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Causal Relationship amongst Risk Factors Impacting the Adoption of Building Information Modeling (BIM) in Nigeria

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Abstract

As the performance of BIM could be impaired when unidentified risks are present during implementation, it has become important for the construction industry of different countries to identify these risk factors as well as the causal relationships amongst them. In Nigeria, while risk factors impacting implementation of BIM have been identified, no attempt exist to unravel the causal relationship amongst these risk factors. This study thus, aims to assess causal relationship amongst risk factors impacting BIM implementation in Nigeria. Through extensive review of literature, risk factors totalling up to 54 were identified and assessed via a questionnaire survey administered to 256 construction firms in major cities of Nigeria, namely; Lagos, Abuja and Kaduna. Categorisations existing in previous literature were used as a basis to group the risk factors into 5 constructs, namely; technological, management, financial, legal and environmental factors while Partial Least Squares Structural Equation Modelling (PLS-SEM) was used to assess the causal relationship. It was found that technological risk factors' effect on management factors was strong and positive. In turn, management factors' effect on environmental factors was strong and positive as well. This implies that risk factors requiring much attention are the technological factors. The study's findings provide construction organisations in Nigeria with knowledge of risk factors possessing highest cause and effect on others, thereby enabling appropriate risk mitigation strategies. The study concludes that construction organisations in Nigeria intending to adopt and implement BIM should formulate risk-response strategies for technological risk factors. Also, findings from the study provide a platform for risk factors to be assessed at project as well as industry levels.

Keywords: Construction organisations, adoption, building information modelling, PLS-SEM, Nigeria

1.0 INTRODUCTION

Successful adoption and implementation of BIM in a construction project becoming increasingly important for ensuring effective delivery of a construction project and provide benefits to all the stakeholders (Eastman et al., 2008; Reddy, 2011). Owing to its numerous benefits, BIM possesses strong potential to grow into the main technology utilized in the construction industry. These benefits include; cost and time saving, decrease in design errors and omissions, reduction in rework, better occupant value, enhanced construction productivity, better information exchange and better stakeholders' relationships (Azhar, 2011; Bryde et al., 2013; Gurevich et al., 2017; McGraw Hill Construction, 2014; Migilinskas et al., 2013; Tuohy & Murphy, 2015). Despite these benefits, the rate of adoption of BIM in Nigeria and other developing countries is still low (Olawumi & Chan, 2019). According to Hamma-Adama et al. (2018), the adoption level of BIM in Nigeria is 22.8%, while awareness level of the concept is 60%.

In established nations like the United States of America, over 75% of the industry have adopted BIM leading to tremendous triumph in their projects (Farnsworth et al., 2015). Likewise, in the UK, implementation of BIM has also improved significantly, with the UK mandating application of BIM in public projects in 2016 (Arayici et al., 2011; Eadie et al., 2015). As asserted by Cao et al. (2015), even with the great potential of BIM, its progress is relatively at an infant stage in the construction sector and consequently, its actual spread among industry practitioners worldwide has been lower than expected. According to Amuda-Yusuf (2018), the use of BIM in Nigeria is still at early stage and direction of the construction industry's wide implementation is still being defined.

Chien et al. (2014) reported that implementation of BIM will not be realised due to presence of unidentified risk factors and thus, identified and assessed critical risk factors impacting BIM projects in the Chinese construction industry. Ghaffarianhoseini et al. (2017) also identified risks and challenges impeding BIM's effectiveness and lack of its widespread uptake. Zhao et al. (2018) and Ngowtanasawan (2017) both conducted studies on the interrelationship amongst BIM risk factors in the Chinese and Thai AEC industries respectively. However, results of these studies are only applicable/limited to the countries in which they were conducted due to the dynamic nature of risks.

Similarly, in Nigeria and other developing countries like Malaysia, Thailand and South Africa, several studies have been carried out in attempt to promote successful adoption and implementation of BIM. These include; readiness assessment (Abubakar et al., 2013); adoption issues (Kori & Kiviniemi, 2015); critical success and risk factors (Abdullahi et al., 2016; Abdulrazaq et al., 2016); barriers (Saka & Chan, 2020). Indeed, risks are dynamic and highly interdependent and thus, it is oversimplified not to overlook the interaction amongst risks (Chapman, 2006; Lam, 2003). Previous research efforts on risk factors associated with BIM implementation in Nigeria and other developing countries, treated risks independently and did not study interactions amongst the risks.

