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Modelling the Hindrances to Building Information Modelling Adoption on Construction Projects in Nigeria

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Abstract: This study was motivated by the need to deploy building information modelling (BIM) and its technologies to improve the realisation of construction projects. Prior to the introduction of BIM, the construction industry was confronted with obstacles and was sluggish in adopting change. Until recently, existing BIM research has mostly focused on large enterprises and there has been an apparent pattern of underrepresentation of medium-sized firms in BIM-related studies. Thus, the purpose of this article is to investigate the major hindrances to BIM's adoption in construction projects as well as the dynamics of these hindrances in a developing country like Nigeria, using the total interpretive structural modelling (TISM) approach. The TISM displayed an 11-level hierarchy of hindrances made up of independent, dependent and linkage categories. Based on the Matrice d'Impacts Croises Multiplication Appliqué a Classement (MICMAC) analysis, "Lack of skilled BIM personnel" had the highest driving and the lowest dependence (independent) power, thus indicating its importance in the adoption of BIM. The findings further showed that "Lack of awareness of BIM" and "Resistance to change" are critical for the adoption of BIM in construction projects. The drivers (dependents) for the ease of adoption of BIM by policymakers and practitioners within the built industry are thus defined in this study. This study contributes to the early studies of BIM adoption from a developing country's perspective.

Keywords: Building information modelling, Public sector construction projects, Hindrances to BIM, Project management, Rivers State

INTRODUCTION

Building information modelling (BIM) can be thought of as a "single source of truth" in a shared workplace environment (Lu, Lai and Tse, 2019). It really has transformed from a conflict detector to an optimisation detector and is currently a collaborative tool. As Lu, Lai and Tse (2019) also stated, BIM and other information technologies are "disruptive technologies" in the architecture, engineering and construction (AEC) industries. There is a call to change the way we work, calling for better collaboration between industry practitioners by moving the resource curve forward with a view to reaping the benefits, especially during the planning and design of construction projects. The acronym BIM has been described at different times as something that still exists but has no single and widely accepted definition. The BIM concept dates back to the 1980s, in the early days of computer-aided

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design (CAD), as conceptually described by researchers around the world and is being deployed in the work of earlier software programmes in the form of CAD (Migilinskas et al., 2013). According to Azhar (2011), BIM has long been adjudged as a technique for reducing project costs, increasing efficiency and quality and minimising delivery times for projects in the construction industry. BIM also provides the ability to model a building project in a traditional virtual world. As Amade et al. (2018) have argued, the position of broader technology application, digitalisation and automation in the economic, social and environmental future cannot be overturned. BIM fundamentally changes the way in which the construction of buildings is performed, communicated and built. BIM is a paradigm shift in the technical breakthrough that has led to an improvement in how construction projects are planned, developed, communicated and constructed by incorporating built environment-related activities that are ab initio fragmented (Kwofie, Aigbavboa and Baiden-Amissah, 2020). Given that the changing market conditions have arisen mainly due to globalisation, technological changes, increased demands, consumer needs, etc., have metamorphosed into an increase in competitiveness in the construction industry (Aladag, Demirdögen and Isk, 2016). In view of this scenario, therefore, there is a need for players in the built environment to rise to the challenge and remain consistent in the long run if they need to remain relevant. They must urgently revert to the use of revolutionary technology. According to Chan, Olawumi and Ho (2019), the adoption and implementation of BIM are steadily growing in the construction sector. Among the many reasons for adopting BIM, the most important is its use in keeping a proper balance and mixing the key variables of the project management triangle, namely schedule, cost and performance, which are crucial areas of interest in executing construction projects. To some extent, the construction industry has been met with many of the world's complaints, mainly due to its inefficiency and lack of competitiveness, which have been attributed to the fractured nature of the industry (Abubakar et al., 2014).

Given the accompanying problems, the industry has begun to experience some relief through a paradigm shift with a view to improving efficiency, improving infrastructure, providing quality and sustainability, as well as minimising life-cycle costs, lead times and duplication through improved cooperation and efficient coordination between all the parties within the construction project value chain. This claim is further corroborated by Saka and Chan (2020), who argued that, with the advent of BIM in the construction industry of developing nations, the manner in which these countries work has changed and they are now reaping the benefits of BIM adoption. Despite increasing research into the adoption and implementation of BIM on construction projects, little research has been made to review and analyse existing relevant literature specifying the adoption and implementation of BIM on public sector construction projects, specifically in Rivers State, Nigeria. As opined by Porwal and Hewage (2013), clients of public sector construction projects have the notion that the BIM market is not ripe and, as such, are afraid to increase project costs by limiting competition. Lu, Lai and Tse (2019) argued that various governments around the world view the use of BIM as a strategic development and as such, efforts have been made to mandate its use in the delivery of public projects. This study, therefore, calls for a review of the literature on the adoption and implementation of BIM to broaden the understanding of researchers and practitioners on the adoption and implementation of BIM, ensuring that public sector construction projects in Rivers State, Nigeria, begin to generate greater value for money invested in their construction projects. It is interesting to know that the results of this study will provide vital information to industry practitioners, other stakeholders, the government and policymakers on issues that inhibit successful BIM adoption and thus help identify key areas where initiatives can help achieve successful BIM adoption and implementation.

