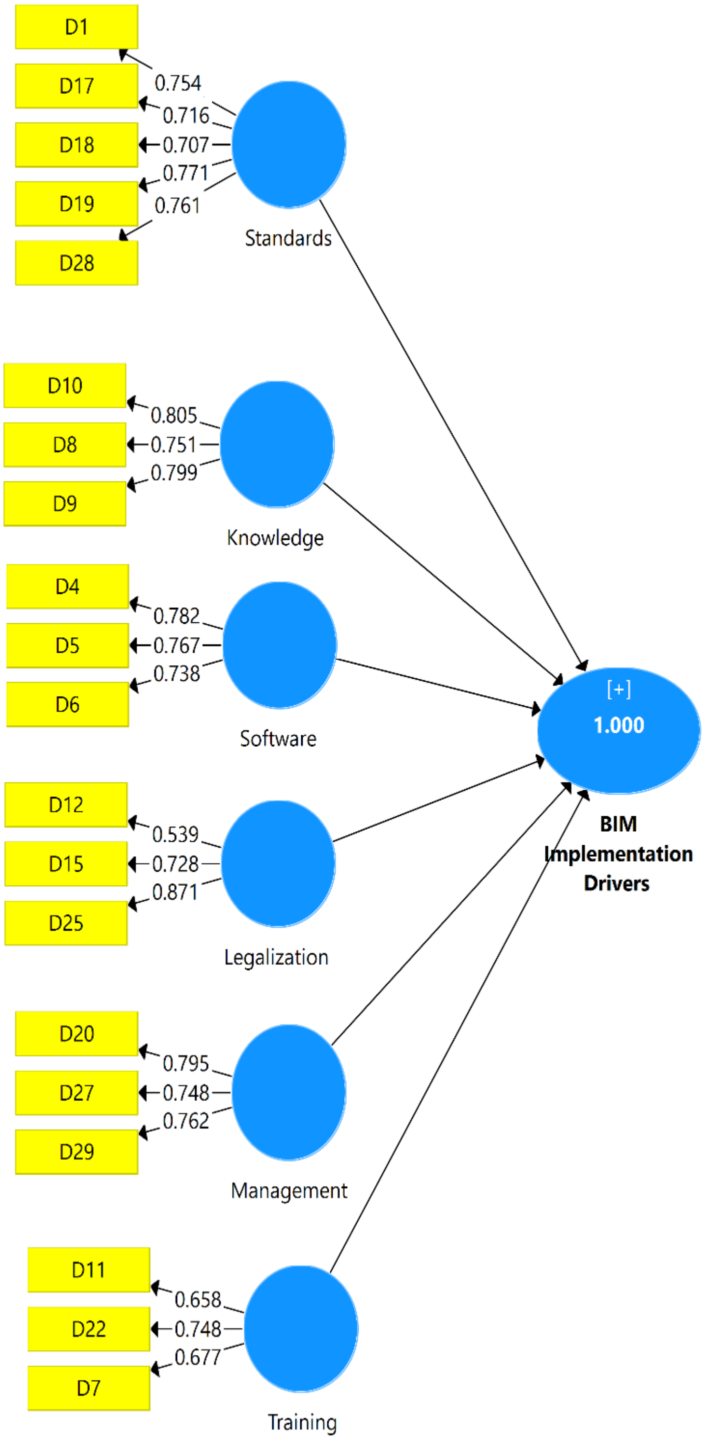

Figure 2. The PLS initial model.

The second technique is Hetrotrait–Monotrait Criterion Ratio (HTMT). To evaluate the discriminative validity of variance-based SEMs, HTMT estimates the precise correlation between the two constructs, assuming they were measured correctly. According to Hair, et al. [125], if the HTMT score is below 0.85 or above 0.90, the two buildings are not interchangeable. If the model's constructors are highly conceptually similar, then the HTMT value should be less than 0.90, and if they are highly conceptually distinct, it should be less than 0.85. The HTMT values for all investigated factors are shown in Table 5. Therefore, the results have shown sufficient discriminating validity.

5.4. Structural Model Analysis

The analysis's primary purpose was to ensure the viability of the suggested curriculum. Using the *p*-value and outer weight (β) at the 95% confidence interval (CI0.95) [137,138], this method examines the robustness and statistical significance of the original dataset selection and, by extension, the observed path coefficient. To ensure the accuracy of the calculated path coefficients [139], a bootstrapping process is used to randomly resample the original data set, creating fresh samples of the exact size as the initial data set [19]. An indicator of the significance of one construct's influence on another, the route coefficient is represented by the value shared by each path [140]. We examined the endogenous construct's route importance by calculating the standardized path coefficients (β) and *p*-values (Figure 3). Table 6 and Figure 3 both displayed bootstrapping findings. Figure 3 shows the significance of each of the drivers group on BIM adoption for sustainable building development graphically.

