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Challenges to the Implementation of Building Information Modeling (BIM) for Sustainable Construction Projects

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Abstract: Successful concepts are adopted throughout the phases of the building lifecycle to provide maximum comfort and benefits to occupiers without compromising the function of such a project. Although there is limited information on building information modeling (BIM) execution in developing countries, BIM drivers have received significant attention from different researchers, but with a limited investigation into the influence of BIM barriers on such building projects. Our goal with this research is to identify and remove any challenges that may stand in the way of using BIM in developing country construction projects. To this end, a comprehensive literature search uncovered impediments to BIM implementation. To assess the relative importance of the numerous challenges to BIM mentioned in the literature, a survey questionnaire was distributed to a sample of specialists in the construction industry. Exploratory factor analysis (EFA) was used to classify these challenges, and partial least square structural equation modeling (PLS-SEM) was created to bring attention to the most pressing ones in the context of BIM adoption. The results of this research will inform policymakers in underdeveloped nations interested in adopting BIM on the pitfalls they should avoid.

Keywords: partial least square structural equation modeling; barriers; Nigeria; BIM; exploratory factor analysis; project lifecycle

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Citation: Kineber, A.F.; Othman, I.; Famakin, I.O.; Oke, A.E.; Hamed, M.M.; Olayemi, T.M. Challenges to the Implementation of Building Information Modeling (BIM) for Sustainable Construction Projects. *Appl. Sci.* **2023**, *13*, 3426. https://doi.org/10.3390/app13063426

Academic Editors: Alcínia Zita Sampaio and Augusto Martins Gomes

Received: 12 November 2022
Accepted: 21 November 2022
Published: 8 March 2023

1. Introduction

1.1. Background

The construction industry regularly reimagines itself by using cutting-edge government tools and novel approaches [1]. It is one of the key societal characteristics that define the comfort, well-being, and quality of life of any country's people [2]. In developing countries, there have been significant changes and tremendous growth in the building sector to meet local economic goals and the need to provide the basic living required of residential buildings [3,4]. Consequently, the government has prioritized affordable housing by enacting several affordable housing regulations [2]. Over 250 major projects in low- and middle-income countries are expected to be finished by 2030 [5].

Nevertheless, in these nations, building projects typically encounter various issues (lack of modern transport and communication infrastructure, industry providing required products, etc.) [6–8]. According to Tah and Carr [9], the building industry is in trouble, resulting in poor outcomes in developing countries. Because of the limited capacity of developing nations to meet the global sustainability criteria, building projects usually face various challenges, including building abandonment, time overruns, budget overruns, insufficient quality, and a high chance of falling short of targeted goals [6,7]. In addition, due to the restricted scale of investment in this industry, many initiatives are later placed on hold or terminated [10]. Taken as a whole, the building industry in developing countries falls short of the expectations of their governments, clients, and society and lags significantly behind other industries in those countries and their counterparts [11,12]. As a result, the literature emphasizes the importance of establishing "overall success-building projects" [13]. According to Wolstenholme et al. [14], quality construction practices are essential to reshaping the industry. As a result, throughout the preliminary and design phases of the construction process, building information modeling (BIM) may be coupled with the success method [15]. BIM is being used in designing and constructing the built environment in an increasing number of places worldwide [16].

BIM is "an intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure" [17]. It has the latent ability to enhance effectiveness and efficiency throughout the lifecycle of the building [18,19]. BIM continues to undergo drastic transformation based on stakeholders' requests to use technology to solve recurring challenges such as productivity, cost, and time management [20]. Moreover, BIM improves communication between management, data, and processes, which yields essential resources for maximizing a building's performance [21]. In light of this, BIM has been recognized as an essential lifecycle management technology that has a significant positive impact on the lifetime of a building project [22,23].

Despite the many tangible benefits engrained in this tool, BIM's full potential and possibilities have not been explored. Many studies have attempted to untangle the Gordian knot of challenges to BIM adoption by looking at things such as the amount of acceptance thus far [24], the nature of the hurdles [23,25], and the motivations [26,27]. The construction sector, especially in underdeveloped nations, lacks systematic initiatives to investigate the challenges of implementing BIM [28]. Several studies have looked at the effectiveness of BIM activities and techniques in many industrialized countries, but few have explored the challenges [28]. So, we asked, "What are the most significant barriers to implementing BIM in low-income countries?" Since no previous research has attempted to catalog and rank the challenges to BIM in low-income nations, the current investigation is the first of its kind. This study has the potential to aid stakeholders in reducing waste and boosting the quality of their construction projects by making use of BIM [29]. Since Nigeria's construction sector has been slow to implement BIM, this study is particularly relevant; therefore, the findings of this study may alter the course of the construction industry, not just in Nigeria but in other emerging nations with similar building practices [30].

1.2. Knowledge of BIM in the Developing Countries

BIM is becoming increasingly popular among construction industry experts throughout the world [31]. The United Kingdom (UK), Canada (Canada), Finland (Finland), and New Zealand (New Zealand) are only a few of the countries with advanced BIM expertise, as reported by the National Building Specification (NBS) [32]. As a result, both awareness and use of building information modeling (BIM) have increased significantly, from 10% in 2011 to about 70% in 2019 [33]. According to McGraw-Hill [34], the percentage of businesses using building information modeling (BIM) in Australia is 64 percent. According to Rodgers et al. [35], the SME adoption rate is 48%. (SMEs); however, the present BIM knowledge is skewed and negative, focusing mostly on the drawbacks rather than the benefits—in contrast, Tookey [36] claimed that there are doubts regarding BIM's advantages in the New Zealand construction industry.

According to Anifowose et al. [37], BIM adoption in the Nigerian construction sector is at the 50% level. The level of education is 58%, according to Ogunmakinde and Umeh [38].

In agreement with Onungwa and Uduma-Olugu [39], Olanrewaju et al. [24] demonstrated an advanced degree of BIM expertise throughout the design process. In this case, the primary motivations for utilizing BIM throughout the design process were to increase owner satisfaction and the quality of the drawings. However, Olapade and Ekemode [40] stated that Nigerians had very little understanding of the potential benefits of adopting BIM for facility management purposes. According to the published research, a wide range of Nigerian construction professionals are familiar with BIM and its benefits. Gamil and Rahman [41] found that in other developing nations, such as Yemen, 38% of construction industry experts are aware of BIM's benefits, and 8% have already used it. Similarly, Asian emerging nations were analyzed by Ismail et al. [42] to determine the extent to which BIM has been adopted. The findings indicated a moderate degree of BIM adoption in the area. Yet, China's hybrid approach puts it ahead of the pack when it comes to BIM adoption (i.e., there are both developed and developing nations inside its borders).