This indicates that although there exist studies on risk factors impeding BIM adoption and implementation, these studies focused mostly on identification and assessment of the risk factors without assessing the causal relationship. Also, although Ngowtanasawan (2017) and Zhao et al. (2018) assessed the causal relationship, result of both studies is limited to the countries in which they were conducted. Consequently, as researchers have emphasized that full adoption and implementation of BIM could be realised when the causal relationship amongst the risk factors are known (Zhao et al., 2018), this study was aimed at assessing the causal relationship amongst risk factors impacting BIM adoption in Nigeria. The study uncovers root risk factors impacting the adoption of BIM in Nigeria and how they inter-relate. The study's findings provide construction organisations in Nigeria with understanding of risk factors having highest cause and effect on the others thereby enabling appropriate risk mitigation strategies. The paper is organised into five parts, with part one as the introduction, part two is the literature review section, part three presents the methodology of research, while part four presents the result from the study and its discussion. The fifth/final part of the paper presents the conclusion.

2.0 LITERATURE REVIEW

2.1 BIM Adoption and Implementation

Studies carried out on adoption and implementation issues proffered different meanings to both concepts. Some researchers use both words interchangeably, not knowing their actual meanings (Ahmed & Kassem, 2018). According to Rogers (2003), adoption is a decision to make full use of an innovation to present best course of action available, while implementation is a phase which occurs once an innovation has been put into use. Succar and Kassem (2015) define BIM adoption as the successful implementation whereby an organisation, following a readiness phase, crosses the point of adoption into one of the BIM capability stages, namely; modelling, collaboration and integration. These different meanings suggest that adoption might be seen of as a broader term that includes implementation as well (Succar & Kassem, 2015).

Globally, research has been carried out on BIM adoption at different levels. Some of these researches assessed adoption of BIM at project level (meso-level), some at organisational level (micro-level) and some at industry level (macro-level). For the purpose of this study, the assessment of causal relationship amongst BIM adoption risk factors was carried out at organisational level in order to obtain an insight as regards risk factors having the greatest influence on adoption of BIM in construction organisations.

A study by Jung and Lee (2015) substantiated that North America, Europe, Oceania, and Asia have advanced rapidly toward the mature stage of BIM, whereas the Middle East/Africa and South America were still in the early phase. Numerous studies on BIM deployment and uptake among construction professionals have been conducted in Nigeria over the years. Alufohai (2012), for instance, investigated BIM adoption in the Nigerian construction industry (NCI) and discovered that BIM adoption among Nigerian clients in the private and public sectors, as well as among different construction professionals (architects, quantity surveyors, civil engineers, etc.) has been quite slow. Hamma-Adama and Kouider (2018) reported that 75% of 14 publications on barriers to adoption of BIM in Nigeria revealed lack of trained personnel in technology as the most significant barrier, while more than 50% of the literature were on poor awareness and knowledge of its potentials.

According to Saka et al. (2019), the NCI is bedeviled by myriads of profound challenges such as cost overrun, time overrun, project abandonment and contractual disputes among others. Consequently, Saka et al. (2019) conceptualized the benefits, challenges and drivers to BIM adoption and implementation in Nigeria's AEC industry. Babatunde et al. (2020a, p. 1441) asserted that "there are no government policies in place to encourage BIM adoption in Nigeria, which is a true reflection of developing countries in general".

2.2 Risk Factors Influencing BIM Adoption

The risk factors in this study were identified via extensive review of literature. These included studies conducted within and outside Nigeria. In 2014, Chien et al. (2014) assessed major risk factors for BIM projects in China. The research revealed 13 risk factors related to technical, management, personnel, financial and legal aspects of BIM adoption. Similarly, according to Eadie et al. (2013), the key barriers to implementing BIM are: 'scale of culture change required/lack of flexibility', and 'lack of supply chain buy-in'.

Based on Liu et al. (2010), three major factors that influence AEC industry in adopting BIM are perceived benefits, external forces and internal readiness. Liu et al.'s (2010) study ranked factors with highest influence on BIM implementation from each category. In the perceived benefit category, quality improvement and improved accuracy were the most important factors in the respondents' view while in the external forces category, respondents' intent to remain competitive in the market was most important but not the pressure from competitors. Moreover, in the internal readiness category, top management support was considered to be the key factor. Although Ghaffarianhoseini et al. (2017) pointed out the need to discuss reality of BIM, its widespread benefits as well as current level of uptake. However, the research only assessed risks and challenges associated with BIM adoption. It is found that the most significant reasons for not adopting BIM include the lack of demand, cost and interoperability issues.