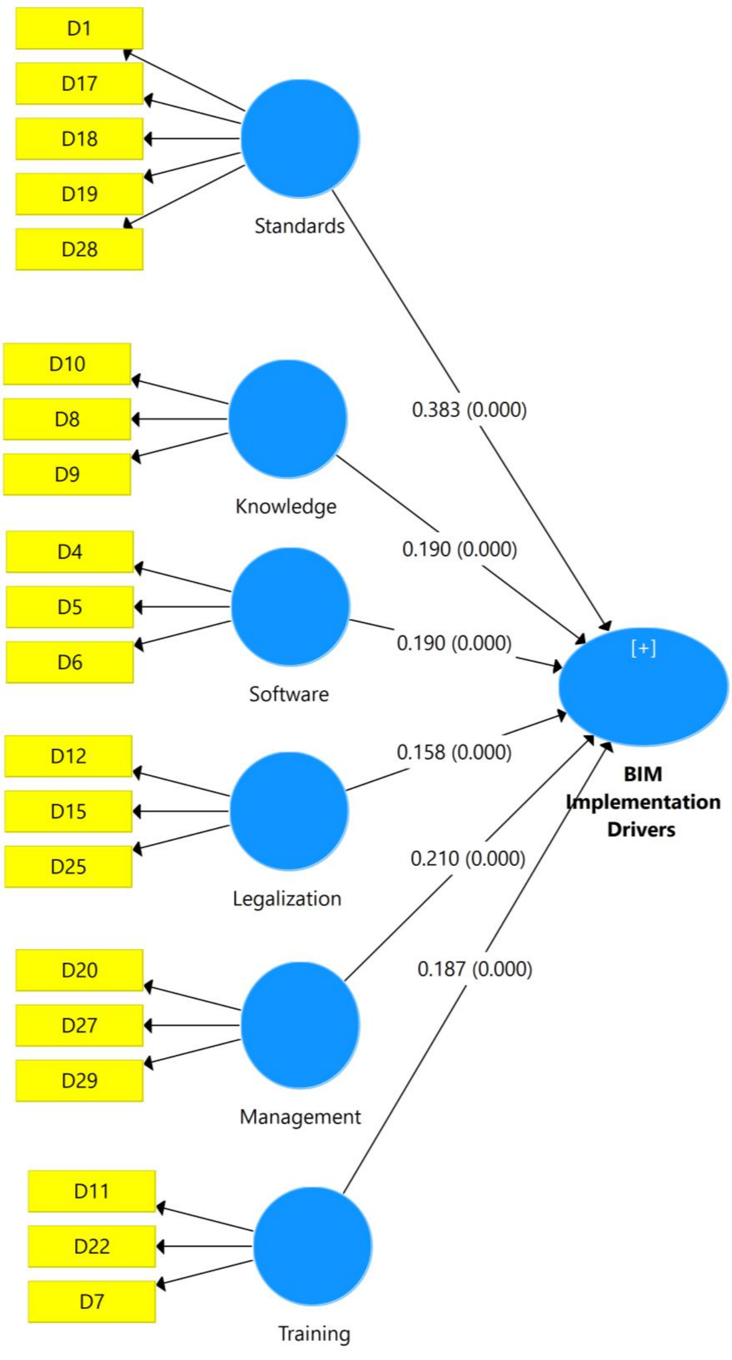

Figure 3. Path analysis.

Table 5. Discriminant validity (HTMT).

Constructs	Training	Knowledge	Legalization	Management	Software	Standards
Training						
Knowledge	0.800					
Legalization	0.754	0.470				
Management	0.729	0.496	0.806			
Software	0.710	0.499	0.488	0.586		
Standards	0.784	0.580	0.622	0.783	0.739	

Table 6. Relative path for the model.

Paths	B	SD	T Statistics (∣O/STDEV∣)	*p* Values
Training -> BIM Implementation Drivers	0.187	0.027	7.010	0
Knowledge -> BIM Implementation Drivers	0.190	0.042	4.565	0
Legalization -> BIM Implementation Drivers	0.158	0.038	4.186	0
Management -> BIM Implementation Drivers	0.210	0.046	4.587	0
Software -> BIM Implementation Drivers	0.190	0.033	5.743	0
Standards -> BIM Implementation Drivers	0.383	0.044	8.674	0

6. Discussion

The research explored 32 underlying strategies for overcoming obstacles to implementing BIM in Nigeria's construction industry; these were further categorized into 23 by ranking. From this study, providing continuous employee training about BIM, more technical professionals should be encouraged and established, and a strategic initiative to drive transformation in the construction industry through the use of information modeling were the three highest rank strategies to aid the adoption of BIM technology in the construction industry. By providing consistent training on BIM technology's nitty-gritty, construction professionals will find it easy to use BIM over traditional methods. Consistent encouragement of technical professionals will have a significant impact on influencing construction professionals. However, Aka, et al. [141] established three techniques, which are to form a BIM institute for the development of young graduates, deter customers from the old ways of construction via cost, and develop BIM execution enforcement bodies, which he later simplified into one entity for affordability reasons. The three were consolidated into one: regulatory organizations charged with enforcing the use of BIM. In addition, he concluded that the Nigerian government should establish a BIM institute to train recent graduates in the field for at least six months, ensure that the endorsement process for BIM projects is more cost-effective and time-efficient than the conventional approach, and mandate the use of BIM for large-scale construction projects. It is essential to urge customers and other parties involved in construction to make BIM adoption a standard requirement for all projects. The adoption and implementation of BIM will be enhanced by the support of the clients, contractors, and government [142,143]. This claim is valid in several international settings, including Singapore, Norway, Denmark, and Finland. For instance, several sizeable Norwegian construction clients insist on using open-format BIM for most of their projects [43]. There is a need to provide information about BIM to construction businesses working in developing nations such as Nigeria to increase its acceptance and implementation there. This will increase awareness of BIM's benefits and the technical expertise required for its adoption [141]. Spreading this knowledge would require concentrated hard work and incorporating professional bodies, industry, and academia [43].

BIM awareness may be increased by fostering a vibrant research community and federal building authorities focusing on BIM expansion nationally [144]. Further, Ahmed and Kassem [41] provided a catalogue and a collection of drivers/determinants that BIM experts may use to conduct multiple studies of the BIM implementation process, providing evidence and insights to decision-makers across various industries. Conversely, working together on a project may boost innovation and make it easier to make choices. If you want to choose how to incorporate and manage technology in your field, you need to have a clear vision for the future. To improve students' access to and equity in IT, institutions can benefit from acquiring BIM knowledge and generating funds by fostering excellent relationships with the community, public, business sector, and alumni [42]. There is a need to provide young software developers with the proper training and resources to create BIM-related software that can be used nationally, establishing BIM standards to checkmate the construction industry. In Singapore, industry foundation classes (IFC) were adopted as the standard for BIM implementation. This body is responsible for transforming the industry in the country by establishing a standard to checkmate the industry.

7. Conclusions

BIM is critical to efficiently delivering sustainable buildings, and developing countries, such as Nigeria need to increase BIM uptake. This study explored the drivers of BIM adoption for sustainable building development using EFA and PLS-SEM. The EFA revealed six unique BIM drivers for sustainable building developments: Standards, Knowledge, Software, Legalization, Management, and Training. The PLS-SEM also showed that the standard-related driver category strongly impacts BIM adoption. Currently, many developing countries such as Nigeria lack critical BIM standards that govern the use of BIM. This is due to the lack of government support for BIM implementation in many developing countries.