In the United Arab Emirates (UAE), BIM is becoming increasingly popular [43]. The study by Shibani et al. [44] indicated, however, that BIM expertise in Lebanon is limited. Data on BIM knowledge in several developing nations have recently grown in publication [45]. It suggests that a lot of time and energy has been spent promoting BIM in developing countries. Simply put, construction experts in emerging economies are starting to see the value in BIM. Nonetheless, the most difficult part of using BIM is getting it used for actual construction projects. According to Olanrewaju et al. [24], only the Eko Atlantic City project in Nigeria has fully executed BIM (i.e., from the design phase all the way through to the operation phase).

1.3. The Developing Country's BIM and Building Lifecycle

Inadequate management of building-related literature, information, and expertise has a deleterious effect on the project lifecycle. The graphical depth and user-friendliness of today's BIM tools and procedures offer several opportunities to enhance building performance [46]. The tool is effective for managing the entire construction process [47]. For creating information-dense product models, it serves as a framework [48]. To assess a building's efficiency, these models consider the geometric and thermal properties of its constituent parts [49]. According to Cheng et al. [50], building information modeling (BIM) has the potential to boost the effectiveness of MEP (Mechanical, Electrical, and Plumbing) system maintenance management. Data such as building geometry and construction type may be sorted out using BIM methodologies, allowing for more informed decision-making [51,52]. On top of that, BIM is defined as an effective tool for acquiring a flawless model that represents the "as-is state" or "as-built" circumstance of a project [53]. According to Saka and Chan [54], the industry's reputation for being slow to adopt new digital technologies such as BIM has hampered development and innovation. More efficient project administration and execution are only two of the many benefits that construction professionals may get from using BIM [55]. BIM has developed as a potential way for developing, merging, and maintaining such connected databases, which include crucial data for a building (or a portfolio of facilities) to support operations and maintenance [56].

According to Nieto-Julián et al. [57], BIM has the potential to aid members of interdisciplinary cultural teams and to make information sharing between them easier. It has been shown by Stransky and Dlask [58] that BIM improves project performance and aids decision-making all through a project's execution. Similar to how Eastman et al. [59] emphasized that BIM strengthens the bond between project participants, we find this to be true as well. Further research has demonstrated the value of BIM in relation to cost estimation and management [55,60]. The major conflict identification in design prior to project execution is where BIM saves money, as stated by Chahrour et al. [61]. Some have even hailed it as a tool for the intelligent automation of contracts and fruitful collaboration across teams [62,63]. The term "Green-BIM", which seeks to lessen the negative effects on the environment from construction operations, is another proof of BIM's importance in promoting sustainable buildings [64,65]. Amarasinghe and Soorige [66] evaluated the use of building information modeling (BIM) in Lifecycle Assessment (LCA) and suggested ways to enhance BIM-LCA assessments. One of the primary selling points of BIM is the visualization capabilities it provides, which enable clients to see their finished project before construction even begins. The benefits of using this BIM allow the design team to modify individual aspects of the building based on input from the customer [55,59]; therefore, the visual interface tool provided by BIM has come to be seen as a vital method for building design, not just during the preliminary stage of design but also during the optimization phase [67].

Furthermore, Lin and Hsu [68] utilized BIM to help with issue conception and management by means of a web-based API. It shows how BIM may help with visualizing problems and how far along a project is. According to Raouf et al. [69], BIM has impacted the project lifecycle differently than conventional engineering project management practices. Different professionals contribute at different times during the project's lifecycle, which is broken up into three distinct phases for the sake of brevity: the design (represented by designers), construction (represented by contractors), and operation (represented by facility managers) [24,70].

2. Barriers to BIM in the Building Industry

One of the main challenges to BIM adoption that Aranda-Mena et al. [71] cite is the incompatibility of different BIM programs. Ku and Taiebat [72] state that because different programs do not work together very well, data created in one program must be stored in another rather than shared between programs, which is counter to the primary purpose of using BIM. This has, to some extent, hindered the implementation of BIM by certain stakeholders and owners who believe that re-entry of information negates the various advantages BIM may have on project delivery [73]. Furthermore, there are seldom any inter-small and medium enterprises (SME) BIM software support solutions [74]. Legal problems have been raised concerning who owns the various designs, manufacturing, analysis, and construction information included in BIM models due to the unusual nature of the data contained within them [75]. In addition, the level of accountability from specialists and the person responsible for design inaccuracy is a big problem when looking into BIM roadblocks [71]. It is easier to assign blame for a project's shortcomings in the traditional paper-based design process than in a BIM application, where architects, engineers, and other professionals cannot easily identify them [23].

Several studies, such as Chan [76], have found that a lack of trained workers is a major roadblock to BIM's widespread adoption. Where there are no workers to advocate for the adoption of BIM, according to Aranda-Mena et al. [71], there is no difficulty in discussing its adoption since there are no individuals to execute it. In addition, Sebastian [77] argues that the inadequacy of BIM's design to incorporate such cutting-edge technology makes it impossible to apply it for projects of this type due to poor coordination and preparation of contract procedures. Since BIM implementation must be included in the contract from the outset, it is not acceptable if a project is not appropriately coordinated and the processes are not well stated [78]. As a result of the necessary tweaks before BIM can be widely implemented, several companies have avoided it. A common building model during the design phase and a coordinated collection of modeling techniques during construction and production as the foundation of all work operations and interactions are the fundamental changes needed for adopting BIM principles into enterprises [72].

Moreover, some specialists have not acknowledged BIM as a viable alternative to conventional building processes, maybe because they see no problems with conventional methods [72]. Similar to other developing countries in Sub-Saharan Africa, Nigeria has not passed legislation to promote BIM adoption and education. This contrasts with what may be found in more developed nations [72,79], such as the UK, China, and the USA. Since the government is still the principal owner of projects, they are expected to set an example for others to follow in BIM implementation [79]; however, the lack of such a regulatory framework (especially as a result of the lack of economic benefits, which leads to waste of resources including labor, transport, etc.) has discouraged other private sectors from pursuing BIM implementation initiatives seriously. A lack of customer and industry stakeholder involvement, inadequate BIM group competence, and the absence of a BIM champion are further challenges for construction firms in emerging markets [80]. Questions of responsibility for design, ownership, patent rights, who should build and administer BIM, and how to allocate or share the cost of adoption are all at the heart of the BIM adoption/usage conundrum [81]. Financial constraints, lack of BIM awareness, poor knowledge of BIM methodology, lack of BIM awareness and advantages, and a lack of governmental backing were all cited as key crucial challenges for BIM by Gamil and Rahman [41]. BIM adoption is immediately hampered by factors such as "geographic location, economic status of the nation, government policy, and desire to change". Table 1 compiles a few of the difficulties noted by different academics.

Table 1. Problems that have been preventing the building industry from fully adopting BIM technology.