In Nigeria, Abdulrazaq et al. (2016) evaluated the impact of risk factors on the adoption of BIM by building design firms. The study found; high level of technical complexity, lack of top management commitment, no stakeholder involvement & participation, proliferation of software, unclear legal liability, excessive workload on BIM experts, change in organisational management, cost of training, insufficient data interoperability and cost of purchasing as the factors with the highest impact on BIM implementation in Nigeria. Ngowtanasawan (2017) developed a causal model of the factors influencing BIM adoption behaviours in the Thai architectural and engineering design industry. The research suggested that the factor with positive significant influence on BIM adoption was BIM characteristics comprising of; quality of the product, relative advantage, trialability, ease of use as well as compatibility. However, the outcome of the study is limited to Thai architectural and engineering industry only. Likewise, Zhao et al. (2018) carried out research on the relationship among BIM risk factors. The results of the study confirmed 15 hypothetical risk paths to be statistically significant. Thirteen (13) chains of risk paths were formed, of which "inadequate relevant knowledge and expertise" was the primary root risk category. Also, "technological issues", "poor information sharing and collaboration," and "liability for data input" had direct effect on the "cost overrun with BIM", while all the other risks indirectly influence cost via these three risk categories. Also, Babatunde et al. (2020b) assessed the barriers to BIM implementation in Nigeria and discovered the main constraints to be: "weak top management support and BIM related issues, cost of BIM software and training issues and incompatibility, legal and cultural related issues".

Table 1 Risk factors impacting on BIM adoption

S/No	BIM Risk Factors	Author(s)
1	Lack of software compatibility	1,2,3,4,5,6,7
2	Model management difficulties	2,5,7,8,9,10
3	Insufficient data interoperability	2, 4,7,9,10,11,13,14,15
4	Lack of BIM standards	3,5,7,9
5	Virus Attacks	6,7
6	Unclear system requirements	7,27
7	No stakeholder involvement and participation	7,16
8	Proliferation of Software application	6,7
9	Lack of technical specifications	7,32
10	Authenticity	7,17
11	High level of technical complexity	7,18
12	IT sophistication	18,19
13	Technological interface among programs	5,8,14,20,21,22,23
14	Low quality of BIM data	23,24,25
15	Design check issues	11,23
16	Changes in the BIM model by unauthorized parties	10,23
17	Management process change difficulties	1,5,7,9,10
18	Lack of top management commitment	3,7,9,30
19	Excessive workload on BIM experts	7,46
20	Workflow transition difficulties	1,5,7,9,17
21	Project information discouragement	7,23
22	Lack of documented project plan	7,25
23	Too much requirements	7,26
24	Changing requirements	7,26
25	Conflict among users	7,27
26	Change in organizational management during the project	7,27
27	Lack of senior management support	7,33,40,42,43
28	Staff resistance and ICT literacy	16,17,18
29	Top management's attitude	17,45
30	BIM personnel and training hours	19,34
31	Reluctance to share information	19,23
32	Poor communication among project participants	8,23,28
33	Lack of available skilled personnel	23,45,46
34	Health risks	5,7,9,10,17
35	Increase in short term workload	5,7
36	Corporate policies that negatively affect project	3,5,7,9,10
37	Other competing initiatives	7,27
38	Lack of supply chain buy-in	16,17,35
39	Lack of demand	17,36,37,38
40	Cultural resistance	15,31,45
41	People scared to adopt change	22,23,27,28
42	Increase in short term cost	29,45
43	Additional Expenditure	7,9,10,17
44	Cost of training	5,7,9,10,17
45	Cost of purchasing	7,8,20
46	Cost of Implementation	7,15
47	Low return on investment	17,45
48	Cost overrun with BIM	15,23,39
49	Unclear legal liability	5,23,28,46
50	Intellectual property	5,7,8,12,17
51	Contractual arrangements	7,15,17
52	Product Liability Risk	17,44,45
53	Professional indemnity insurance	17,43
54	System of procurement not accommodating BIM	8,13,17

Note: Luthra (2010)-1; Gu and London (2010)-2; Migilinskas et al. (2013)-3; Porwal and Hewage (2013)-4; Chien et al. (2014)-5; Akinnagbe and Adelakun (2014)-6; Abdulrazaq et al. (2016)-7; Azhar (2011)-8; Won et al. (2013)-9; Bryde et al. (2013)-10; Azhar et al. (2012)-11; Fan (2014)-12; Kuiper and Holzer (2013)-13; Ding et al. (2019)-14; Ghaffarianhoseini et al. (2017)-15; Kappelman et al. (2006)-16; Eadie et al. (2013)-17; Ahuja et al. (2016)-18; Liu et al. (2010)-19; Thompson and Miner (2006)-20; Arayici et al. (2011)-21; Stanley and Thurnell (2014)-22; Zhao et al. (2018)-23; Krygiel and Nies (2008)-24; Becerik-Gerber and Rice (2010)-25; Fairley et al. (2003)-26; Wallace et al. (2004)-27; Dossick and Neff (2010)-28; Okakpu et al. (2018)-29; Schmidt et al. (2001)-30; Mehran (2016)-31; Takim et al. (2013)-32; Zahrizan et al. (2013)-33; Oyewole and Dada (2019)-34; Aouad et al. (2006)-35; BCIS (2011)-36; Zakari et al. (2014)-37; Saleh (2015)-38; Hamma-Adama and Kouider (2018)-39; Babatunde et al. (2020b)-40; Kerosuo et al. (2015)-41; Kori and Kiviniemi (2015)-42; Ezeokoli et al. (2016)-43; Zhou et al. (2012)-44; Ya'acob et al. (2018)-45; Khoshfetrat et al. (2022)-46