7.1. Conceptual and Empirical Contributions

Particularly in emerging nations with many unknowns, the created model highlights the necessity of BIM implementation drivers. The model emphasizes the essential factors influencing BIM adoption. By capitalizing on these factors, policymakers and other government institutions may develop a strategy to increase BIM usage in the AECO sector. Firstly, the study analyzed all the primary factors that encourage BIM implementation in the AECO industry. This lays the groundwork for further research into the factors that encourage BIM adoption in the AECO sector, particularly for sustainable building development. As a result, the theoretical framework developed in this study may be used to improve BIM acceptance in Nigeria and other developing countries by pinpointing the specific drivers of BIM implementation that are most crucial to these countries. The research also makes several significant theoretical and practical advances, including:

- While there are several pieces of research on BIM deployment in industrialized nations, there is little on the topic in Nigeria [32]. The present research fills this void by analyzing the key factors influencing the widespread adoption of BIM;
- The study's model represents the first predictive model to be built in the construction industry to quantify the impact of drivers for BIM use for sustainable building development in the AECO sector. Hopefully, this resource will accelerate the spread of BIM in underdeveloped nations. This approach is empirical since it seeks to achieve what no other researchers have done: investigate the theoretical links between the various components that make up the "BIM implementation drivers".

7.2. Managerial Implications

Building industry experts may maximize their effect by gaining insight into the below managerial implications as they get an appreciation for the factors that drive BIM implementation:

- It offers AECO company's critical drivers that can be implemented to deal with the problems and obstacles connected with BIM adoption, leading to greater client satisfaction due to higher-quality visualization;
- It facilitates choice-making by analyzing the effects of BIM drivers throughout the project's lifecycle.

7.3. Limitations and Areas for Future Studies

The following are the limitations of this study and areas for future research:

- The sample size used for the study is small. Future studies should include more respondents to the survey in order to improve the generalization of the research;
- In terms of geographical scope, the work is limited to Nigeria only. Future research can target other developing countries in Africa to examine the drivers for BIM adoption because different countries may have different motivators;
- This study also showed that standards-related drivers significantly affect BIM adoption for sustainable developments compared to other categories of drivers. Future studies could focus on addressing the BIM standards gaps in developing countries.

Author Contributions: Research Idea: A.F.K. Conceptualization, A.F.K., A.E.O. and I.O.F.; Methodology, A.F.K.; Software, A.F.K.; Validation, I.O.F., I.O., A.F.K., A.E.O., O.I.O., M.M.H. and T.M.O.; Formal Analysis, A.F.K.; Investigation, T.M.O.; Resources, A.E.O. and I.O.F.; Data Curation, A.F.K.; Writing—Original Draft Preparation, A.F.K., O.I.O. and M.M.H.; Writing—Review and Editing, I.O.F., I.O., A.F.K., A.E.O., O.I.O., M.M.H. and T.M.O.; Visualization, A.F.K. and M.M.H.; Supervision, A.F.K., A.E.O. and I.O.F.; Project Administration, A.E.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from the YUTP, 1/2021 (015LC0-367).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to express their utmost gratitude to the YUTP, 1/2021 (015LC0-367) for funding this research, and to the University Tecknologi PETRONAS.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Olanrewaju, O.; Idiake, J.; Oyewobi, L.; Akanmu, W.P. Global economic recession: Causes and effects on Nigeria building construction industry. *J. Surv. Constr.* **2018**, *9*, 9–18.
2. Olanrewaju, O.I.; Babarinde, S.A.; Chileshe, N.; Sandanayake, M. Drivers for implementation of building information modeling (BIM) within the Nigerian construction industry. *J. Financ. Manag. Prop. Constr.* **2021**, *26*, 366–386. [CrossRef]
3. Edwards, D.J.; Pärn, E.; Love, P.E.; El-Gohary, H. Research note: Machinery, manumission, and economic machinations. *J. Bus. Res.* **2017**, *70*, 391–394. [CrossRef]
4. Owusu-Manu, D.-G.; Edwards, D.J.; Mohammed, A.; Thwala, W.D.; Birch, T. Short run causal relationship between foreign direct investment (FDI) and infrastructure development. *J. Eng. Des. Technol.* **2019**, *17*, 1202–1221. [CrossRef]
5. Rady, M.; Mahfouz, S.Y. Effects of Concrete Grades and Column Spacings on the Optimal Design of Reinforced Concrete Buildings. *Materials* **2022**, *15*, 4290. [CrossRef] [PubMed]
6. Araújo, C.; Almeida, M.; Bragança, L. Analysis of some Portuguese thermal regulation parameters. *Energy Build.* **2013**, *58*, 141–150. [CrossRef]
7. Carvalho, J.P.; Bragança, L.; Mateus, R. Optimising building sustainability assessment using BIM. *Autom. Constr.* **2019**, *102*, 170–182. [CrossRef]
8. Mousa, A. A Business approach for transformation to sustainable construction: An implementation on a developing country. *Resour. Conserv. Recycl.* **2015**, *101*, 9–19. [CrossRef]
9. Fang, Z.; Gao, X.; Sun, C. Do financial development, urbanization and trade affect environmental quality? Evidence from China. *J. Clean. Prod.* **2020**, *259*, 120892. [CrossRef]
10. Kineber, A.F.; Kissi, E.; Hamed, M.M. Identifying and Assessing Sustainability Implementation Barriers for Residential Building Project: A Case of Ghana. *Sustainability* **2022**, *14*, 15606. [CrossRef]
11. Kissi, E.; Boateng, E.; Adjei-Kumi, T. Strategies for implementing value management in the construction industry of Ghana. In Proceedings of the DII-2015 Conference on Infrastructure Development and Investment Strategies for Africa, Livingstone, Zambia, 16–18 September 2015; pp. 255–267.
12. Adeyemi, L.A.; Idoko, M. *Developing Local Capacity For Project Management—Key To Social And Business Transformation In Developing Countries, 2008*; Project Management Institute: Newtown Square, PA, USA, 2008.
13. Maceika, A.; Bugajev, A.; Šostak, O.R. The Modelling of Roof Installation Projects Using Decision Trees and the AHP Method. *Sustainability* **2020**, *12*, 59. [CrossRef]