S/N	Problem	[82]	[83]	[84]	[85]	[43]	[86]	[87]
1	Lack of government, clients, and contractor support	✓						
2	Failures in technological support		✓					
3	High cost of BIM application and inadequate BIM awareness			✓				
4	The construction industry's lack of trained professionals	✓						
5	Accessibility and cost of specialized BIM software				✓			
6	Computer self-efficacy					✓		
7	Lack of information technology infrastructure to enhance BIM use	✓						
8	Challenges in implementing new forms of teamwork		✓					
9	Resistance to change of professionals in the construction industry	✓						
10	The failure to retrain professional members in the use and application of BIM	✓						
11	Problems with BIM interoperability at every stage of a project		✓					
12	Lack of BIM cooperation guidelines and standards		✓					
13	Data privacy and data ownership issues		✓					
14	Lack of managers' awareness and support				✓			
15	Contractual environment						✓	
16	Inefficient BIM education on collaboration		✓					
17	Failure to acquire individual BIM knowledge			✓				
18	Lack of reference materials to recommend BIM application to Professionals							
19	Lack of qualified BIM experts		✓					
20	Not having sufficient knowledge when it's needed		✓					
21	Problem of BIM application incompatibility							✓
22	Frequency update on software							
23	Fragment nature of the construction industry							✓
24	Lack of initiative and education	✓						
25	Conflicts between project managers, information technology managers, and building information modeling managers		✓					
26	Fear of Safety and reliability of building information modeling						✓	✓
27	Cost of required hardware upgrade for BIM				✓			
28	Lack of common data environment		✓					
29	Lack of standard BIM protocols for cross-industry collaboration							
30	Lack of standards to guide the implementation of BIM	✓						
31	Complicated nature of BIM tools		✓					
32	Awkward team configuration and structure		✓					
33	Team members tend to work in isolation during projects		✓					
34	Opposition to information sharing		✓					
35	Designers and the supply chain downstream have not established a reliable method of working together		✓					

3. Research Methods

As the first step in designing a research plan, a conceptual model provides a graphical description of the issue based on the literature study and generates intermediate ideas (hypotheses) that may be evaluated using empirical evidence [88]. This phase is divided into three stages: (1) defining the model's constructs, (2) categorizing the constructs, and (3) determining the relationships between them [89]. As shown in Figure 1, the research design is adapted from Kineber et al. [90], and Figure 2 depicts the steps used to obtain those results.

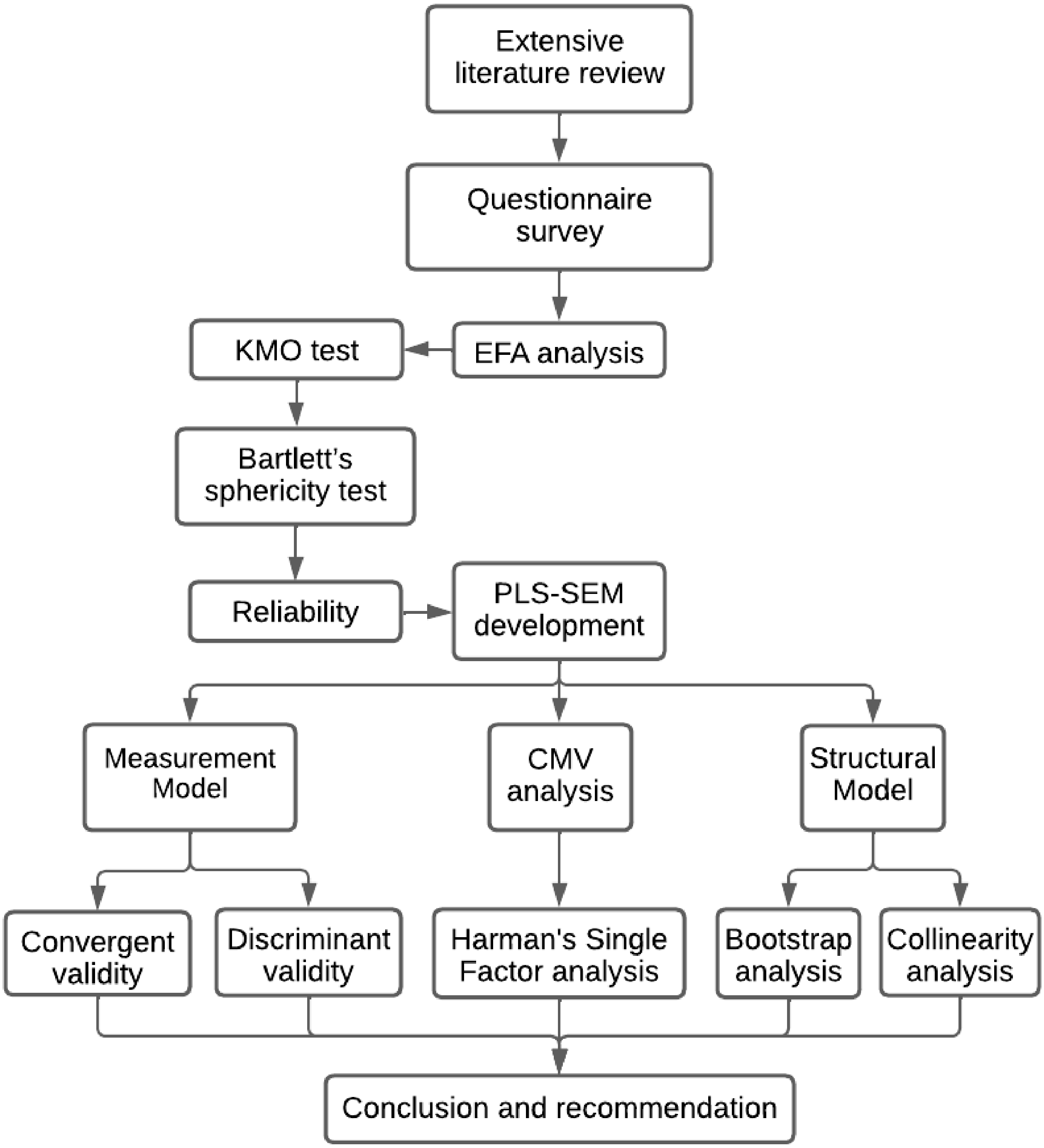

Figure 1. Research design.