With the rising research on hindrances to BIM adoption, numerous conceptual and empirical models for achieving the desired BIM result have been provided. However, such a model that exposes the structural relationships among the multiple hindrances to BIM adoption does not exist. As a result, existing models cannot always assist project managers in obtaining the required objectives regarding hindrances to BIM adoption. An attempt has been made to construct a conceptual model of BIM utilising the total interpretive structural modelling (TISM) technique, which would be valuable, notably for BIM users, to devise the accurate dependent powers of the components that affect BIM. A TISM technique was used to resolve these challenges. It creates an integrated structural framework (Sharma, Tiwari and Chaubey, 2016) that aligns the mutual interactions between BIM variables and determines the impact of these aspects on user contentment. TISM is an innovative variation of Warfield's interpretive structural modelling (ISM) technique (Bag, 2016) that is used to model and structure elements in order to gain a better understanding of their interactions.

TISM has previously been used in a wide range of human endeavours, including management, science, engineering and technology (Sharma, Tiwari and Chaubey, 2016; Mohanty, 2017; Ajmera and Jain, 2018; Hota and Nasim, 2020; Hasan, Dhir and Dhir, 2019; Chen et al., 2018; Sandeepa and Chand, 2018; Wuni and Shen, 2019, to name a few). TISM is a version of the ISM-based technique that analyses both nodes and connections in a diagraph (Rana, Dwivedi and Hughes, 2021). It also includes several key transitive relationships to provide a more comprehensive explanatory framework than its counterpart. The TISM technique seeks to resolve three fundamental issues about theory development. Prior researchers recently presented the ISM approach for evaluating BIM barriers (Saka and Chan, 2020). We included the TISM model in this section to address the barriers to BIM adoption. According to Chen et al. (2018), the main characteristic of the TISM model is its ability to translate ambiguous ideas into a structural model and specifically apply the model to complex decision system analysis for better interpretation of results. This strategy was used to fill gaps in the current body of literature. In this article, the TISM technique was used to achieve the following key objectives: (1) To identify the hindrances to the effective adoption and implementation of BIM in public sector construction projects, (2) To develop a relationship between the hindrances using TISM and (3) To analyse and discuss the managerial implications.

LITERATURE REVIEW

Overview of BIM

According to Hardin and McCool (2015), the construction industry has seen only a few important technological improvements compared to others during the last 50 years. Many advancements in material science, implementation approaches and energy efficiency, including prefabrication, eco-friendly materials and green building design, have occurred. However, the tools used by project management teams mainly remained unchanged. Innovation is also rapidly becoming an element of how contractors conduct their business and differentiate themselves from competitors. As a result of a strong supply and demand environment, better tools are developed between technology providers and construction management businesses interested in investing to boost their efficiency, as evidenced by the rise of BIM-compliant contractors. Aladag, Demirdögen and Isk (2016) described BIM as a tool to generate and manage building data using CAD and information and communications technology (ICT) software. BIM includes spatial information and material properties and enables various actors to share and update information. Hannele et al. (2012) are of the view that BIM is seen as a "generic technology" that, in principle, has a lot of benefits ranging from greater construction performance, fewer errors, more reliable and up-to-date details, being more illustrative and exposing a building and its characteristics to all stakeholders.

According to Taner (2013), the construction industry is hampered by several issues stemming from a failure to offer high-quality services and goods at a lower cost to the user. Identifying and eliminating these accompanying problems from the outset will help to improve the issues that occur there. The industry's predisposition to adopt the most recent improvement approaches is strong evidence of the industry's sensitivity to failure as compared to what exists in the manufacturing environment. There is a lack of design and integration in many projects, often combined with weak team communication. As a result, many programmes are either way over budget or behind schedule. The traditional two-dimensional design delivery approach appears insufficient to convey information to all parties involved. Recent advances in information technology systems have facilitated BIM development. BIM has been developed to address problems that contribute to the lack of productivity in the AEC industry (Bapat, Sarkar and Gujar, 2021; Walasek and Barszcz, 2017). Although Rahman et al. (2012) claimed that the construction industry suffered from poor performance compared to other industries, the volume of garbage produced due to the design process is the result of this impasse. The AEC industry is also seen as sluggish in technological adoption and has been adjudged to conform to old business models and processes for decades (Hamma-Adama, Salman and Kouider, 2020; Kwofie, Aigbavboa and Baiden-Amissah, 2020; Takim, Harris and Nawawi, 2013). Although the global adoption of BIM has been slow due to perceived risks and barriers at this point in the development of technology and its supporting processes and standards, there are also differences in the knowledge and understanding of BIM (Li, Greenwood and Kassem, 2019), resulting in perceptions by organisations and individuals as to what technology can achieve; this also contributes to the abandonment and frustration of those who participate in it.

According to Saka, Chan and Siu (2020), the adoption of BIM in the construction industry is sluggish and not progressing as expected. They further stated that both developed and developing countries still face the challenge of adopting BIM. However, some developed countries are making concerted efforts to ameliorate the situation. As stated by Olapade and Anthony (2012), the terrain throughout Nigeria is littered with the remains of derelict buildings, bridges, railroads, ports and other construction projects. Olapade and Anthony (2012) argued that it is impossible to claim that the initiatives mentioned above were properly discontinued prior to their implementation. The large percentage of delays related to the project completion in Nigeria also negatively impacts contractors' trustworthiness to provide the best value to their customers. According to Ayangade, Wahab and Alake (2009), non-compliance with the norms of the tendering process and the selection of qualified hands to deliver projects on schedule, cost and quality targets have weakened the way the bulk of construction projects in Nigeria have been procured. Akpan et al. (2014) suggested that the performance of construction projects in Nigeria falls far short of global best practices owing to the frequent collapse of most projects. A critical assessment of the implementation of BIM in Nigeria's construction industry will help to create a space for innovation and value-added activities in the industry for the benefit of all. BIM enables construction and design teams to make the most of their existing technical infrastructure (Waqar, Qureshi and Alaloul, 2023). The BIM process simplifies the generation and management of data across the whole AEC project life cycle by unifying all essential multidisciplinary construction and design documents into a single repository. As the BIM technique has proven to be highly effective in solving most of the AEC industry's difficulties, Zaia, Adam and Abdulrahman (2023) recommended that it be used to lessen construction issues such as minimising construction material waste and reducing risks in the Iraqi AEC industry. Reducing material waste will promote project performance, increase value for individual consumers and benefit the national economy.