14. Acre, F.; Wyckmans, A. The impact of dwelling renovation on spatial quality: The case of the Arlequin neighbourhood in Grenoble, France. In *Smart Sustainable Built Environment*; Wiley: Hoboken, NJ, USA, 2015.
15. Parn, E.A.; Edwards, D. Cyber threats confronting the digital built environment: Common data environment vulnerabilities and block chain deterrence. In *Engineering, Construction Architectural Management*; Emerald: Bingley, UK, 2019.
16. Ghosh, A.; Edwards, D.J.; Hosseini, M.R. Patterns and trends in Internet of Things (IoT) research: Future applications in the construction industry. *Eng. Constr. Arch. Manag.* **2020**, *28*, 457–481. [CrossRef]
17. Alshami, A.; Elsayed, M.; Mohandes, S.R.; Kineber, A.F.; Zayed, T.; Alyanbaawi, A.; Hamed, M.M. Performance Assessment of Sewer Networks under Different Blockage Situations Using Internet-of-Things-Based Technologies. *Sustainability* **2022**, *14*, 14036. [CrossRef]
18. Newman, C.; Edwards, D.; Martek, I.; Lai, J.; Thwala, W.D.; Rillie, I. Industry 4.0 deployment in the construction industry: A bibliometric literature review and UK-based case study. *Smart Sustain. Built Environ.* **2020**, *10*, 557–580. [CrossRef]
19. Kineber, A.F.; Othman, I.; Oke, A.E.; Chileshe, N.; Buniya, M.K. Impact of Value Management on Building Projects Success: Structural Equation Modeling Approach. *J. Constr. Eng. Manag.* **2021**, *147*, 04021011. [CrossRef]
20. Shirowzhan, S.; Sepasgozar, S.M.; Edwards, D.J.; Li, H.; Wang, C. BIM compatibility and its differentiation with interoperability challenges as an innovation factor. *Autom. Constr.* **2020**, *112*, 103086. [CrossRef]
21. Autodesk. Building Information Modelling (BIM). 2020. Available online: https://www.autodesk.com/solutions/bim (accessed on 10 January 2021).
22. Abubakar, M.; Ibrahim, Y.M.; Kado, D.; Bala, K. Contractors' Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry. In Proceedings of the Conference on Computing in Civil and Building Engineering, Orlando, FL, USA, 23–25 June 2014; pp. 167–178. [CrossRef]
23. Pärn, E.A.; Edwards, D.J.; Sing, M.C.P. The building information modelling trajectory in facilities management: A review. *Autom. Constr.* **2017**, *75*, 45–55. [CrossRef]
24. Oraee, M.; Hosseini, M.R.; Edwards, D.J.; Li, H.; Papadonikolaki, E.; Cao, D. Collaboration barriers in BIM-based construction networks: A conceptual model. *Int. J. Proj. Manag.* **2019**, *37*, 839–854. [CrossRef]
25. Yan, H.; Demian, P. *Benefits and Barriers of Building Information Modelling*; Tingshua University Press: Beijing, China, 2008.
26. Olanrewaju, O.I.; Chileshe, N.; Babarinde, S.A.; Sandanayake, M. Investigating the barriers to building information modeling (BIM) implementation within the Nigerian construction industry. *Eng. Constr. Arch. Manag.* **2020**, *27*, 2931–2958. [CrossRef]
27. Olanrewaju, O.; Babarinde, S.A.; Salihu, C. Current State of Building Information Modelling in the Nigerian Construction Industry. *J. Sustain. Arch. Civ. Eng.* **2020**, *27*, 63–77. [CrossRef]
28. Babatunde, S.O.; Perera, S.; Ekundayo, D.; Adeleye, T.E. An investigation into BIM-based detailed cost estimating and drivers to the adoption of BIM in quantity surveying practices. *J. Financ. Manag. Prop. Constr.* **2019**, *25*, 61–81. [CrossRef]
29. Kineber, A.F.; Oke, A.E.; Elseknidy, M.; Hamed, M.M.; Kayode, F.S. Barriers to the Implementation of Radio Frequency Identification (RFID) for Sustainable Building in a Developing Economy. *Sustainability* **2023**, *15*, 825. [CrossRef]
30. Eadie, R.; Odeyinka, H.; Browne, M.; McKeown, C.; Yohanis, M. An analysis of the drivers for adopting building information modelling. *J. Inf. Technol. Constr.* **2013**, *18*, 338–352.
31. Olawumi, T.O.; Chan, D.W. An empirical survey of the perceived benefits of executing BIM and sustainability practices in the built environment. *Constr. Innov.* **2019**, *19*, 321–342. [CrossRef]
32. Olanrewaju, O.I.; Kineber, A.F.; Chileshe, N.; Edwards, D.J. Modelling the Impact of Building Information Modelling (BIM) Implementation Drivers and Awareness on Project Lifecycle. *Sustainability* **2021**, *13*, 8887. [CrossRef]
33. Chan, A.P.C.; Ho, D.C.K.; Tam, C.M. Design and Build Project Success Factors: Multivariate Analysis. *J. Constr. Eng. Manag.* **2001**, *127*, 93–100. [CrossRef]
34. Yu, A.T.; Shen, Q.; Kelly, J.; Lin, G. A Value Management Approach to Strategic Briefing: An Exploratory Study. *Arch. Eng. Des. Manag.* **2006**, *2*, 245–259. [CrossRef]
35. Rodgers, C.; Hosseini, M.R.; Chileshe, N.; Rameezdeen, R. Building information modelling (BIM) within the Australian construction related small and medium sized enterprises: Awareness, practices and drivers. In Proceedings of the ARCOM 2015: 31st Annual Conference of the Association of Researchers in Construction Management, Lincoln, UK, 7–9 September 2015; pp. 691–700.
36. Rady, M.; Mahfouz, S.Y.; Taher, S.E.-D.F. Optimal Design of Reinforced Concrete Materials in Construction. *Materials* **2022**, *15*, 2625. [CrossRef] [PubMed]
37. Wong, K.K.-K. Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. *Mark. Bull.* **2013**, *24*, 1–32.
38. Bagozzi, R.P.; Yi, Y. On the evaluation of structural equation models. *J. Acad. Mark. Sci.* **1988**, *16*, 74–94. [CrossRef]
39. Azhar, S.; Khalfan, M.; Maqsood, T. Building information modeling (BIM): Now and beyond. *Australas. J. Constr. Econ. Build.* **2012**, *12*, 15–28.
40. Succar, B.; Kassem, M. Macro-BIM adoption: Conceptual structures. *Autom. Constr.* **2015**, *57*, 64–79. [CrossRef]
41. Ahmed, A.L.; Kassem, M. A unified BIM adoption taxonomy: Conceptual development, empirical validation and application. *Autom. Constr.* **2018**, *96*, 103–127. [CrossRef]
42. Hedayati, A.; Mohandes, S.; Preece, C. Studying the obstacles to implementing BIM in educational system and making some recommendations. *J. Basic Appl. Sci. Res.* **2015**, *5*, 29–35.