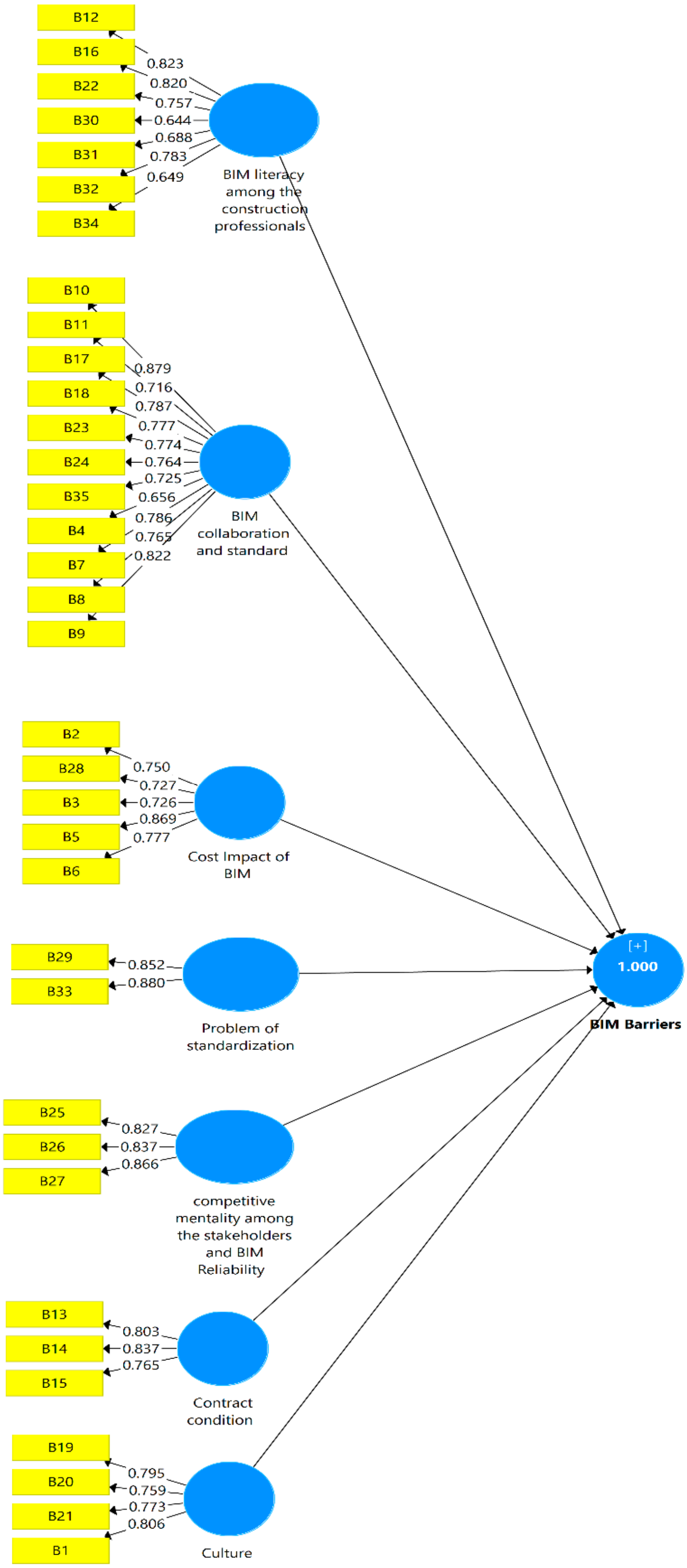

Figure 2. The PLS model.

3.1. Construct Validity Analysis

Exploratory factor analysis (EFA) was used to categorize the BIM-related components (Table 1) by critically reviewing the prior literature (Table 1) to determine the significant BIM-related hurdles. Additionally, EFA was used to assess the validity of the constructs by evaluating the non-dimensionality, reliability, and validity of the measurement components of each construct. Because of its consistency and simplicity of understanding, principal component analysis (PCA) was used [91]. Because the Varimax rotation promotes more load dispersion among variables, it was chosen in place of straight oblimin or Promax [92,93]; therefore, factor analysis was performed using the 100 completed questionnaires and the 35 identified factors [94,95].

3.2. Analytical Technique

In order to investigate the challenges faced by BIM, a structural equation modeling (SEM) approach was utilized to shed light on the connections between the numerous and non-observable variables [29,96]. The SEM approach was conducted to test various models concerning the interrelationships among the BIM barriers [97]. According to Byrne [98], SEM has lately been popular for non-experimental investigations, particularly in which hypothesis analysis methodologies were not followed closely enough. In addition, to create the relationship among BIM barriers based on the aim of this study, the partial least square (PLS) model, including both reflective and formative factors, was conducted; however, three major assessments were considered in the analysis of PLS-SEM in this study, including the common method variance, measurement model, and structural model [99].

The common method bias, also known as CMB, is an attempt to explain the inaccuracy in examination outputs brought on by the fact that data gathering could bring about an increase in trigger issues [100–102]. As a result, it is essential to notice these difficulties and issues to determine whether or not a CMV is present. Consequently, a formal, systematic, one-factor analysis was utilized, similar to the one recommended in Harman's analysis [103]. Through the analysis of convergent validity (i.e., the degree to which all measurements agree with one another) and discriminant validity, the measurement model that elucidates the pre-existing association between the measurements and their construct was selected. This model was successfully applied (i.e., exploring the evaluated concept) [104,105].

4. Results

4.1. Characteristics of the Respondent

A self-administered questionnaire was administered to a population of construction professionals viz architect, quantity surveyor, engineers, and project manager with a registered firm under the professional governing body. A total of 261 questionnaires were administered in which a total of 102 questionnaires were recovered and thereby used for the analysis. The questionnaire contained information on the highest qualification of the respondents, years of experience, number of projects currently engaged in, membership status of the professional body, and the method of pricing preliminaries. These pieces of information proved very useful in the discussions of findings.

Table 2 shows the academic qualification of the respondent, which includes OND/HND, B.sc/B.tech, which is more than half of the total number of respondents, and the M.sc/M.tech, the respondents, as shown above, had adequate educational qualification required in the construction industry. It shows that respondents with years of experience between 6–10 years have the highest number of respondents, followed by 1–5 years, 11–15 years, 15–20 years, and above 20 years, respectively. In the same way, member under the ICE/COREN professionals body has the largest percentage of 40.2%, followed by the PMI body with 24.5%; NICS has 7.8%, and RIBA has 5.9%. Further, it shows that the respondents with 11–15 projects currently engaged in have the highest number of respondents, followed by 6–10 projects, 1–5 projects, 16–20 projects, and above 20, respectively. Further, 41.2% of the respondents are corporate/associate, which is the highest percentage, followed by probationer members professional body that has 24.5%, fellow has a percentage of 20.6%, while the graduate has the lowest percentage of members with 13.7%.

Table 2. Characteristics of the respondents.