Hindrances Faced with Effectively Implementing and Adopting BIM on Public Sector Construction Projects

Since transitioning from the traditional architect-contractor project delivery process, BIM has been referred to as the construction industry's next paradigm leap. As a result, BIM has been touted as "one of the most intriguing recent advances in the AEC sector", capable of cutting down project costs, enhancing performance and quality and shortening project duration (Azhar, 2011). In developed economies, the construction industry has seen a growing interest in using BIM due to the multitude of advantages discovered through its implementation (Eastman et al., 2011; Okorie, 2021; Saka, Chan and Siu, 2020). BIM implementation makes it easier for project stakeholders to share information more effectively and on time, thus facilitating the early development of the key data needed for design and detailing. Despite these benefits, the extent to which BIM has permeated the building industry differs significantly among countries. Identifying the impediments to BIM adoption was viewed as a precondition to the development of BIM adoption. In response, investigators in numerous countries have attempted to identify barriers to BIM adoption. In addition to the various benefits of BIM for project stakeholders, there are many hindrances to its implementation (Azhar, Khalifan and Maqsood, 2012). In other words, Table 1 lists the various obstacles to implementing BIM.

Table 1. Hindrances to BIM adoption on construction projects

Code	Hindrances	Authors/Sources
H1	Associated costs with use of BIM	Ahmed (2018); Eastman et al. (2011); Ghaffarianhoseini et al. (2016); Li et al. (2017); Talebi (2014)
H2	Lack of insurance applicable to BIM implementation	Tan et al. (2019)
H3	A myriad of legal uncertainties	Abubakar et al. (2014); Eadie et al. (2014); Eastman et al. (2011); Walasek and Barszcz (2017)

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Table 1. *Continued*

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H2	Lack of insurance applicable to BIM implementation	Tan et al. (2019)
H3	A myriad of legal uncertainties	Abubakar et al. (2014); Eadie et al. (2014); Eastman et al. (2011); Walasek and Barszcz (2017)
H4	Difficulty in adapting to the BIM processes	Ahmed (2018); Chan (2014); Chan et al. (2019); Eastman et al. (2011); Olawumi et al. (2018); Tan et al. (2019)
H5	Lack of integration of user's and project's requirements	Kassem, Brogden and Dawood (2012); Talebi (2014); Walasek and Barszcz (2017)
H6	Lack of top management support	Abubakar et al. (2014); Gamil and Rahman (2019)
H7	Negative attitude towards working collaboratively	Eastman et al. (2011); Tan et al. (2019)
H8	Problems of interoperability	Eadie et al. (2014); Ghaffarianhoseini et al. (2016); Lu, Lai and Tse (2019); Sun et al. (2017), Talebi (2014); Walasek and Barszcz (2017)
H9	Lack of user security/protection for intellectual property rights	Mehran (2016); Tan et al. (2019)
H10	Cost of BIM implementation (software and training)	Abubakar et al. (2014); Ahmed (2018); Eadie et al. (2014); Eastman et al. (2011); Kekana, Aigbavboa and Thwala (2014); Liu et al. (2015); Lu, Lai and Tse (2019); Gamil and Rahman (2019)
H11	Lack of a standard form of contract for BIM implementation	Chan et al. (2019); Kekana, Aigbavboa and Thwala (2014); Lu, Lai and Tse (2019); Mehran (2016); Tan et al. (2019)
H12	Lack of awareness of BIM	Ahmed (2018); Gamil and Rahman (2019); Sawhney and Singhal (2013); Tan et al. (2019); Onungwa and Uduma-Olugu (2016); Zakaria et al. (2014)

(*Continued on next page*)

Table 1. *Continued*

Code	Hindrances	Authors/Sources
H13	Lack of skilled BIM personnel	Abubakar et al. (2014); Ahmed (2018); Chan (2014); Eadie et al. (2014); Gamil and Rahman (2019); Ghaffarianhoseini et al. (2016); Kekana, Aigbavboa and Thwala (2014); Kassem, Brogden and Dawood (2012); Liu et al. (2015); Li et al. (2017); Sawhney and Singhal (2013); Sun et al. (2017); Tan et al. (2019)
H14	Resistance to change	Abubakar et al. (2014); Ahmed (2018); Chan et al. (2019); Eastman et al. (2011); Kassem, Brogden and Dawood (2012); Li et al. (2017); Lu, Lai and Tse (2019); Olawumi et al. (2018); Tan et al. (2019); Yan and Demian (2008); Zakaria et al. (2014)