43. Demirdoven, J. An interdisciplinary approach to integrate BIM in the construction management and engineering curriculum. In Proceedings of the BIMAS2015 9th BIM Academic Symposium, Washington, DC, USA, 7–8 April 2015; Volume 1, pp. 211–251.
44. Saka, A.B.; Chan, D.W.M. A Scientometric Review and Metasynthesis of Building Information Modelling (BIM) Research in Africa. *Buildings* **2019**, *9*, 85. [CrossRef]
45. Stransky, M.; Dlask, P. Process of matching work items between bim model and cost estimating software. *Eng. Rural Dev.* **2018**, *17*, 856–864. [CrossRef]
46. Eastman, C.M.; Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, 2nd ed.; John Wiley & Sons: Hoboken, NJ, USA, 2011.
47. Nagalingam, G.; Jayasena, H.S.; Ranadewa, K. Building information modelling and future quantity surveyor's practice in Sri Lankan construction industry. In Proceedings of the Second World Construction Symposium, Abu Dhabi, United Arab Emirates, 22–24 October 2013; pp. 81–92.
48. Chahrour, R.; Hafeez, M.A.; Ahmad, A.M.; Sulieman, H.I.; Dawood, H.; Rodriguez-Trejo, S.; Kassem, M.; Naji, K.K.; Dawood, N. Cost-benefit analysis of BIM-enabled design clash detection and resolution. *Constr. Manag. Econ.* **2021**, *39*, 55–72. [CrossRef]
49. McNamara, A.J.; Sepasgozar, S.M. Intelligent contract adoption in the construction industry: Concept development. *Autom. Constr.* **2021**, *122*, 103452. [CrossRef]
50. Badi, S.; Ochieng, E.; Nasaj, M.; Papadaki, M. Technological, organisational and environmental determinants of smart contracts adoption: UK construction sector viewpoint. *Constr. Manag. Econ.* **2021**, *39*, 36–54. [CrossRef]
51. Aidy, A.; Rady, M.; Mashhour, I.M.; Mahfouz, S.Y. Structural Design Optimization of Flat Slab Hospital Buildings Using Genetic Algorithms. *Buildings* **2022**, *12*, 2195. [CrossRef]
52. Chileshe, N.; Jayasinghe, R.S.; Rameezdeen, R. Information flow-centric approach for reverse logistics supply chains. *Autom. Constr.* **2019**, *106*, 102858. [CrossRef]
53. Kineber, A.F.; Oke, A.E.; Hamed, M.M.; Rached, E.F.; Elmansoury, A.; Alyanbaawi, A. A Partial Least Squares Structural Equation Modeling of Robotics Implementation for Sustainable Building Projects: A Case in Nigeria. *Sustainability* **2023**, *15*, 604. [CrossRef]
54. Amarasinghe, I.A.; Soorige, D.; Geekiyanage, D. Comparative study on Life Cycle Assessment of buildings in developed countries and Sri Lanka. *Built Environ. Proj. Asset Manag.* **2021**, *11*, 304–329. [CrossRef]
55. Lin, Y.-C.; Hsu, Y.-T. Enhancing the Visualization of Problems Tracking and Management Integrated BIM Technology for General Contractor in Construction. In *Collaboration and Integration in Construction, Engineering, Management and Technology*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 427–432. [CrossRef]
56. Costa, A.A.; Grilo, A. BIM-Based E-Procurement: An Innovative Approach to Construction E-Procurement. *Sci. World J.* **2015**, *2015*, 905390. [CrossRef]
57. Grilo, A.; Jardim-Goncalves, R. Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective. *Autom. Constr.* **2011**, *20*, 107–114. [CrossRef]
58. Vasudevan, G.; Wei, C.C. Implementation of BIM with Integrated E-Procurement System in Malaysian Construction Industry. In *Advances in Civil Engineering Materials*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 165–171. [CrossRef]
59. Wu, Z.; Lu, Y.; He, Q.; Hong, Q.; Chen, C.; Antwi-Afari, M.F. Investigating the Key Hindering Factors and Mechanism of BIM Applications Based on Social Network Analysis. *Buildings* **2022**, *12*, 1270. [CrossRef]
60. Ebekozien, A.; Aigbavboa, C.O.; Aigbedion, M.; Ogbaini, I.F.; Aginah, I.L. Integrated project delivery in the Nigerian construction sector: An unexplored approach from the stakeholders' perspective. *Eng. Constr. Arch. Manag.* **2022**, *ahead of print*. [CrossRef]
61. Aka, A.; Iji, J.; Isa, R.B.; Bamgbade, A.A. Assessing the relationships between underlying strategies for effective building information modeling (BIM) implementation in Nigeria construction industry. *Arch. Eng. Des. Manag.* **2021**, *17*, 434–446. [CrossRef]
62. Peng, P.; Ao, Y.; Li, M.; Wang, Y.; Wang, T.; Bahmani, H. Building Information Modeling Learning Behavior of AEC Undergraduate Students in China. *Behav. Sci.* **2022**, *12*, 269. [CrossRef]
63. Rathnasinghe, A.P.; Wijewickrama, M.K.C.S.; Kulatunga, U.; Jayasena, H.S. Integration of BIM and Construction Supply Chain Through Supply Chain Management; An Information Flow Model. In Proceedings of the International Conference on Sustainable Built Environment, Kandy, Sri Lanka, 13–15 December 2008; pp. 604–614. [CrossRef]
64. Bouška, R. Evaluation of Maturity of BIM Tools across Different Software Platforms. *Procedia Eng.* **2016**, *164*, 481–486. [CrossRef]
65. Olugboyega, O.; Windapo, A. Modelling the indicators of a reduction in BIM adoption barriers in a developing country. *Int. J. Constr. Manag.* **2021**, 1–11. [CrossRef]
66. Semaan, J.; Underwood, J.; Hyde, J. An Investigation of Work-Based Education and Training Needs for Effective BIM Adoption and Implementation: An Organisational Upskilling Model. *Appl. Sci.* **2021**, *11*, 8646. [CrossRef]
67. Crowther, J.; Ajayi, S.O. Impacts of 4D BIM on construction project performance. *Int. J. Constr. Manag.* **2021**, *21*, 724–737. [CrossRef]
68. Maina, J.J. Barriers to effective use of CAD and BIM in architecture education in Nigeria. *Int. J. Built Environ. Sustain.* **2018**, *5*. [CrossRef]
69. Lee, S.; Yu, J.; Jeong, D. BIM Acceptance Model in Construction Organizations. *J. Manag. Eng.* **2015**, *31*, 04014048. [CrossRef]
70. Zou, P.X.W.; Xu, X.; Jin, R.; Painting, N.; Li, B. AEC Students' Perceptions of BIM Practice at Swinburne University of Technology. *J. Prof. Issues Eng. Educ. Pract.* **2019**, *145*, 05019002. [CrossRef]