S/N	Information	Frequency Percentage (%)
A. Highest academic qualification		
OND/HND	10	9.8
B.SC/B.TECH	42	41.2
M.SC/M.TECH	49	48.0
OTHERS	1	1.0
TOTAL	102	100.0
B. Years of experience		
1–5 years	23	22.5
6–10 years	40	39.2
11–15 years	22	21.6
15–20 years	15	14.7
Above 20 years	2	2.0
Total	102	100.0
C. Numbers of project currently engaged on		
1–5 projects	21	20.6
6–10 projects	25	24.5
11–15 projects	39	38.2
16–20 projects	12	11.8
Above 20 projects	5	4.9
Total	102	100.0
D. Professional body of respondents		
RIBA	6	5.9
NICS	8	7.8
CIBSE	22	21.6
ICE/COREN	41	40.2
PMI	25	24.5
Total	102	100.0
E. Membership status		
Graduate	14	13.7
Probationer	25	24.5
Corporate/Associate	42	41.2
Fellow	21	20.6
Total	102	100.0

4.2. EFA Analysis

Factor analysis was used to analyze the major barriers to BIM adoption in Nigeria's construction industry. This analysis explored and detected the relationship among variables and categorized the factors in a concise and comprehensive form. Table 3 shows that the Kaiser–Meyer–Olkin Measure of Sampling Adequacy (KMO) value of 0.916 retrieved from the data was adequate and satisfactory for factor analysis and Bartlett's Test of Sphericity for correlation adequacy between the variables indicating a p-value < 0.05 was highly significant and considered suitable for factor analysis.

Table 3. Kaiser–Meyer–Olkin measure of sampling adequacy.

Kaiser–Meyer–Olkin Measure		
Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.916
Bartlett's Test of Sphericity	Approx. Chi-Square	2311.112
	Df	595
	Sig.	0.000

The rotated component matrix has 35 variables that constitute the major barriers to adopting BIM technology in Nigeria's construction industry (Table 4). The first component revealed that the principal factor account for 17.417% of the total variance, and the second component constitute 12.00% of the total variance.

Table 4. Total variance explained for the major barriers to the adoption of BIM technology in the construction industry.

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	15.483	44.238	44.238	6.096	17.417	17.417
2	1.955	5.587	49.825	4.200	12.000	29.417
3	1.503	4.295	54.120	3.458	9.879	39.296
4	1.380	3.943	58.063	3.186	9.103	48.399
5	1.216	3.475	61.538	2.564	7.325	55.724
6	1.107	3.163	64.700	2.255	6.443	62.167
7	1.005	2.872	67.573	1.892	5.406	67.573
8	0.957	2.734	70.307			
9	0.856	2.445	72.752			
10	0.778	2.222	74.974			
11	0.768	2.196	77.170			
12	0.699	1.997	79.166			
13	0.683	1.950	81.116			
14	0.602	1.720	82.836			
15	0.581	1.661	84.497			
16	0.482	1.377	85.874			
17	0.463	1.324	87.198			
18	0.438	1.250	88.448			
19	0.391	1.118	89.566			
20	0.366	1.046	90.613			
21	0.350	1.001	91.614			
22	0.302	0.863	92.476			
23	0.299	0.853	93.330			
24	0.281	0.803	94.133			
25	0.270	0.771	94.903			
26	0.256	0.733	95.636			
27	0.247	0.705	96.341			
28	0.217	0.621	96.962			
29	0.206	0.588	97.550			
30	0.190	0.542	98.091			
31	0.172	0.490	98.582			
32	0.154	0.440	99.022			
33	0.150	0.428	99.450			
34	0.104	0.297	99.747			
35	0.089	0.253	100.000			

Extraction Method: Principal Component Analysis.

Table 3 also suggests a rotation sums of squared loadings of 67.573, which is above 50%, indicating the suitability of using EFA. Table 4 strongly influences each of the barriers based on the varimax rotation; therefore, it is essential to identify these factors before interpreting the seven extracted BIM barriers. The seven extracted components were named as follows: BIM literacy among the construction professionals, BIM collaboration and standard, cost impact of BIM, accessibility to current updates of BIM development, problem of standardization, competitive mentality among the stakeholders, and BIM Reliability and Contract condition. Although no specific procedure was followed in naming the factors in Table 5, the names were justified based on the background and the level of knowledge of the researcher.

Table 5. Related components of the BIM barriers.

Constructs	Barriers	Loading
BIM literacy among the construction professionals	B9	0.680
	B10	0.750
	B4	0.520
	B24	0.554
	B23	0.687
	B17	0.556
	B18	0.564
	B11	0.850
	B7	0.780
	B35	0.654
	B8	0.950
BIM collaboration and standard	B16	0.856
	B34	0.687
	B12	0.786
	B32	0.569
	B22	0.785
	B31	0.654
	B30	0.458
Cost Impact of BIM	B5	0.965
	B2	0.650
	B3	0.856
	B6	0.654
	B28	0.576
Problem of standardization	B29	0.789
	B33	0.657
Competitive mentality among the stakeholders and BIM Reliability	B25	0.756
	B26	0.650
	B27	0.860
Contract condition	B15	0.650
	B14	0.756
	B13	0.745

Table 5. *Cont.*

Constructs	Barriers	Loading
Culture	B19	0.654
	B20	0.650
	B21	0.890
	B1	0.685

4.3. Common Method Bias

Variation due to common technique bias is used to highlight the error variance in the measured variables and to determine the validity of the analysis [99,106]. A single-factor analysis was conducted on the suggested model to determine the variance introduced by the classic approach [107]. If the overall variance of variables is less than 50%, it is commonly considered that a common procedure bias does not affect the acquired data [103]. The current investigation reveals that the common method variation does not affect the outcome because the first set of components accounts for 42.23% of the overall variance.

4.4. Measurement Model

The measuring model defines how things are right now regarding some latent components [108]. Evaluating the BIM barriers in PLS-SEM necessitates the evaluation of both convergent and discriminant validity [109]. Measured as a subset of construct validity, convergent validity is the degree to which two or more barriers of the same construct are consistent and logically organized [104]. Estimating the convergent validity of the suggested constructs in PLS-SEM may be performed with the help of the composite reliability scores (ρ_c), Cronbach's alpha (α), and average variance extracted (AVE) [110].

Table 4 indicates that the composite reliability of all the BIM barriers exceeded the minimum acceptable value of 0.60 and was thus approved [111,112]. Similarly, the Cronbach alpha exceeded the minimum acceptable value of 0.60, showing a moderate to high reliability, as advised by Perry et al. [113]. The AVE was also employed to test the converging validity of the construct variables using Equation (1) [110]:

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

where AVE is the average variance extracted; λ_i is the component loading of each item to a latent variable, and $\mathrm{var}(\varepsilon_i) = 1 - \lambda_i^2$. AVE values estimated using PLS 3.0 software were more than 0.5, indicating that the measurement model is convergent and internally stable—this is seen in Table 6; however, Hulland [104] says that if the analysis is explanatory, a value of 0.40 or higher is reasonable for external stress. All exterior loads are allowed in the first model, as shown in Figure 3.

Table 6. Construct's reliability and validity analyses.