2.3 Research Hypotheses

Categorisations existing in previous literature were used as a basis to group the risk factors into 5 constructs, namely; technological, management, financial, legal and environmental factors. Studies including those conducted by Chien et al. (2014), Ya'acob et al. (2018) and Khoshfetrat et al. (2022) also categorized BIM risk factors as such. Ghaffarianhoseini et al.'s (2017) study discovered the main reasons for not adopting BIM to be lack of demand, cost and interoperability issues. Cost was categorised under financial risk factors while interoperability was categorised under technological risk factors in this study. Zou et al. (2017) opined that; technological limitations may cause risks during BIM implementation. Ghaffarianhoseini et al. (2017) also suggested that full benefits of BIM had not been fully realised owing to technical issues. Technological as well as environmental factors were still buttressed in Shehzad et al. (2022)'s study to affect BIM adoption and its diffusion. Zhao et al. (2018) assessed the interrelationship between some categories of BIM risk factors and suggested that practitioners should be sensitive towards technological risks as they represent secondary root risks on the chain of risk paths. Indeed, risks are interdependent and cannot be managed separately (Chapman, 2006; Zhao et al., 2018). It was upon this basis that the ensuing hypotheses of this study were formed:

H1 - TECHNOLOGICAL risk factors directly influence Management risk factors;
H2 - TECHNOLOGICAL risk factors directly influence Financial risk factors;
H3 - MANAGEMENT risk factors directly influence Environmental risk factors;
H4 - MANAGEMENT risk factors directly influence Financial risk factors;
H5 - LEGAL risk factors directly influence Environmental risk factors.

3.0 METHODOLOGY

The quantitative research approach was used in this study. Through an extensive review of literature, a total of 54 risk factors were identified and assessed via a questionnaire survey. The questionnaire was administered to 256 construction firms in Abuja, Lagos and Kaduna states, where construction firms are predominant in Nigeria. Also, according to Oyowole (2019), Lagos State is one of the most populous and economically vibrant southwestern state, being considered as the main nerve center of construction activities in Nigeria. As the adoption of BIM in the Nigerian construction sector is still in its infancy stage, purposive sampling was used to administer the questionnaire to only construction organisations that demonstrate good knowledge and understanding of BIM. Prior to sending out the questionnaires, experts' opinions were sought on the relevance of these risk factors to the Nigerian construction industry and all the factors were confirmed to be relevant. The questionnaire was done on a six-point Likert scale, which according to previous studies, forces choice and gives better data. The values ranged from 0-5, zero (0) was included for situations where some factors did not occur or had no impact, 3 indicated high occurrence/impact and 5 indicated highest occurrence/impact. This in line with previous studies carried out on risk assessment (Odeyinka et al., 2008). Both descriptive and inferential analysis were used to analyse data obtained from the field survey. In other to assess the causal relationship amongst the constructs, structural equation modelling (SEM) was used. SEM is a suitable technique for uncovering directional relationship among variables (Zhao et al., 2018). It models relationship amongst observed and latent constructs. Two types of SEM exist in literature; covariance-based structural equation modelling (CB-SEM) and partial least squares structural equation modelling (PLS-SEM). According to Hair et al. (2014), there is not much difference in the result obtained from the two approaches. Data characteristics such as minimum sample size, non-normal data, formative constructs, scale of measurement, exploratory research, secondary data, theory testing and focus on prediction are amongst the most often stated reasons for applying PLS-SEM (Henseler et al., 2009; Hair et al., 2019). For this study small sample size, non-normal data and exploratory research informed the decision of choosing PLS-SEM over CB-SEM. According to Barclay et al. (1995), the minimal sample for a PLS model should be equal to the larger value of ten times the largest number of variables used to measure a latent construct; or ten times the largest number of paths directed at a latent construct in the structural model (the rule was utilised by Zhao et al., 2018 as well). In this study, the largest number of variables used to measure a construct was 14 and the largest number of paths directed at a latent construct was two in each model and thus, the minimal sample size was 140 for the former and for the latter 20. Derived sample size for this study was 256 which is larger than the minimal sample size in both cases. Figure 1 presents the research process.