METHODOLOGY

The TISM method is used in this work to provide a realistic and context-rich way of developing theory and contributing to the body of literature. Warfield (1974) invented ISM as an interactive learning tool that uses expert judgment to model a group of connected variables (directly or indirectly) with a phenomenon (Rana, Dwivedi and Hughes, 2021). TISM (Parameswar and Dhir, 2019) is a modern version of ISM (Warfield, 1974) that is used to develop hierarchies of structure for a set of elements that influence a dependent factor. TISM is involved creating a directed acyclic graph for a complex system from a set of elements and factors and it allows mental models to be articulated into a structure that can be used to represent the effect of various factors on a dependent variable. TISM is used to resolve three basic questions: "what", "why" and "how", which aid in the development of the conceptual framework. "What" refers to the fundamental measures of the concept and it is described by identifying the primary components and elements that influence the concept via a literature review. To explain why these items are linked in a particular way, the term "why" is employed. The word "how" describes the interaction of the fundamental components and factors, as well as the chronological interrelationship between the basic concepts of elements and ideas. TISM assists in determining the structure of a system (Deshmukh and Mohan, 2017). Hence, a qualitative framework for understanding hindrances to BIM adoption in the public sector has been developed in this study (Yeravdekar and Behl, 2016).

The investigation is undertaken in stages. First, it locates relevant obstacles to BIM adoption in Nigeria's public sector construction project delivery. Table 1 briefly highlights the hindrances and sources used to identify them. Experts listed 14 key hindrances to BIM adoption on public sector construction projects in Nigeria. In this investigation, TISM is applied; the method starts with categorising relevant variables to a situation or subject under inquiry (Hota and Nasim, 2020; Sandbhor and Botre, 2014; Wuni and Shen, 2019). This method is accompanied by a system for requesting feedback from experts, industry professionals and academics to create adequate correlations among the chosen variables. TISM is an approach that assists us in understanding the relationship between variables that can be uni-directional, bi-directional or no relationship. The relationship was found after collecting data from professionals using a questionnaire created following the objectives. The primary goal was to select the most relevant obstacles from a list of 14 hindrances that were selected for the study. The questionnaire was distributed to 32 professionals who were targeted for the study and conversant with the issue of discourse using a purposive or judgmental sampling technique, which forms the actual focus or target of an inquiry (Saunders, Lewis and Thornhill, 2016).

Engineers, project managers, quantity surveyors, builders, estate surveyors and other construction industry players were among the respondents (experts). The 14 highlighted hindrances were again compiled into an Excel spreadsheet and distributed to respondents. The data collected was cross-sectional. The set of 14 variables was then used in the next round of data gathering to generate a structural self-interaction matrix (SSIM). The 14 sorted variables were compiled and delivered to stakeholders in a grid or matrix format. The questionnaires were sent via email to 32 respondents, with 28 responding. These responses were used to establish a contextual link between the various barriers. The study's response rate was 87.5%, which is much higher than the national average. The questionnaire successfully elicited detailed responses about the 14 variables' unique correlations. Experts were supposed to provide answers in the V, A, X and O formats. In the case of a significant obstacle, the following brief is provided: If factor *j* is determined to be the dominant factor after factor *i* has been addressed, factor *i* should be prioritised in terms of addressing factor *j*. Four symbols were used to represent the type and direction of the relationship between a pair of hindrances, *i* and *j* (referring to the serial number of factors in the row and column, respectively). This setting was utilised in the creation of an SSIM:

1. V: Hindrance *i* must be addressed prior to hindrance *j*,
2. A: Hindrance *j* must be addressed prior to hindrance *i*,
3. X: Both hindrances *i* and *j* must be treated concurrently and
4. O: Hindrances *i* and *j* can be treated independently.

RESULTS AND FINDINGS

The goal of examining the relationship in such a linear fashion was to understand the underlying level of priority and linkage among some of the variables. Since SSIM was designed to reflect unique interactions between components, reverse combinations were initially ignored. To avoid duplicity, one of the pair's relationships was erased. The table also removed each hindrance's link to itself because no degree of precedent or relationship that could be drawn with comparable variables.

In light of the objectives of the proposed study, TISM is the appropriate methodology. All 14 factors related to hindrances to BIM adoption were identified using semi-structured interviews. The created TISM and theoretical model were expanded to incorporate TISM and Matrice d'Impacts Croises Multiplication Appliqué a Classement (MICMAC) analysis. When creating a TISM, one should consider the driving and reliant power of each variable. The MICMAC analysis completes this task. According to the MICMAC analysis, hindrances are classified as "Autonomous Hindrances" (weak driving and dependency power), "Linkage Hindrances" (strong driving power and strong reliance power), "Dependent Hindrances" (weak driving power but strong dependence power) and "Independent Hindrances" (strong drive power but weak dependence power) (Attri, Dev and Sharma, 2013; Behl, Singh and Venkatesh, 2016; Wuni and Shen, 2019). Microsoft Excel was used to perform the MICMAC analysis. According to Yeravdekar and Behl (2016), one of the ISM shortcomings is its inability to tie variables together and represent the reasons for transitivity and causation between variables. TISM can be used to overcome this limitation. The current study employs TISM to generate a theory for impediments to BIM adoption on public-sector construction projects in Nigeria. The present ISM model, however, has some shortcomings. First, the ISM model fails to account for the nature of understanding relationships; second, the model is opaque. Finally, the TISM model is built. The steps taken were as follows (Hasan, Dhir and Dhir, 2019):

Step 1: Identify and define the elements

This step entails identifying and defining the components whose interactions will be examined. This could be accomplished using pre-existing theories, producing new ideas, or field understanding. Previous research can also be utilised to define the elements chosen for study. The modelling elements used in this study were identified as hindrances to BIM implementation through a thorough literature review.