71. Peterson, F.; Hartmann, T.; Fruchter, R.; Fischer, M. Teaching construction project management with BIM support: Experience and lessons learned. *Autom. Constr.* **2011**, *20*, 115–125. [CrossRef]
72. Tzortzopoulos, P.; Ma, L.; Junior, J.S.; Koskela, L. Evaluating Social Housing Retrofit Options to Support Clients' Decision Making—SIMPLER BIM Protocol. *Sustainability* **2019**, *11*, 2507. [CrossRef]
73. Durdyev, S.; Mbachu, J.; Thurnell, D.; Zhao, L.; Hosseini, M. BIM Adoption in the Cambodian Construction Industry: Key Drivers and Barriers. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 215. [CrossRef]
74. Li, P.; Zheng, S.; Si, H.; Xu, K. Critical Challenges for BIM Adoption in Small and Medium-Sized Enterprises: Evidence from China. *Adv. Civ. Eng.* **2019**, 1–14. [CrossRef]
75. Redmond, A.; Hore, A.; Alshawi, M.; West, R. Exploring how information exchanges can be enhanced through Cloud BIM. *Autom. Constr.* **2012**, *24*, 175–183. [CrossRef]
76. Tang, S.; Shelden, D.R.; Eastman, C.M.; Pishdad-Bozorgi, P.; Gao, X. A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends. *Autom. Constr.* **2019**, *101*, 127–139. [CrossRef]
77. Dallasega, P.; Rauch, E.; Linder, C. Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review. *Comput. Ind.* **2018**, *99*, 205–225. [CrossRef]
78. Elmualim, A.; Gilder, J. BIM: Innovation in design management, influence and challenges of implementation. *Archit. Eng. Des. Manag.* **2014**, *10*, 183–199. [CrossRef]
79. Machado, R.L.; Vilela, C. Conceptual framework for integrating bim and augmented reality in construction management. *J. Civ. Eng. Manag.* **2020**, *26*, 83–94. [CrossRef]
80. Shukra, Z.A.; Zhou, Y. Holistic green BIM: A scientometrics and mixed review. *Eng. Constr. Arch. Manag.* **2021**, *28*, 2273–2299. [CrossRef]
81. Olugboyega, O.; Aina, O.O. Analysis of building information modelling usage indices and facilitators in the Nigerian construction industry. *J. Logist. Inf. Serv. Sci.* **2016**, *3*, 1–36.
82. Qin, X.; Shi, Y.; Lyu, K.; Mo, Y. Using a tam-toe model to explore factors of building information modelling (bim) adoption in the construction industry. *J. Civ. Eng. Manag.* **2020**, *26*, 259–277. [CrossRef]
83. Besné Yanguas, A.; Pérez, M.Á.; Necchi, S.; Peña Camarillas, E.; Fonseca Escudero, D.; Navarro Delgado, I.; Redondo Domínguez, E. A Systematic Review of Current Strategies and Methods for BIM Implementation in the Academic Field. *Appl. Sci.* **2021**, *11*, 5530. [CrossRef]
84. Othman, I.; Al-Ashmori, Y.Y.; Rahmawati, Y.; Amran, Y.M.; Al-Bared, M.A.M. The level of Building Information Modelling (BIM) Implementation in Malaysia. *Ain Shams Eng. J.* **2021**, *12*, 455–463. [CrossRef]
85. Le, P.L.; Chaabane, A.; Dao, T.-M. BIM contributions to construction supply chain management trends: An exploratory study in Canada. *Int. J. Constr. Manag.* **2022**, *22*, 66–84. [CrossRef]
86. Papadonikolaki, E.; Vrijhoef, R.; Wamelink, H. The interdependences of BIM and supply chain partnering: Empirical explorations. *Arch. Eng. Des. Manag.* **2016**, *12*, 476–494. [CrossRef]
87. Liao, L.; Teo, E.A.L. Organizational Change Perspective on People Management in BIM Implementation in Building Projects. *J. Manag. Eng.* **2018**, *34*, 04018008. [CrossRef]
88. Murphy, M. Implementing innovation: A stakeholder competency-based approach for BIM. *Constr. Innov.* **2014**, *14*, 433–452. [CrossRef]
89. Farnsworth, C.B.; Beveridge, S.; Miller, K.R.; Christofferson, J.P. Application, advantages, and methods associated with using BIM in commercial construction. *Int. J. Constr. Educ. Res.* **2015**, *11*, 218–236. [CrossRef]
90. Gao, G.; Liu, Y.-S.; Wang, M.; Gu, M.; Yong, J.-H. A query expansion method for retrieving online BIM resources based on Industry Foundation Classes. *Autom. Constr.* **2015**, *56*, 14–25. [CrossRef]
91. Dakhil, A.; Underwood, J.; Al Shawi, M. BIM benefits-maturity relationship awareness among UK construction clients. In Proceedings of the First International Conference of the BIM Academic Forum, Glasgow, UK, 13–15 September 2006; pp. 13–15.
92. Wetzel, E.M.; Thabet, W.Y. The use of a BIM-based framework to support safe facility management processes. *Autom. Constr.* **2015**, *60*, 12–24. [CrossRef]
93. Whyte, J.K.; Hartmann, T. How digitizing building information transforms the built environment. *Build. Res. Inf.* **2017**, *45*, 591–595. [CrossRef]
94. Papadonikolaki, E.; Wamelink, H. Inter-and intra-organizational conditions for supply chain integration with BIM. *Build. Res. Inf.* **2017**, *45*, 649–664. [CrossRef]
95. Shepherd, D. Assessing your Practice and Guiding it to BIM-Readiness. In *BIM Management Handbook*; RIBA Publishing: London, UK, 2019; pp. 36–49. [CrossRef]
96. Lee, Y.-C.; Eastman, C.M.; Solihin, W.; See, R. Modularized rule-based validation of a BIM model pertaining to model views. *Autom. Constr.* **2016**, *63*, 1–11. [CrossRef]
97. Pinheiro, S.; Wimmer, R.; O'Donnell, J.; Muhic, S.; Bazjanac, V.; Maile, T.; Frisch, J.; van Treeck, C. MVD based information exchange between BIM and building energy performance simulation. *Autom. Constr.* **2018**, *90*, 91–103. [CrossRef]
98. Kassem, M.; Iqbal, N.; Kelly, G.; Lockley, S.; Dawood, N. Building information modelling: Protocols for collaborative design processes. *J. Inf. Technol. Constr.* **2014**, *19*, 126–149.
99. Suwal, S.; Jäväjä, P.; Salin, J. BIM Education: Implementing and Reviewing "OpeBIM"—BIM for Teachers. In *Computing in Civil and Building Engineering*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 2151–2158.