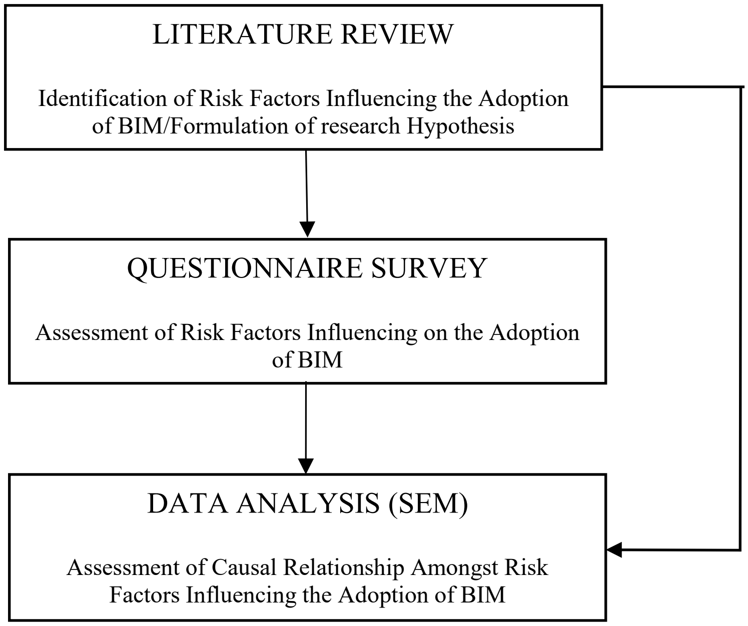

Figure 1 The research process

4.0 RESULTS

4.1 Characteristics of Surveyed Respondents

A total of 256 questionnaires were administered and 133 were retrieved, which amounted to a response rate of 52%. Recognizing Moser and Kalton (1971)'s statement that if a response rate of above 40% is retrieved from a survey, the results could be generalized and accepted as valid, the 52% response rate for this study was thus, considered adequate. Table 2 reveals that majority of the respondents were quantity surveyors and also have not more than 5 years BIM experience. This is may well be associated with the low level of BIM adoption in Nigeria.

Table 2 Characteristics of surveyed respondents

	Characteristics of Surveyed Respondents	Responses
1	Professional discipline	Architects (22.6%), QS (30.8%), Engineers (30.1%) and Builders (16.5%)
2	Respondent's experience	>5 years (35.3%), 6-10 years (25.6%), 11-15 years (30.1%), 16-20 years (7.5%), and over 20 years (1.5%)
3	Educational qualification	HnD (10.5%), BSc (39.8%), MSc (37.6%), PhD (8.3%), Others (3.8%)
4	Professional qualification	Probational Member (38.3%), Corporate Member (44.4%), Fellow (17.3%)
5	Annual turnover of firms	Up to N10M (16.5%), N11-100M (37.6%), N101M-300M (33.1%) and over N300M (12.8%)
6	Services delivered by the organisation	Building Works (25.6%), Civil Engineering Works (30.1%), Both (5.3%)
7	Rank in the organisation	Top Management (40.6%), Middle Management (30.1%), Operative Management (28.6%)
8	Years of BIM experience	> 5 years (41.4%%), 5-10 years (53.1%), Above 10 years (5.3%)

4.2 Assessment of Causal Relationship amongst Factors Impacting on the Adoption of BIM Using PLS-SEM

4.2.1 Evaluation of the Measurement Model

4.2.1.1 Assessment of Construct Reliability

The measurement model assesses quality of the manifested items or variables in measuring constructs of the study. Model evaluation was carried out via the assessing the measurement and structural models. To evaluate the measurement model, construct reliability and validity were conducted. According to Hair et al. (2014), reflective models are measured based on individual loadings of each indicator which ranges from 0 to 1. The threshold for each indicator loading to ascertain its contribution to the model is 0.70. Indicators that fail to reach the specified threshold of 0.70 are not significantly contributing to the measurement model. Thus, such indicators were dropped to enhance the constructs' validity and reliability. Table 3 shows the effect of dropping indicators based on constructs' reliability and validity measures. The Cronbach's alpha and composite reliability are measures of internal consistency and reliability of the constructs respectively.

All the constructs have Cronbach's alpha higher than 0.50 threshold, as suggested by Hair et al. (2014), indicating strong internal consistency. All constructs except legal have composite reliability above the 0.70 threshold indicating high reliability.

Table 3 Construct reliability and validity

Constructs	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Technological	0.808	0.885	0.865	0.667
Management	0.897	0.904	0.909	0.743
Financial	0.690	0.504	0.703	0.545
Legal	0.501	0..460	0.523	0.486
Environmental	0.787	0.880	0.805	0.582

4.2.1.2 Assessment of Discriminant Validity

Discriminant validity refers to the extent to which a construct is empirically distinct from other constructs in the structural model (Hair et al., 2019). Henseler et al. (2015) proposed the heterotrait-monotrait (HTMT) ratio of the correlations. The HTMT is defined as mean value of the item correlations across constructs relative to (geometric) mean of the average correlations for items measuring the same construct. Discriminant validity problems are present when HTMT values are high. Henseler et al. (2015) proposed a threshold value of 0.90 for structural models with constructs that are conceptually very similar. From the results of the study presented in Table 4, all values are within the threshold except for the correlations between management and legal factors and that of technological and legal factors indicating lack of discriminant validity within the two categories.

