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Building Information Model as a Collaborative Knowledge Management Tool for Construction Professionals

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Authors' contributions

This work was carried out in collaboration among all authors. Author ECO initiated the idea designed, carried out data acquisition and compiled the first draft of the manuscript. Author EIN manage literature searches and data acquisition. Author FOE proof read the original manuscript and data analysis. All authors read and approved the final manuscript

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ABSTRACT

Aim: The aim of this study is to assess benefit of BIM as a collaborative knowledge management tool for construction professionals.
Study Design: It was a mixed design research, the study was effected via literature review and a well-structured questionnaire. Likewise, interviews were carried out to substantiate the findings of the questionnaire survey.
Place and Duration of the Study: The study was conducted in Kaduna State, Nigeria for a period of 2 years.
Methodology: Being a mixed design research, a total of 250 questionnaires were administered and 235 were properly completed and returned representing a percentage response of 94%. Data garnered were analysed using relative importance index and presented in tables and charts.
Results: The study found that 94% of construction industry's professionals are familiar with the

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concept of BIM but 94.47% of them never applied it whereas 4.68% rarely apply BIM, while 0.85 often apply BIM. Also, the research identified that all the thirteen areas where BIM can be used as a KM tool for collaboration among construction professionals were significantly important, however, Constructability Reviews and 4D Simulations which involves providing an interface to visualize the entire structure and simulate the construction process stood out as the most important.

Conclusion: The study concludes by recommending that the built environment professional bodies in Nigeria should carry out a proper sensitization programme in-order to train and retrain professionals in Nigerian construction industry as regards BIM tools and its applications. Also, BIM should be introduced as an integral part of the school curriculum for the training of future construction professionals so equipped them with the requisite BIM knowledge.

Keywords: Knowledge management; BIM; collaboration; professionals.

1. INTRODUCTION

The advancement in technology and the speed of execution of modern construction projects involve interrelationship of the voluminous interdependent activities and knowledge of past projects by professionals of the industry [1]. According to Laura et al. [2] in the past there has been no structured approach to learning from construction projects once they are completed. At present the construction industry is adapting concepts of knowledge management (KM) to improve the situation, as Knowledge is noted to be one of the most important resources contributing towards managerial decision-making and for enhancing the competitive advantage of construction firms [3]. Knowledge has been described as information, which has been used and becomes a part of a person's knowledge-based experience and behavioural patterns [4,5]. Individuals as well as professionals have different knowledge-based capacity and experience, thus leading to different problem-solving approaches and decision-making. When choosing a construction professional, knowledge and experience are significant [6]. Professional must therefore be capable of knowing how to synchronize, use, manage, and utilize such knowledge in a project. According to Hesham [7] lessons learned from the construction industry have proved that reusing and sharing knowledge can enhance construction projects successfully by decreasing cost and time of completion and improving the whole competitiveness of the organisation.

Relevant technology such as BIM which is trending can help standardize mundane tasks and utilize resources more effectively [8] however, change is often considered to be disruptive to employees, hence management push is considered crucial. To help management increase adoption process, parameters identified in Unified Theory of Acceptance and Use of Technology (UTAUT) are scrutinized in [9]. The general parameter is the performance expectancy which is defined as 'the degree to which an individual believes that using a particular technology will help him or her to attain success in job performance [10]. If this thinking is perpetuated on an organization level and beyond it becomes an industry mindset. On a larger scale, alternative procurement routes that are designed depending on various evaluation practices and on risk allocation dynamics amongst various stakeholders are considered being another factor in resisting change. As gaining a collective agreement on discontinuing conventional practices, in the fragmented environment of construction is difficult [11].

From the foregoing, understanding that knowledge management deals with the management of both organisational and personal knowledge, there is the need to harness this potential. For an organization, the culture is usually the most influential element in designing an effective KM strategy and follow-up plan for implementation. For personal knowledge, [12] suggest that knowledge is a private good that is exchanged in the expectation of a commensurable return. Hall [13] also argues that knowledge is a private commodity and it is up to the owner to decide whether to share it or not. To entice people to share their knowledge as part of a social exchange transaction, they need to be persuaded it is worth doing so. Therefore, there is the need to focus on the collaboration and collaborative potentials of knowledge management professionals in the construction industry. Thus, this study seeks appraise the benefits of building information model as a collaborative knowledge management tool for construction professionals.