Constructs	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
BIM collaboration and standard	0.931	0.941	0.593
BIM literacy among the construction professionals	0.861	0.894	0.549
Contract condition	0.723	0.844	0.643
Cost Impact of BIM	0.829	0.88	0.596
Culture	0.790	0.864	0.614
Problem of standardization	0.669	0.858	0.751
The competitive mentality among the stakeholders and BIM Reliability	0.797	0.881	0.711

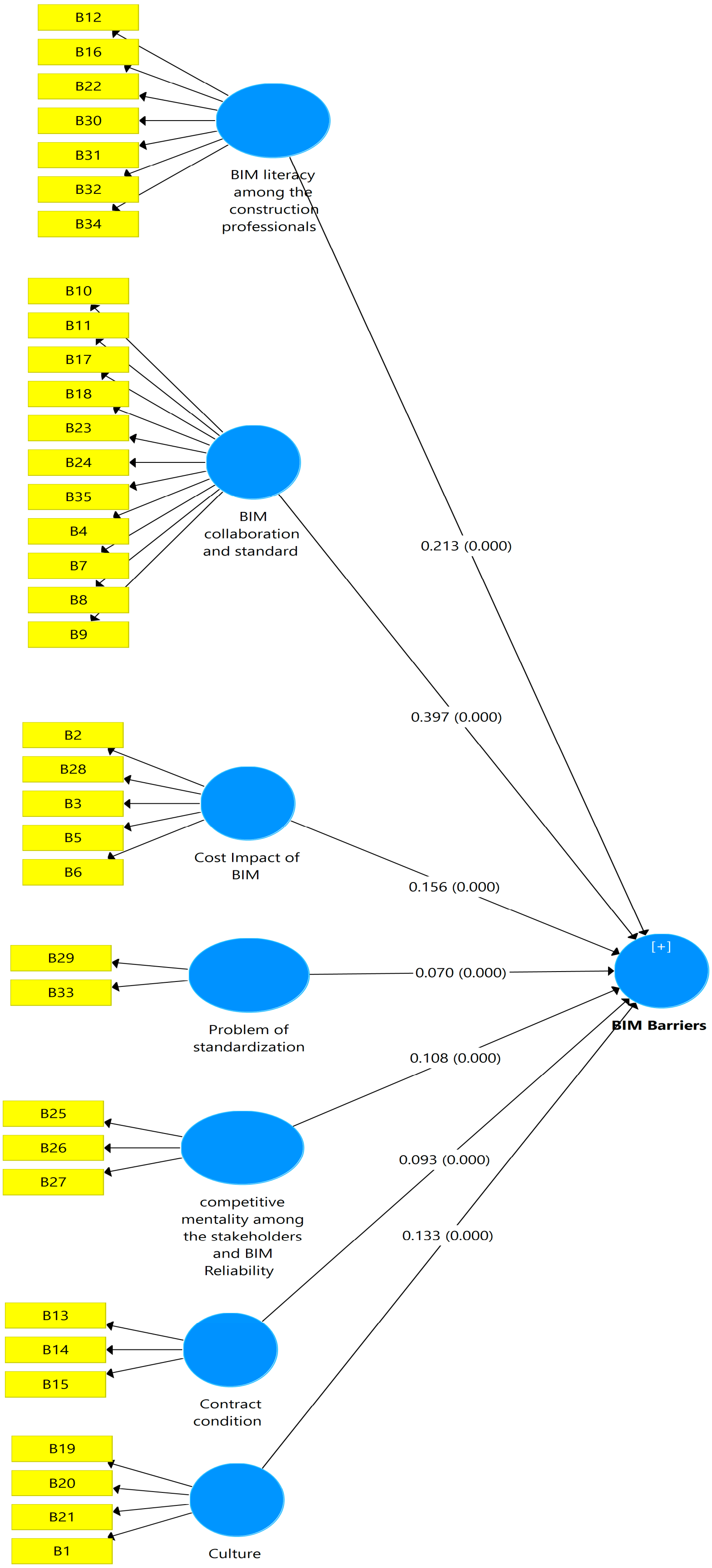

Figure 3. Path analysis.

The discriminant validity assessment was conducted to confirm the distinct and unique nature of the evaluated construct [105]. The Fornell–Larcker criteria and hetrotrait–monotrait criterion ratio (HTMT) were used in the current study to assess the discriminant validity. Table 7 shows that the BIM challenges are recognized and accepted based on Fornell and Larcker criteria, as the square root of the AVE is higher than the correlation between the build indications and elements [110,114].

Table 7. Discriminant validity analysis (Fornell–Larcker).

Constructs	BIM Collaboration and Standard	BIM Literacy among the Construction Professionals	Contract Condition	Cost Impact of BIM	Culture	Problem of Standardization	The Competitive Mentality among the Stakeholders and BIM Reliability
BIM collaboration and standard	**0.770**						
BIM literacy among the construction professionals	0.701	**0.741**					
Contract condition	0.633	0.682	**0.802**				
Cost Impact of BIM	0.701	0.668	0.588	**0.772**			
Culture	0.759	0.655	0.569	0.626	**0.783**		
Problem of standardization	0.662	0.602	0.420	0.537	0.608	**0.867**	
The competitive mentality among the stakeholders and BIM Reliability	0.720	0.587	0.585	0.559	0.665	0.518	**0.843**

Bolded numbers are the square root of AVE.

The hetrotrait–monotrait criterion ratio (HTMT) was also used to assess the discriminating validity of variance-based SEMs by estimating the precise correlation between the two constructs. Hair et al. [105] recommended an HTMT value of less than 0.85 for model structures with dissimilar concepts and 0.90 for a model construct with extremely similar concepts. Table 8 displays the HTMT values for all components studied in this study, demonstrating sufficient discriminating validity.

Table 8. Discriminant validity (HTMT).

Constructs	BIM Collaboration and Standard	BIM Literacy among the Construction Professionals	Contract Condition	Cost Impact of BIM	Culture	Problem of Standardization	The Competitive Mentality among the Stakeholders and BIM Reliability
BIM collaboration and standard							
BIM literacy among the construction professionals	0.792						
Contract condition	0.768	0.858					
Cost Impact of BIM	0.794	0.785	0.757				
Culture	0.782	0.791	0.745	0.771			
Problem of standardization	0.731	0.794	0.602	0.721	0.835		
The competitive mentality among the stakeholders and BIM Reliability	0.73	0.695	0.769	0.677	0.83	0.699	

4.5. Structural Model Analysis

Methodological validity of the research pathways and path coefficient measurement (*p*-value and outer weight (β) at 95% CI—0.95) [115,116] are evaluated here. The bootstrapping process, which includes randomly resampling the original data set to obtain fresh samples of the same size as the initial data set [13], helps to check the data set's dependability and the inaccuracy of the measured path coefficients [116]. The route coefficient "measures the extent to which one construct influences another" [117] and is "shown by the value between every path" [117]. This study evaluated pathway significance for the exogenous concept with its standardized path coefficients (β) and *p*-values (Figure 3). Table 9 and Figure 3 display the bootstrapping method's outcomes.

Table 9. Hypothesis and relative path for the model.