Step 2: Defining the contextual relationship

The contextual relationship between variables, factors, or elements of interest is studied in order to develop TISM. The context-specific link discovered between elements in this case is "Element X influences or improves Element Y", as shown in Table 2.

Step 3: Relationship interpretation

The interpretation of relationships is an essential step since it affords TISM a competitive advantage against standard ISM. Although ISM can aid in interpreting the form of a relationship, it cannot describe why that particular relationship occurs. This stage distinguishes TISM from ISM by explaining the relationship's cause. As a result, in TISM, the relationship is interpreted in terms of causality: "How should Element X help or enhance Element Y?" that will aid in extracting extensive knowledge. A pair-wise comparison is the fourth step. An "interpretive logic-knowledge base" is created for pair-wise comparisons of selected samples; for each comparison, the result can be "Yes" (Y) or "No" (N). If the response is Y, an explanation is given. Table 2 depicts a sample interpretive logic knowledge base.

Table 2. Structural self-interaction matrix (SSIM)

		H14	**H13**	**H12**	**H11**	**H10**	**H9**	**H8**	**H7**	**H6**	**H5**	**H4**	**H3**	**H2**	**H1**
S/No	Code														
1	H1	V	X	O	V	X	V	X	X	V	X	V	X	V	
2	H2	O	O	O	X	O	X	X	X	X	X	X	X		
3	H3	V	A	X	O	A	X	A	A	V	X	X			
4	H4	V	X	V	X	O	O	O	X	V	X				
5	H5	V	X	X	V	A	A	X	O	O					
6	H6	V	O	O	X	X	A	X	X						
7	H7	X	A	V	V	V	X	O							
8	H8	V	X	V	X	V	V								
9	H9	X	V	X	V	X									
10	H10	V	V	V	X										
11	H11	V	A	O											
12	H12	A	V												
13	H13	V													
14	H14														

Step 4: Performing a transitivity check on the reachability matrix

Value "1" is entered into each cell in the knowledge base for each Y to generate the reachability matrix. In the event of a knowledge base entry "N", value "0" should be entered. This reachability matrix is then submitted to a transitivity test, which states that if X–Y and Y–Z exist, then X–Z exists. The transitivity test is repeated until 100% transitivity is obtained (as shown in Table 3). Because we uncovered a transitive relationship, we updated the "No" in the knowledge base to "Yes" and the term "transitive" was added to the interpreting column, along with an interpretation for that transitive association. Tables 3 and 4 show the reachability matrix and transitivity check.

Step 5: The steps described are the traditional TISM process, as modified (Sushil, 2017)

The five steps mentioned are merged into one in the modified TISM process, wherein we do transitivity checks and sequential pair-wise comparisons simultaneously. As a result, pairs having transitive links do not need to be compared later in the updated TISM process. In a single step, our approach minimises the number of expert-based paired comparisons and produces a fully transitive reachability matrix (Hasan, Dhir and Dhir, 2019; Deshmukh and Mohan, 2017).

Step 6: Partitioning of elements

Levels were partitioned in the same way, just like in the ISM methodology. If the intersection of the reachability set and the antecedent set is the same as the reachability set in the case of an element, that aspect is considered at the highest level. When the element at the top level is found, it is detached from the other elements and the process is continued until the level of all other elements is found. One can now start working on the diagram. The level partition matrices and level matrix are shown in Tables 5 and 6 and the 11 level partitioning iterations were completed. In Table 5, Factor H2 titled "Lack of insurance for BIM implementation", is discovered at Level 1; hence, it is placed at the apex of the TISM hierarchy and eliminated from the first cycle. H12 (Lack of awareness of BIM) is placed at Level 2 in the next iteration (second iteration) and thus occupies level II in the hierarchy. Then, in the second iteration, we exclude Elements H12 from consideration. Element H14 (Resistance to change) is set to Level 3 in the third iteration. Following that, we removed Element H14 from the third iteration. Element H6 (Lack of top management support) is moved to Level 4 in the fourth iteration. Element H11 (Lack of a standard form of contract for BIM implementation) is transferred to level 5 in the fifth iteration. Elements H3 (A myriad of legal uncertainties), H4 (Difficulty in adapting to BIM processes) and H5 (Lack of integration of user's and project's requirements) are elevated to Level 6 in the sixth iteration. The iteration process is repeated until the 11th level is reached, with Element H13 (Lack of skilled BIM personnel) at the bottom (Level 11) (as shown in Table 6).

Table 3. Reachability matrix with transitivity

	H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**	**H11**	**H12**	**H13**	**H14**
H1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
H2	0	1	1	1	1	1	1	1	1	0	1	0	0	0
H3	1	1*	1*	1	1	1	0	0	1	0	0	1	0	1
H4	0	1	1	1	1	1	1	0	0	0	1	1	1	1
H5	1	1	1	1	1	0	0	1	0	0	1	1	1	1
H6	0	1	0	0	0	1	1	1	0	1	1	0	0	1
H7	1	1	1	1	0	1	1	0	1	1	1	1	0	1
H8	1	1	1	0	1	1	0	1	1	1	1	1	1	1
H9	0	1	1	0	1	1	1	0	1*	1*	1*	1	0	1
H10	1	0	1*	0	1	1	0	0	1*	1	1	1*	0	1
H11	0	1	0	1	0	1	0	1	0	1	1*	0	0	1
H12	0	0	1	0	1	0	0	0	1	0	0	1	0	0
H13	1	0	1	1	1	0	1	1	0	0	1	0	1	1
H14	0	0	0	0	0	0	1	0	1	0	0	1	0	1

Note: * indicates transitive links.