2. LITERATURE REVIEW

2.1 Construction Industry and BIM

The construction sector in a country's economy is an important employer of a nation's workforce as it employs between 2 to 10% of total workforce of most countries [14]. Nigeria had gained an impressive economic growth during the last three decades. Therefore, the list of the professionals actively involved in the construction industry includes but not limited to, Architects, Builders, Estate surveyors and valuers, Land surveyors, Quantity surveyors, Town planners, Civil, Electrical, Mechanical and Structural Engineers. Construction industry is becoming highly volatile and competitive due to increasing progression in information and communication technologies. These are often considered to be company's superior assets in providing profitability and competitive edge in the market. However, the most valuable resource is "knowledge", which is a refined form of information. The conservative, fragmented and adversarial conventional aspects of the industry are seen in the negative light for making implementation of these technologies difficult in the beginning due to various factors.

On the other hand, BIM has been widely adopted in the architecture, engineering, and construction (AEC) industry with 3D computer-aided design (CAD) technologies [15]. The objective of BIM is to build a building information model that represents the functional and physical features of a facility virtually prior to building it physically, and the basic premise is collaboration among different team membership and stakeholders in all phases of a construction project [16]. Unlike traditional 3D modeling technologies, BIM provides a collaborative platform for different disciplines to share and exchange information [17] and an interactive environment for project management throughout the lifecycle of a facility. The traditional way of communication in the AEC industry was done by drawings printed on papers, and the process was further facilitated by the development of the CAD technologies [18]. However, graphical elements (e.g. lines, symbols, etc.) in drawings and CAD files only represented 2D geometry Proceedings of the CIB W78 2013: 30th International Conference – Beijing, China, 9-12 October of a facility, and no information related to building components was included [19]. Later on, although 3D CAD emerged and complex drawings could be turned into vivid 3D graphic prototypes, the models usually became useless at the preconstruction stage and the benefits were "seldom realized post construction due to the breakdown in continuity of data collection [18]. Furthermore, data was still shared and exchanged among project teams via a printed set of plans that were stored and managed in fragment [15]. As stated by Chen, et al. and Davenport and Prusak [20, 21] data is "computerized representations of models and attributes of real or simulated entities", and exists in the form of "syntactic entities and patterns without meaning". Therefore, drawings and 2D/3D CAD technologies can be categorized as Building Data Modeling (BDM), which can simulate the components of a facility with sufficient data size and storage (e.g. drawings, spreadsheets, etc.), but is not capable of representing more comprehensive information such as relationships between data and symbols [16]. According to Howell and Batcheler [19], object-oriented CAD systems (OOCAD) has been developed recently, and it can represent relationships between building elements with both graphic and non-graphic attributes assigned to them. BIM is the latest generation of OOCAD systems with the inclusion of parametric 3D geometric and functional information, which enables the function to represent complex building component relationships. Data is interpreted into information prior to being stored in BIM models, and all information will be easily retrieved and modified by different project teams. Relationships and meanings of the elements in a BIM model are clearly defined, therefore different project disciplines can collaborate together through one single virtual model.

2.2 Knowledge Management (KM) and BIM

Single Data Entry: Multiple Uses: Traditional construction practices require the same information to be used multiple times by multiple organizations. Identical information normally is entered into different programs that provide specific solutions. Examples are structural analysis, code compliance, material quantities and cost estimates. These works are by nature repetitive in nature and this provide an opportunity for inconsistency and error. Moreover, even if information is digitally translated from one program to another, translation can alter or corrupt the data.

Versioning can be a nightmare, even with compatible programs. Drawing backgrounds is a recurring example of this problem. The architect's consultants need to upload and maintain the basic design backgrounds they receive from the architect. These backgrounds, however, will change as the design develops and each party must take considerable care to ensure that each is working with the latest versions of the basic documents. The contractors and vendors must take the information provided by the designers, often in paper form, and enter it into their systems. As the design develops, changes in one party's documents must be transferred back to the others. Errors begin to creep into the documents because updates are incompletely or incorrectly entered, and work can be wasted because parties are working from outdated information. By consolidating information into a unified data source, the likelihood of data entry, translation, or versioning errors is greatly decreased [22].