Paths	B	p-Values
BIM collaboration and standard -> BIM Barriers	0.397	0
BIM literacy among the construction professionals -> BIM Barriers	0.213	0
Contract condition -> BIM Barriers	0.093	0
Cost Impact of BIM -> BIM Barriers	0.156	0
Culture -> BIM Barriers	0.133	0
The problem of standardization -> BIM Barriers	0.070	0
The competitive mentality among the stakeholders and BIM Reliability -> BIM Barriers	0.108	0

5. Discussion

BIM's implementation in developing nations, including Nigeria, is not as swift as probable compared to forward-thinking economic countries where the speed of adoption is intense [18,118]. BIM adoption in developing countries is hindered by several factors, including a lack of government and contractor support, insufficient training and retraining of professional members in the usage and application of BIM, a lack of initiative and education, an inability to modify the existing work practices, and a lack of understanding on the roles and benefits of employing a BIM approach [82,119]. As a result, BIM adoption efforts in Nigeria's public sector and among the many construction players have been painfully slow.

Architects often implement BIM only to boost the visual quality of presentation [120]. Furthermore, between the specialized bodies attracted by this advent of technology in Nigeria, there is a restriction in the use of BIM because they failed to keep in stride with the up-to-date technological progression [82]. Fear of change [39], high up-front costs associated with BIM application [121], a dearth of BIM-skilled labor in the construction industry [122], a general lack of interest on the part of clients, as well as questions of data ownership, cultural resistance, prolonged processes, and doubts about the return on investment are some of the other challenges to BIM adoption in the construction sectors of developing nations [123].

This primary aspect is a technological one, including application and software compatibility, quality and progress monitoring authorization, layout clash detection and visualization, and BIM standards and protocols. This is meant to form the basis of the BIM interface. To counter this danger, researchers summarize the existing state of research on BIM deployment and suggest future study topics [43]. Non-BIM and non-construction professionals sometimes have a skewed impression of BIM due to a lack of integrated characterization [43]. A lack of awareness of BIM's economic implications and outcomes and the absence of an all-inclusive list of BIM benefits and associated cost savings persist, even though construction professionals are aware of BIM's benefits in the construction sector [124]. It is also expensive to purchase BIM software in Nigeria. Most construction companies cannot afford computers and the several expensive accessories that come with them, such as software. The cost of purchasing the software is very high to install on each of the personal computer systems, which has brought about the use of the trier versions of BIM tools. This is compounded by the hefty price tag associated with learning BIM software. A significant impediment to the efficient introduction of BIM assessment technology is the widespread belief that training costs are high, that the education needs are unclear, and that the learning curve is severe [125].

Additionally, most educational facilities lack IT specialists and faculty members comfortable working with BIM software in the classroom [125]. It will be difficult for such educators to provide the education and train those kids in the information age of the 21st century. Proper IT use is hindered at Nigerian universities due to a lack of IT-trained faculty members to teach students hands-on computer skills.

The Nigerian construction sector has challenges in using BIM due to inadequate information technology infrastructure. Poorly built university IT infrastructure includes internet and computer access [126]. Unfortunately, it seems unlikely that the end-users (faculty and students) possess the necessary intelligence and information management competence to exploit the potential available to them fully. Teachers can benefit greatly from having access to high-quality reference resources since they are widely acknowledged as instrumental in the classroom [127]. First-year educators might feel safe and confident with the help of textbooks. Textbooks and other reference materials for BIM technology are not usually provided by the teachers and are not readily available for students. Not enough trained people are available, hindering the development of marketable BIM knowledge and the dissemination of appropriate BIM-based paradigms [128]. According to Mehran [43], the adoption of BIM is affected by the organizational dimension and structure, which includes vendors for BIM experts, professional training in BIM technologies, and support from top management and clients.

This result agreed with those of Ugliotti [129]. He noted that problems with mismatched personnel, procedures, technologies, and processes are only two examples of the many roadblocks to BIM adoption that are experienced throughout the phase of operation and maintenance. Vass and Gustavsson [130] claim that the proliferation of digital technologies has transformed the industry by eradicating potential drawbacks, and that traditional methods are rapidly going extinct. Significant obstacles to BIM adoption in infrastructure projects include a lack of connectivity between BIM and current technologies and the inability to combine practical knowledge in BIM models with current management system information and software resources, as discussed by Hoang et al. [131]. People and process restrictions and hurdles, followed by technological barriers, are what Saka and Chan [132] found to be the most significant impediments to the widespread use of BIM in Africa. As a result, the BIM procedure must fit along with regular business [133–136]. To increase the number of organizations using BIM, the government must provide a hand, and a new method of communication must be developed. In this study, they examined the most pressing obstacles to the widespread use of BIM in the Iraqi construction sector. According to their research, the lack of BIM-related investments, the scarcity of professionals, the absence of a national BIM standard, and the reluctance to change that social and cultural factors may impact the adoption of BIM are the key challenges to BIM adoption in Iraq's construction sector.

Furthermore, problems such as insufficient stakeholder management, resistance to cultural shifts, and a lack of user awareness all contribute to poorer BIM implementation [137,138]. Competencies in BIM include things such as collaboration, experience, and knowledge of the technology [139]; therefore, interdisciplinary cooperation is fundamental to the success of BIM implementation [140]. However, specialized knowledge is required for effective BIM implementation. Succar [141] suggested that BIM is acknowledged as a large body of knowledge in the expanding field of construction. As mentioned in [142], BIM should be used to describe the design's goal and include the designer's prior knowledge. As a result, there should be continued investment in BIM research to inspire experts in the building industry to learn the language.

To improve upon the conventional approach, which has been plagued by the issue of inefficient communication amongst project teams, many construction companies in the developed world are now using BIM tactics that have helped them achieve success; therefore, the problems of ineffective collaboration that occur in the construction business have been held to be solved by the implementation of BIM expertise. Nevertheless, according to this research and the reviewed works of literature, certain challenges have been responsible for the low implementation of BIM by construction specialists in the Nigeria construction business, such as designers and the supply chain downstream have not established a reliable method of working together, lack of computer self-efficacy, lack of standard BIM protocols for cross-industry collaboration, resistance to change of specialists in the construction business, lack of information infrastructural to enhance BIM use, to mention a few, these are validated by Agoras [83] and Oraee et al. [143]. Unestablished working collaboration between designers (including the architect, and civil engineers, to mention a few) and the downstream supply chain was ranked the highest major challenges, inhibiting the adoption of BIM Technology in the industry because of the large discrimination between the construction professionals. The education system of the country also contributes to these challenges by not encouraging smooth collaboration between these construction professionals at the student level. Hence, due to these challenges, it is obvious that construction firms have not thoroughly maximized BIM in Nigeria, and to accomplish this improvement in the industry, it will require acclimatizing and employing certain underlying strategies [82]. The nation's economic system also could not help professionals to be computer self-efficacy because BIM workstation is very costly and heavy-duty due to their graphics requirement. This survey found that the lack of common BIM protocols for cross-sector collaboration and the reluctance to change among construction industry experts were ranked equally as the most significant factors preventing the widespread use of BIM technology. On the contrary, opposition to information sharing [82], fear of safety and reliability of building information modeling [144] and failures in technology support [83] were ranked the least three among the 35 major challenges that affect the execution of BIM expertise in the industry. These were ranked low because participants have seen the benefits of BIM technology that overwrite them.