Table 4. Reachability matrix

	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14
H1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
H2	0	1	1	1	1	1	1	1	1	0	1	0	0	0
H3	1	1	1	1	1	1	0	0	1	0	0	1	0	1
H4	0	1	1	1	1	1	1	0	0	0	1	1	1	1
H5	1	1	1	1	1	0	0	1	0	0	1	1	1	1
H6	0	1	0	0	0	1	1	1	0	1	1	0	0	1
H7	1	1	1	1	0	1	1	0	1	1	1	1	0	1
H8	1	1	1	0	1	1	0	1	1	1	1	1	1	1
H9	0	1	1	0	1	1	1	0	1	1	1	1	0	1
H10	1	0	1	0	1	1	0	0	1	1	1	1	0	1
H11	0	1	0	1	0	1	0	1	0	1	1	0	0	1
H12	0	0	1	0	1	0	0	0	1	0	0	1	0	0
H13	1	0	1	1	1	0	1	1	0	0	1	0	1	1
H14	0	0	0	0	0	0	1	0	1	0	0	1	0	1

Table 5. First iteration

	Reachability Variables	Antecedent Variables	Intersection Variables	Level
H1	1,2,4,5,6,7,8,9,10,11,13,14	1,3,5,7,10	1,5,7,10	
H2*	2,3,4,5,6,7,8,9,11	1,2,3,4,5,6,7,8,9,11	2,3,4,5,6,7,8,9,11	1
H3	1,2,3,6,9,14	2,3,4,5,7,8,10,12,13	2,3	
H4	2,3,4,5,6,7,12,13,14	1,2,4,11	2,4,	
H5	1,3,5,8,11,13,14	1,2,4,5,9,10,12	1,5	
H6	2,6,7,8,10,11,14	1,2,3,4,6,7,9	2,6,7	
H7	1,3,6,7,9,10,11,12	1,2,4,6,7,13,14	1,6,7	
H8	2,3,8,9,10,12,13,14	1,2,5,6,8,11	2,8	
H9	2,5,6,9,10,11,12	1,2,3,7,8,9,10,12,14	2,9,10,12	
H10	1,3,5,9,10,11,12,14	1,2,6,7,8,9,10,11	1,9,10,11	
H11	2,4,8,10,11,14	1,2,5,6,7,9,10,11,13	2,10,11	
H12	3,5,9,12	2,4,7,8,9,10,12,14	9,12	
H13	3,7,11,13,14	1,4,5,8,13	13	
H14	7,9,12,14	1,2,3,4,5,6,8,10,11,13,14	14	

Table 6. Second to 11th iterations

	Reachability Variables	Antecedent Variables	Intersection Variables	Level
H1*	1,8,13	1,8,13	1,8,13	9
H3*	1,3,9	1,3,4,5,7,8,9,10,13	1,3,9	6
H4*	3,4,5,7,13	1,3,4,5,7,13	3,4,5,7,13	6
H5*	1,3,5,8,13	1,3,4,5,8,9,10,13	1,3,5,8,13	6
H6*	6,7,8,10,11	1,3,4,6,7,8,9,10,11	6,7,8,10,11	4
H7*	1,7,9	1,7,9,13	1,7,9	8
H8*	8,13	8,13	8,13	10
H9*	9	1,7,8,9	9	8
H10*	1,9,10	1,7,8,9,10	1,9,10	7
H11*	4,8,10,11	1,4,5,7,8,9,10,11,13	4,8,10,11	5
H12*	3,5,9,12	3,4,5,7,8,9,10,12,14	3,5,9,12	2
H13*	13	13	13	11
H14*	7,9,14	1,3,4,5,6,7,8,9,10,11,13,14	7,9,14	3

Step 7: Creating the diagraph

A diagram depicts the interrelationships of hindrances to BIM adoption based on the numbers assigned to them. The elements are displayed as a diagraph, with the components placed following the reachability matrix's levels and linkages. We keep transitive linkages whose explanation is critical. Figure 1 shows the diagram for the hindrances. Figure 1 depicts that H12 (Lack of awareness of BIM) and H14 (Resistance to change) played a significant role in impeding BIM adoption on construction projects in Nigeria and they are located at the top of the TISM diagram.