100. Jang, R.; Collinge, W. Improving BIM asset and facilities management processes: A Mechanical and Electrical (M&E) contractor perspective. *J. Build. Eng.* **2020**, *32*, 101540. [CrossRef]
101. Pérez, J.J.; Senderos, M.; Leon, I. Implementing BIM in Architectural Graphic Expression Subjects in the First-Degree Courses. In Proceedings of the Congreso Internacional de Expresión Gráfica Arquitectónica, Cartagena, Spain, 2–4 June 2022; pp. 107–114. [CrossRef]
102. Arayici, Y.; Aouad, G. Building information modelling (BIM) for construction lifecycle management. *Constr. Build. Des. Mater. Tech.* **2010**, *2010*, 99–118.
103. Liao, L.; Teo, E.A.L. Managing critical drivers for building information modelling implementation in the Singapore construction industry: An organizational change perspective. *Int. J. Constr. Manag.* **2019**, *19*, 240–256. [CrossRef]
104. Shields, P.M.; Tajalli, H. Intermediate Theory: The Missing Link in Successful Student Scholarship. *J. Public Aff. Educ.* **2006**, *12*, 313–334. [CrossRef]
105. Christensen, C.M. The Ongoing Process of Building a Theory of Disruption. *J. Prod. Innov. Manag.* **2006**, *23*, 39–55. [CrossRef]
106. Kineber, A.F.; Othman, I.; Oke, A.E.; Chileshe, N.; Zayed, T. Exploring the value management critical success factors for sustainable residential building—A structural equation modelling approach. *J. Clean. Prod.* **2021**, *293*, 126115. [CrossRef]
107. Field, A. *Discovering Statistics Using SPSS (3. Baskı)*; Sage Publications: New York, NY, USA, 2009.
108. Costello, A.B.; Osborne, J. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Pract. Assess. Res. Eval.* **2005**, *10*, 7.
109. Robert, O.K.; Dansoh, A.; Kuragu, J.K.O. Reasons for adopting Public–Private Partnership (PPP) for construction projects in Ghana. *Int. J. Constr. Manag.* **2014**, *14*, 227–238. [CrossRef]
110. Al-Mekhlafi, A.-B.; Isha, A.; Chileshe, N.; Abdulrab, M.; Saeed, A.; Kineber, A. Modelling the Relationship between the Nature of Work Factors and Driving Performance Mediating by Role of Fatigue. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6752. [CrossRef]
111. Kineber, A.F.; Othman, I.; Oke, A.E.; Chileshe, N.; Zayed, T. Value management implementation barriers for sustainable building: A bibliometric analysis and partial least square structural equation modeling. *Constr. Innov.* **2021**, *ahead of print*. [CrossRef]
112. Amaratunga, D.; Kulatunga, U.; Liyanage, C.; Hui, E.C.; Zheng, X. Measuring customer satisfaction of FM service in housing sector. *Facilities* **2010**, *28*, 306–320. [CrossRef]
113. Fotovatfard, A.; Heravi, G. Identifying Key Performance Indicators for Healthcare Facilities Maintenance. *J. Build. Eng.* **2021**, *42*, 102838. [CrossRef]
114. Byrne, B.M. Multivariate Applications Series. In *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*; Routledge/Taylor & Francis Group: New York, NY, USA, 2010.
115. Ringle, C.M.; Sarstedt, M.; Straub, D.W. Editor's Comments: A Critical Look at the Use of PLS-SEM in "MIS Quarterly". *MIS Q.* **2012**, *36*, 3–14. [CrossRef]
116. Yuan, K.-H.; Wu, R.; Bentler, P.M. Ridge structural equation modelling with correlation matrices for ordinal and continuous data. *Br. J. Math. Stat. Psychol.* **2011**, *64*, 107–133. [CrossRef]
117. Kineber, A.F.; Hamed, M.M. Exploring the Sustainable Delivery of Building Projects in Developing Countries: A PLS-SEM Approach. *Sustainability* **2022**, *14*, 15460. [CrossRef]
118. Podsakoff, P.M.; MacKenzie, S.B.; Lee, J.-Y.; Podsakoff, N.P. Common method biases in behavioral research: A critical review of the literature and recommended remedies. *J. Appl. Psychol.* **2003**, *88*, 879–903. [CrossRef]
119. Williams, L.J.; Cote, J.A.; Buckley, M.R. Lack of method variance in self-reported affect and perceptions at work: Reality or artifact? *J. Appl. Psychol.* **1989**, *74*, 462. [CrossRef]
120. Strandholm, K.; Kumar, K.; Subramanian, R. Examining the interrelationships among perceived environmental change, strategic response, managerial characteristics, and organizational performance. *J. Bus. Res.* **2004**, *57*, 58–68. [CrossRef]
121. Podsakoff, P.M.; Organ, D.W. Self-Reports in Organizational Research: Problems and Prospects. *J. Manag.* **1986**, *12*, 531–544. [CrossRef]
122. Oke, A.E.; Kineber, A.F.; Albukhari, I.; Dada, A.J. Modeling the robotics implementation barriers for construction projects in developing countries. *Int. J. Build. Pathol. Adapt.* **2021**, *ahead of print*. [CrossRef]
123. Al-Ashmori, Y.Y.; Othman, I.; Rahmawati, Y.; Amran, Y.H.M.; Sabah, S.H.A.; Rafindadi, A.D.; Mikić, M. BIM benefits and its influence on the BIM implementation in Malaysia. *Ain Shams Eng. J.* **2020**, *11*, 1013–1019. [CrossRef]
124. Hulland, J. Use of partial least squares (PLS) in strategic management research: A review of four recent studies. *Strateg. Manag. J.* **1999**, *20*, 195–204. [CrossRef]
125. Hair, J.F.; Anderson, R.E.; Babin, B.J.; Black, W.C. *Multivariate Data Analysis: A Global Perspective*; Pearson: Upper Saddle River, NJ, USA, 2010; Volume 7.
126. MacKenzie, S.B.; Podsakoff, P.M. Common Method Bias in Marketing: Causes, Mechanisms, and Procedural Remedies. *J. Retail.* **2012**, *88*, 542–555. [CrossRef]
127. Harman, H.H. *Modern Factor Analysis*; Univirsity of Chicago: Chicago, IL, USA, 1967.
128. Hair, J.F., Jr.; Hult, G.T.M.; Ringle, C.; Sarstedt, M. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*; Sage Publications: New York, NY, USA, 2016.
129. Olanrewaju, O.I.; Kineber, A.F.; Chileshe, N.; Edwards, D.J. Modelling the relationship between Building Information Modelling (BIM) implementation barriers, usage and awareness on building project lifecycle. *Build. Environ.* **2021**, *207*, 108556. [CrossRef]