As evident from the preceding discussion, BIM barriers impede BIM development and adoption. Because of this, several engineering projects have experienced substantial setbacks. Previous studies that have investigated the challenges of BIM have often combined a literature study with a questionnaire survey. While researchers have made great strides in identifying specific barriers, less attention has been paid to examining the interrelationships among these hurdles and the effects they have on one another. In contrast to previous studies, these employ realistic research methodologies and a new perspective to examine the challenges of BIM. Although this study's findings are impressive, Dong [145] has used the decision-making test and evaluation laboratory (DEMATEL) method to investigate the obstacles to and suggestions for implementing BIM in project costs and has concluded that the lack of policy support from the government and industry firms has the greatest impact on all other factors and that executive management motivation has evolved into the direct cause of BIM's advancement. China strongly promotes the use of BIM; thus, many scholars have looked at the problems that arise during its implementation. By combining these data with the current research landscape in China's construction industry, Liu et al. [146] were able to undertake an exploratory study on the obstacles to BIM adoption in China's construction sector. Boya et al. [147] used a government-industry game model to come to the conclusion that the Chinese government's economic policy reduces the uptake of BIM in the country. Li et al. [148] conducted a literature review, interviews, and a questionnaire survey to investigate the slow promotion of BIM in China from the perspectives of the project owner, designer, and contractor. According to the research, the primary barriers to the widespread adoption of building information modeling are the owners' lack of familiarity with BIM, the designers' focus on the unpredictability of the return on technology investment, and the contractors' reluctance to adopt a new way of doing business. Zhou et al. [149] highlighted six obstacles to applying the BIM method in China: a lack of government leadership, organizational challenges, legal issues, high application costs, a challenge to the shift in thinking style, and a lack of external incentives. To the same end, Ozorhon and Karahan [150] investigate what factors influence the adoption of building information modeling in developing countries where BIM is still in its infancy. In addition, Ma et al. [151] employed the same technique (principal component analysis) as this study to investigate the causes of the lack of BIM utilization in AEC projects in China. Expertise and capabilities, technical conditions, system inertia, extra input, changes to work routines, and adoption risks were all identified as underlying factors across all the obstacles in the main component analysis.

6. Conclusions

To maximize profits without sacrificing the project's functionality, successful concepts should be used across all project lifecycle stages of construction developments. Despite the limited BIM adoption in developing nations, several studies have concentrated on BIM drivers individually, but few have looked at the impact of BIM challenges on construction developments. This research aims to solve challenges to BIM application in construction in developing nations. To identify the BIM-related hurdles, a thorough literature research was conducted. After that, exploratory factor analysis (EFA) was performed to classify these challenges. Additionally, 100 construction professionals in Nigeria were surveyed using a questionnaire to produce partial least square structural equation modeling (PLS-SEM). The model's conclusions indicated the most significant implementation hurdles for BIM that should be avoided. The study's conclusions will serve as a guideline or guide for policymakers in developing nations that want to finish projects successfully by avoiding BIM challenges and maximizing the accomplishment of construction developments via the usage of BIM.

6.1. Conceptual and Empirical Contributions

This research's generated model investigates the major challenges of using BIM. These challenges may be used by policymakers, such as government agencies and construction industry regulators, to develop a strategy for increasing BIM use in the AECO sector. The study began by assessing the most significant challenges to implementing BIM in the building industry. This lays the groundwork for further research into the challenges of implementing BIM in the AECO sector. In order to increase BIM acceptance in Nigeria or other developing nations, the theoretical constructs emerging from this study would be useful in constructing a mathematical tool for determining the BIM implementation hurdles that need to be overcome. The research also achieved several important theoretical and practical advances, including the following:

- The study makes a theoretical contribution by illuminating new ideas that can be included in the existing framework. For instance, challenges to implementing BIM have an effect on BIM adoption and understanding at all stages of a project's lifespan.
- While several studies have been conducted on the subject of BIM deployment in industrialized nations, research on the topic in Nigeria is still in its infancy. This research fills that need by focusing on the most pressing issues impeding the widespread implementation of BIM and the factors that are directly related to those issues.
- The study's model is the first predictive model to assess the impact of BIM implementation hurdles on BIM utilization and awareness across the AECO industry's project lifecycle. Hopefully, this resource will accelerate the spread of BIM in underdeveloped nations. This contribution is empirical since it focuses on doing what no previous research has performed: evaluating the theoretical linkages between two variables ("BIM implementation hurdles" and "BIM usage and awareness in project lifecycle").

6.2. Managerial Implications

The following suggestions are made in order to comprehend how challenges in BIM deployment affect BIM usage and knowledge throughout the project lifecycle:

- Helping AECO companies remove impediments to BIM adoption boosts customer satisfaction through better visual representation.
- It helps with decision making when considering the effects of BIM barriers on BIM consciousness throughout the project's lifespan.

6.3. Insufficiencies and Directions for Further Study

Although the current study has some significant contributions, some limitations are worthy of consideration for future research directions. Firstly, the geographical limitations of the study can affect the generalization of its finding. Future studies can broaden the scope to include other Nigerian states and perhaps international comparisons. Second, the research is cross-sectional and misses some details about the institutional and historical settings of BIM's adoption. As a result, future research should focus on longitudinal studies to better understand the dynamic between BIM implementation hurdles and BIM utilization throughout the project's lifetime. Third, other than the PLS-SEM used in the current study, other technology adoption theories, such as the technology organization and environment model (TOEM) and the technology acceptance model (TAM), can be used to investigate the nature of the connection between BIM implementation challenges and BIM usage understanding throughout the project lifecycle.

Author Contributions: Research Idea: A.F.K., Conceptualization, A.F.K., I.O., I.O.F., A.E.O. and T.M.O.; Writing—original draft, M.M.H.; Writing—review & editing, M.M.H.; Visualization, M.M.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from the YUTP grant reference (YUTP-FRG 1/2022) and grant cost center (015LC0-405).

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, grant number YUTP-FRG 1/2022 and cost center, grant number 015LC0-405 for funding this research, and to the University Tecknologi PETRONAS.

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

Abbreviations

AVE	Average Variance Extracted
CMB	Common Method Bias
EFA	Exploratory Factor Analysis
KMO	Kaiser–Meyer–Olkin
PLS	Partial Least Squares
SPSS	Statistical Package for The Social Sciences
SEM	Structural Equation Modeling
SD	System Dynamic

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