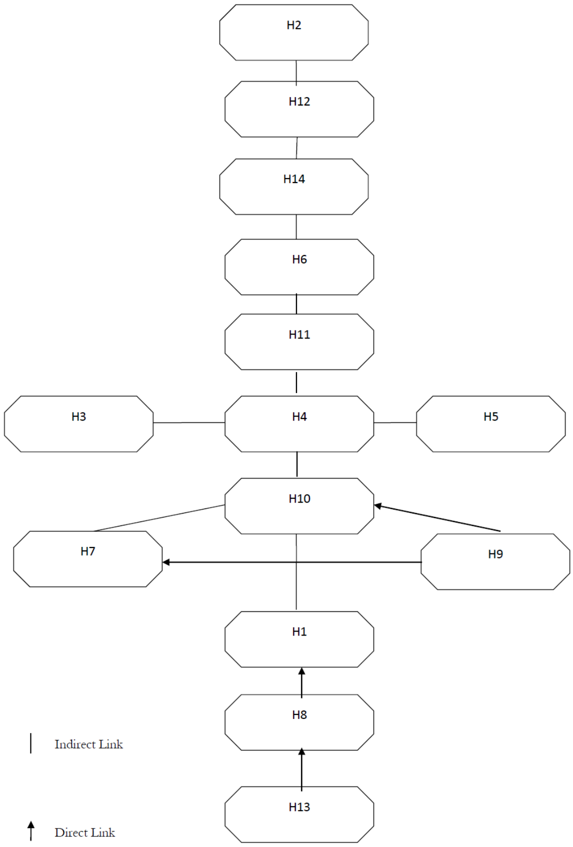

Figure 1. TISM model for hindrances to BIM

Step 8: Creating the interaction matrix

The final diagraph is translated into a binary matrix; *1 denotes direct and significant transitive linkages. This is further improved as an interpretative matrix using knowledge and understanding to provide the correct interpretation. The interaction matrix for asymmetrical intentions in connection to the TISM is shown in Table 4.

Step 9: Creating a complete interpretive structural model

The formation of a total interpretive structural model is the result of pair-wise interpretive logic comparisons, a reachability matrix with transitivity and a binary interaction matrix. Each relationship depicted in the diagram is given an interpretation in TISM. Figure 1 illustrates the TISM created for the current study.

One primary goal of this study's use of the MICMAC test is to analyse the driving and reliant power of observed hindrances. The factors are divided into four groups depending on their ability to drive and depend on others: autonomous, dependent, independent and linkage as shown in Figure 2. Figure 2 recognises both the driving and dependent power of asymmetric motives, which aids in understanding the interdependence that exists between asymmetric motive determinants. The following are the main findings of the MICMAC analysis: Quadrant I elements have very little driving power and reduced reliance power. In our investigation, quadrant I is currently empty. This result signifies that none of the elements fall under this group. Since no element is detected in this quadrant, all elements identified in the study are important. As a result, each of the 14 identified impediments substantially impacts BIM adoption in Nigeria. The impact determined by the second quadrant (Quadrant II) has a high degree of reliance but a low degree of driving power. During our research, we discovered the following two hindrances in this quadrant: H12 (Lack of awareness of BIM), which has high dependence power (9) and low driving power (4) and is assigned to Level 2 of the TISM hierarchy; H14 (Resistance to change), which has low driving power (4) and strong dependence power (12) and also present in the TISM Model Level 3.

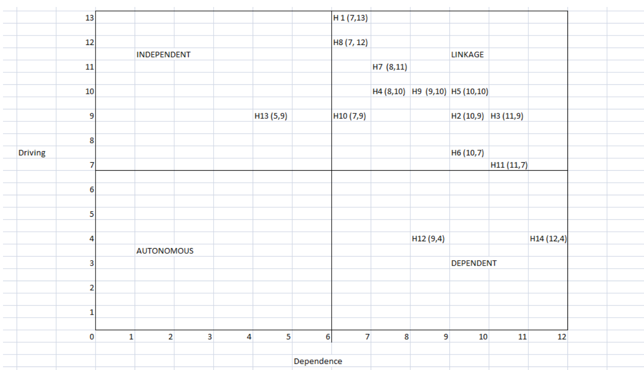

Figure 2. MICMAC analysis for hindrances to BIM

The third quadrant is linkage (Quadrant III) which elements have strong reliance as well as high driving power. These elements are not stable since every action on them has an enormous impact on other elements as well as on themselves. The following are the 11 linkage elements identified in the current study: H1 (Costs associated with the use of BIM) has a high degree of dependence (7) and driving power (13); H8 (Problems of interoperability) also has high dependence (7) and driving power (12) and classified as Level 10 in the TISM model; H7 (Negative attitude towards working collaboratively) has high driving (11) and dependence power (8) and occurs at TISM Model Level 8; H10 (Cost of BIM implementation: Software and training) has strong driving (9) and dependence power (7) and occurs at TISM Model Level 7; H4 (Difficulty in adapting to the BIM processes); H9 (Lack of user security and protection for intellectual property rights); H5 (Lack of integration of user's and project's requirements); H2 (Lack of insurance applicable to BIM implementation); H3 (A myriad of legal uncertainties); H6 (Lack of top management support); and H11 (Lack of a standard form of contract for BIM implementation).

The fourth quadrant (Quadrant IV: Independent) contains elements with low dependence but high driving power. One element is present in this quadrant, according to our research and it is H13 (Lack of skilled BIM personnel), which has high driving power of 9 and low dependence power of 5. The element is found at Level 11 of the TISM hierarchy.

DISCUSSION

The current study aims to identify hindrances to BIM adoption on construction projects in Rivers State, Nigeria. The TISM approach was used to determine the interrelationships among the identified hindrances in order to achieve this goal. According to the study's findings (as shown in Figure 2), H12 "Lack of awareness of BIM" and H14 "Resistance to change" had a direct impact on hindrances to BIM adoption. Ahmed (2018), Gamil and Rahman (2019), Sawhney and Singhal (2013), Tan et al. (2019), Onungwa and Uduma-Olugu (2016), Zakaria et al. (2014), Abubakar et al. (2014), Chan et al. (2019), Eastman et al. (2011), Kassem, Brogden and Dawood (2012), Li et al. (2017), Lu, Lai and Tse (2019), Olawumi et al. (2018), Tan et al. (2019) and Yan and Demian (2008); all found similar scenarios in their findings.