Table 4 Discriminant validity

Constructs	Environmental	Financial	Legal	Management	Technological
Environmental					
Financial	0.592				
Legal	0.840	0.813			
Management	0.856	0.808	1.189		
Technological	0.799	0.696	0.974	0.882	

4.3 Structural Model Assessment

The R^2 measures the variance which is explained in each of the endogenous constructs and is therefore a measure of the model's explanatory power (Shmueli & Koppius, 2011). The R^2 is also referred to as in-sample predictive power. It ranges from 0 to 1, with higher values indicating a greater explanatory power. As a guideline, R^2 values of 0.75, 0.50 and 0.25 can be considered substantial, moderate and weak (Hair et al., 2011; Henseler et al., 2009). Acceptable R^2 values are based on the context and in some disciplines an R^2 value as low as 0.10 is considered satisfactory. For this study all R^2 were greater than the required threshold indicating great explanatory power of the constructs as shown in Table 5.

Table 5 R^2 values

Constructs	R^2	R^2 Adjusted
Technological	0.577	0.573
Management	0.688	0.612
Legal	0.562	0.532
Financial	0.125	0.118
Environmental	0.223	0.225

4.4 The Model Specification

Partial least square structural equation modelling (PLS-SEM) was used to model the causal relationship amongst the factors impacting the adoption of BIM in Nigeria. The partial least square structural model was initially set up with five 5) reflective constructs. The five (5) constructs include BIM technological risk factors with (14) indicators, management risk factors with (9) indicators, financial risk factors with (7) indicators and legal risk factors with (7) indicators. The original model had forty-four (44) reflective indicators associated with the five (5) constructs in total. Figure 2 shows hypothetical model prior to running the analysis.