130. Fornell, C.; Larcker, D.F. Evaluating structural equation models with unobservable variables and measurement error. *J. Mark. Res.* **1981**, *18*, 39–50. [CrossRef]
131. Perry, R.H.; Charlotte, B.; Isabella, M.; Bob, C. *SPSS Explained*; Routledge: London, UK, 2004.
132. Othman, I.; Kineber, A.; Oke, A.; Zayed, T.; Buniya, M. Barriers of value management implementation for building projects in Egyptian construction industry. *Ain Shams Eng. J.* **2020**, *12*, 21–30. [CrossRef]
133. Amos, D.; Au-Yong, C.P.; Musa, Z.N. The mediating effects of finance on the performance of hospital facilities management services. *J. Build. Eng.* **2021**, *34*, 101899. [CrossRef]
134. Shah, R.; Goldstein, S.M. Use of structural equation modeling in operations management research: Looking back and forward. *J. Oper. Manag.* **2006**, *24*, 148–169. [CrossRef]
135. Shook, C.L.; Ketchen, D.J., Jr.; Hult, G.T.M.; Kacmar, K.M. An assessment of the use of structural equation modeling in strategic management research. *Strateg. Manag. J.* **2004**, *25*, 397–404. [CrossRef]
136. Chin, W.W.; Newsted, P.R. Structural equation modeling analysis with small samples using partial least squares. *Stat. Strateg. Small Sample Res.* **1999**, *1*, 307–341.
137. Hair, J.F., Jr.; Matthews, L.M.; Matthews, R.L.; Sarstedt, M. PLS-SEM or CB-SEM: Updated guidelines on which method to use. *Int. J. Multivar. Data Anal.* **2017**, *1*, 107–123. [CrossRef]
138. Chin, W.W. Commentary: Issues and opinion on structural equation modeling. *MIS Quarterly.* **1998**, *22*, 7–16.
139. Chin, W. Issues and opinion on structural equation modeling management. *Inf. Syst. Q.* **1998**, *22*, 19–24.
140. Adabre, M.A.; Chan, A.P.; Edwards, D.J.; Adinyira, E. Assessing critical risk factors (CRFs) to sustainable housing: The perspective of a sub-Saharan African country. *J. Build. Eng.* **2021**, *41*, 102385. [CrossRef]
141. Manzoor, B.; Othman, I.; Gardezi, S.S.S.; Altan, H.; Abdalla, S.B. BIM-Based Research Framework for Sustainable Building Projects: A Strategy for Mitigating BIM Implementation Barriers. *Appl. Sci.* **2021**, *11*, 5397. [CrossRef]
142. Ayinla, K.; Adamu, Z. Bridging the digital divide gap in BIM technology adoption. *Eng. Constr. Arch. Manag.* **2018**, *25*, 1398–1416. [CrossRef]
143. Cao, D.; Li, H.; Wang, G.; Huang, T. Identifying and contextualising the motivations for BIM implementation in construction projects: An empirical study in China. *Int. J. Proj. Manag.* **2017**, *35*, 658–669. [CrossRef]
144. Silva, M.J.F.; Salvado, F.; Couto, P.; e Azevedo, V. Roadmap Proposal for Implementing Building Information Modelling (BIM) in Portugal. *Open J. Civ. Eng.* **2016**, *6*, 475–481. [CrossRef]