Given the relative influence and hierarchy of the impediments in the TISM graph and MICMAC analysis (as shown in Figures 1 and 2), the TISM model indicates that the "Lack of skilled BIM personnel" (H13) is the most important hindrance with the highest driving power and lowest dependency power. According to Figure 1, H13 persuades BIM adoption through reduced interoperability difficulties (H8) and related expenses with BIM use (H1), both of which are linkage hindrances in the TISM model. Since H13 is located at the 11th (final) level of the TISM model, its tremendous driving force allows it to impact and improve the model's other hindrances. "Lack of awareness of BIM" (H12) and "Reluctance to change" (H14) are all positioned in the second and third levels, indicating that they have a substantial influence on BIM adoption, but their success is heavily dependent on the success of the third to eleventh level hindrances. With reference to Figure 1, the "Lack of skilled BIM personnel" (H13) directly links with problems of interoperability (H8) with a view to having hands-on involvement in BIM's adoption. Moving up the hierarchy, the associated costs with the use of BIM (H1) do not have any direct link to any other hindrance. As a result, we can conclude that a lack of skilled BIM personnel is a precursor to BIM hindrance and, as a result, reduces the tendency for BIM's adoption. The current study shows a high level of interdependence between the hindrances to BIM's adoption, which leads to the creation of a much-needed platform for BIM adoption in the near future. Hence, this model can be used to help determine an organisation's success. This study will assist management in focusing their attention on the most relevant parts while also giving significant decision-making recommendations regarding the critical relationship between challenges to BIM adoption in the Nigerian construction industry. A further expansion of elements, using data obtained from industry experts, researchers and so on, will provide a clearer understanding of the state of BIM's adoption in Nigeria. Through a systematic framework, the application of TISM in this study provides useful insights into the interrelationships between identified items. The TISM methodology used has implications for researchers, academics and practitioners. Further research should be able to look at the driver-dependent interrelationships amongst elements of interest using MICMAC analysis, which is a significant step forward in BIM's research.

CONCLUSIONS

The importance of BIM's adoption in a developing country like Nigeria cannot be overstated because it has inherent potential to drive the nation's economy. BIM adoption in the Nigerian construction industry is required to bridge the digital divide between industry players and firms that are BIM compliant. It is also required for the integration and amelioration of the fragmented nature of the construction industry, which has been causing many intractable problems. This research discussed and elicited a summary of the hindrances to BIM's adoption on construction projects in Nigeria and this was demonstrated with the deployment of TISM as a technique for modelling the hindrances towards a better understanding of how they interact. Initially, an expert survey was conducted to validate the research constructs from the Nigerian context and all of the hindrances were discovered to be significant and were strongly supported by the experts. Based on the outcome of the TISM, 14 hindrances have been divided into 11 levels. The following is a summary of the key findings of the TISM analysis for hindrances to BIM's adoption on construction projects. Subject matter experts were involved in the TISM process, which led to the articulation of the interpretive logic and the directional relationships for each paired comparison. The TISM technique classified the hindrances in hierarchy based on expert opinions and the outcomes show that "Lack of awareness of BIM" (H12) and "Resistance to change" (H14) are the most important hindrances to BIM adoption. The MICMAC analysis thereafter classified the hindrances into four main groups. Each of the groups has its own set of characteristics. The classification portrayed each hindrance in a more glaring form and selected the most important hindrances, the sensitive hindrances and the hindrances that are influenced easily by the other hindrances. This makes it so much easier for decision-makers and interested parties willing to engage in long-term BIM adoption in the Nigerian construction industry to intervene. This research is crucial since it recognises BIM from the point of view of public players in the sector, which is missing from the few existing BIM studies in less developed climes. This study also laid the groundwork for a dynamic analysis of the effects of these hindrances on BIM adoption in developing countries such as Nigeria. Furthermore, the identified hindrances can easily influence the pace of BIM adoption in developing countries since they're the economic backbone and a BIM-enabled construction industry is a BIM-responsive construction sector. The study's limitation may be that only 28 experts responded to the questionnaire survey; however, the TISM's emphasis is still on specialists who are qualified and skilled in the subject area and not really on the group of specialists. According to the literature, there are many hindrances to BIM adoption on construction projects; however, the current study groups them into 14 major hindrances. In terms of future research, this hindrance to the study on BIM adoption could be adapted to sooth other developing nations. Given the identified hindrances to BIM adoption, applied research cases involving government agencies as well as other sister-related agencies associated with the construction project implementation might provide solutions to these problems relating to hindrances to BIM application in Nigeria. It is possible to conduct research on the perceptions and attitudes of built environment practitioners and clients toward BIM's adoption.

Certain limitations exist with regards to this study. TISM was used as a qualitative tool in this study. Despite the fact that this tool is highly relevant when likened to ISM, there may be some subjectivity in an expert's opinion. At the same time, this study was limited to experts within the Nigerian construction industry. The study can be generalised further by considering the perspectives of other stakeholders in BIM's adoption and its technology. In our study, 14 variables were investigated in order to model the hindrances. Many more hindrances can be identified, grouped into categories and used to further develop TISM. Considering that such a model has not yet been statistically substantiated, it can be validated using more appropriate software. The linear structural relationship approach, also known as structural equation modelling (SEM), can be used to test the validity of such a hypothetical model. As a result, it could be used in subsequent research to evaluate the model's validity.

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