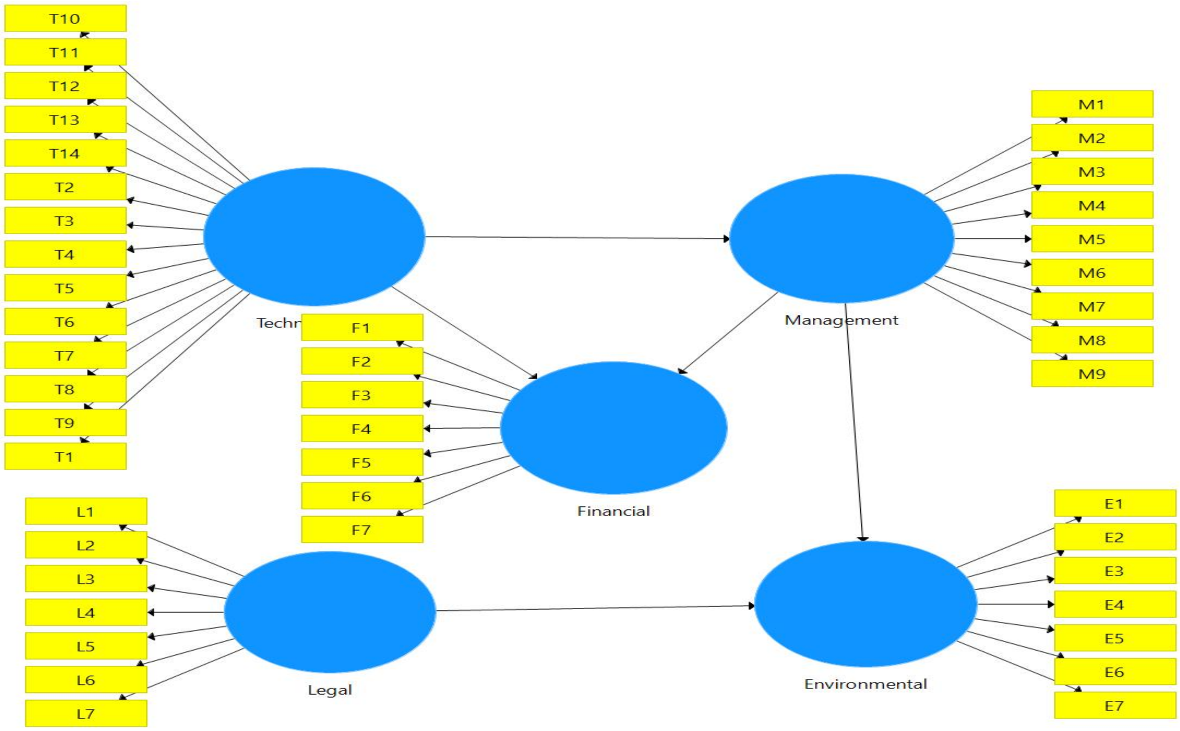

Figure 2 Hypothetical PLS model

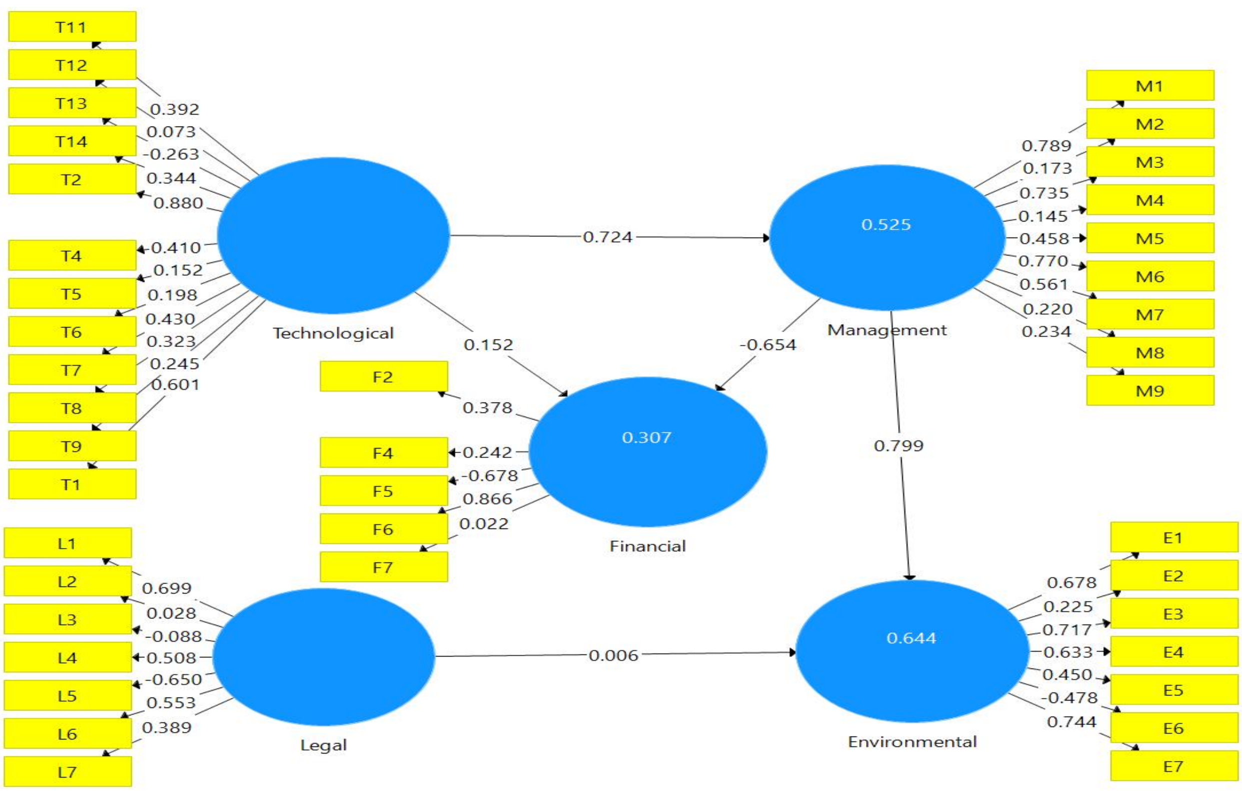

Figure 3 Modified PLS algorithm model with constructs and indicators

For technological factors, two (2) indicators (T3 and T10) were dropped and for financial two (2) indicators (F1 and F3) were removed from the model due to multicollinearity with other indicators. The values on the arrow on Figure 3 shows the PLS algorithm model with (40) indicators are the path coefficients ranging between -1 and +1 while indicating relationship between constructs while those on the circles present the R^2 values indicating strength of constructs.

4.4.1 Evaluation of the Structural Model

The techniques associated with evaluation of structural model include assessing collinearity of predictor latent variables, assessment of path significance for hypothesis testing, and assessment of predictive power of the model. For the assessment of collinearity of latent predictor variables, the variance inflation factor (VIF) scores were all below 5.0, indicating that collinearity does not pose any problem in the structural model, as opined by Hair et al. (2014).

4.4.2 Assessing Path Significance for Hypotheses Testing

Table 6 exhibits results of the hypothetical risk paths that were tested using bootstrapping technique on SmartPLS3 software with an alpha protection level of 5% and 5,000 independent sub-samples. Conservative no sign change of option after the bootstrapping algorithm was used. The standardized confidence interval estimation method was chosen at 95% confidence level. The result depicts the causal relationship amongst categories of BIM risk factors. The path coefficients, having standardized values from -1 to +1, represent the hypothesized relationships among the constructs. Estimated path coefficients close to +1 represent strong positive relationships and estimated path coefficients close to -1 represent strong negative or moderating relationships (Hair et al., 2014). Out of five (5) hypothetical paths, 3 paths were supported. The path coefficient from Technological to management is 0.706, this shows that there is a strong positive influence, technological to financial is 0.127 depicting a low level of influence. The path coefficient from management to financial is -0.567, this shows that there is a weak negative influence, management to environmental is 0.773 indicating a strong positive influence. The path from legal to environmental is 0.043 depicting a weak influence. These show that of the five (5) hypotheses, only two were confirmed which are the paths from Technological to management and management to environmental.

Table 6 Bootstrapping (hypotheses testing)

Code	Hypothetical Risk Path	Path Coefficients	Result
H1	Technological -> Management	0.706	Supported
H2	Technological -> Financial	0.127	Not supported
H3	Management -> Financial	-0.567	Not supported
H4	Management -> Environmental	0.773	Supported
H5	Legal -> Environmental	0.043	Not supported

5.0 DISCUSSION

The result of the PLS-SEM shows paths with strongest positive effect and therefore strongest influence to be the paths from technological to management and from management to environmental factors. This indicates that technological factors exacerbated the occurrence of other categories of factors. Technological risks refer to technical issues relating to the implementation of BIM in construction projects (Chien et al., 2014). The technological factors include; virus attacks (T1), changing requirements (T2), authenticity of software (T4), IT sophistication (T5), high level of technical complexity (T6), too much requirements (T7), low quality of BIM data (T8), insufficient data interoperability (T9), changes in the BIM model by unauthorized parties (T11), lack of BIM standards (T12), lack of software compatibility (T13) and technological interface among programs (T14). Management factors include; staff resistance and ICT literacy (M1), lack of top management commitment (M2), top management's attitude (M3), lack of senior management support (M4), increase in short term workload (M5), BIM personnel and training hours (M6), no stakeholder involvement and participation (M7), lack of available skilled personnel (M8) and excessive workload on BIM experts (M9). The environmental risk factors are; people scared to adopt change (E1), conflict among users (E2), design check issues (E3), reluctance to share information (E4), health risks (E5), lack of demand (E6) and cultural resistance (E7). The interoperability between application and software compatibility issues are considered a major risk in adopting and implementing BIM. A major function of BIM is collaboration where different parties use the same BIM model and are able to make changes and share information as the project progresses (Ya'acob et al., 2018). However, challenges arise when this cannot be achieved due to compatibility issue in transferring the data from their existing software to a new BIM software. Thus, mitigation of technological risk factors is necessary for construction organisations' successful BIM implementation. Ya'acob et al. (2018) further suggested that assessment and mitigation strategies be provided for technological, management, financial and legal risk factors for successful BIM adoption and implementation. In Zhao et al.'s (2018) study, technological issues also had a strong influence on other BIM risk factors such as cost overrun with BIM, design check issues and poor information sharing and collaboration. However, this result differs from that of Ngowtanasawan (2017)'s study which suggested that the factor with a positive significant influence on BIM adoption was BIM characteristics comprising of quality of the product, relative advantage, trialability, ease of use, and compatibility. This was not unexpected because he buttressed that the outcome of the study was limited to Thai architectural and engineering industry only.

6.0 CONCLUSION

The objective of this study was to assess the causal relationship amongst risk factors that impact the adoption of BIM by construction organisations in Nigeria. A list of risk factors was gathered from literature and assessed by the construction organisations based on their likelihood of occurrence and magnitude of impact. The BIM risk factors were grouped into Technological (T), Management (M), financial (F), and Legal (L) and Environment (E), based on relevant prior literature. Five (5) hypothetical network of risk factors were formed from the five (5) categories of factors. The study confirmed two (2) hypothetical paths to be significant. The hypotheses were confirmed using PLS-SEM. It was confirmed that technological factors directly influence management factors and management factors directly influence environmental risk factors.

The study presents researchers with knowledge on the categories of risk factors that have highest cause and effect on the others, thereby enabling further studies to be directed at these categories of risk factors. The research findings would also enable construction organisations in Nigeria develop appropriate risk-response strategies for those risk factors with the highest effect on successful BIM adoption. Also, the categories of risks that have highest effect on others will be paid more attention when managing risks in their organisations.

The study provides a platform for assessing the risk factors impacting BIM adoption and implementation at both project and industry levels, as successful BIM adoption is in three levels i.e. project, organisation and industry levels. Due to the dynamic nature of risks, the results obtained from this study may differ across regions. Also, practitioners should focus more on technological and management risks when adopting and implementing BIM in their organisations.

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