Design Efficiency: Generally, BIM design can aid a traditional design process. BIM software can reduce the cost of preparing 2D drawings in a conventional project, especially when designs are changing rapidly. For example, in Revit, any change in view of building plan will automatically updates any section affected. However, in Tekla Structures, changes in dimension or geometry will automatically update details and related features. Thus, using data-rich elements instead of drawn objects accelerates creation of contract drawings [22]. This can be easily achieved with BIM.

Consistent Design Bases: BIM modeling ensures that all parties working from the model share the same base. Conventionally, not all participants may be operating directly from the model but if the participants are using software that is compatible with the model, the base information can be moved, imported, or exported from the model. Moreover, periodic imports into 3D visualization software, such as NavisWorks's Jetstream, quickly expose inconsistencies [22].

3D Modeling and Conflict Resolution: BIM model render the design in three dimensions and does not require separate software to explore the model visually [22]. This allows better exploration of space, visualization of light studies, and improved communication and understanding of design concepts within the team and with project stakeholders [22].

Conflict Identification and Resolution: On complex projects, conflict identification and resolution are an extraordinarily expensive and difficult task. In many instances, designers do not have the time or budget to fully explore and resolve conflict issues and full coordination cannot be accomplished during the design phase because the contractor later will design key systems, such as HVAC or life safety equipment, that are not reflected in the design drawings. In complete design-bid build project, construction details and layouts may require information regarding the actual equipment that will be installed. This information deficit typically is addressed by warning the contractor that the design is "diagrammatic" and that coordination will be required. Traditionally, the contractor coordinates physical drawings of different systems by overlaying them in order to determine if the various systems actually can be constructed in the allowed space. Alternatively, drawings for each discipline are merged and printed as color-coded composite drawings. Conflicts that are identified are brought to the designer's attention through the request for information process, where solutions can be developed and clarifications issued. Light table resolution, however, is inherently a two-dimensional process applied to a three-dimensional problem. It is notoriously difficult and fraught with error, and thus conflicts are a primary source of contractor claims. Building information modeling greatly reduces conflict issues by integrating all the key systems into the model. Design BIM systems can detect internal conflicts, and model viewing systems such as NavisWorks can detect and highlight conflicts between the models and other information imported into the viewer. The solution can then be checked to ensure that it resolves the problem and to determine if it creates other, unintended, consequences. In a complex project, the savings derived from coordination can completely offset the model's cost [22].

Take-offs and Estimating: BIM model contains information or can link information, necessary in the generation of bills of materials, size and area estimates, productivity, materials cost, and/or related estimation information. It avoids the processing of material take-offs manually, thus reducing error and misunderstanding. Moreover, the linked cost information evolves in step with the design changes. The estimating advantages are so significant that some contractors will create models on 2D-designed projects to use the model's estimating capabilities [22].

Shop and Fabrication Drawing: BIM models provide construction details and fabrication information most time. This reduce costs by reducing the detailing effort and increases fabrication accuracy. Additionally, conflicts are resolved through BIM model, there is greater confidence that prefabricated material will fit when delivered. This allows more construction work to be performed offsite in optimal factory conditions. Subcontractors in the steel and MEP trades regularly use models to fabricate their products [22].

Visualization of Alternative Solutions and Options: BIM model is a 3D process, thus, are excellent methods for evaluating alternative approaches. Moreover, the ability to evaluate how changes affect key attributes, such as energy use, enhances the model's usefulness as a thinking tool. However, the software interface can interfere with the creative process. In a study of one system, users noted that it was not "sketchy," and therefore impeded the initial creative process. This may lead to using freeform design tools initially, with the results being loaded into the BIM system for refinement [22].

Energy Optimization: Building information modeling systems such as Autodesk's Revit can provide information for energy analysis. They can be used to evaluate lighting design and options, and, in conjunction with their material take-off capabilities, they can generate documentation necessary for LEED certification [22].

Constructability Reviews and 4D Simulations: Using BIM model, the contractor can visualize the entire structure, gaining a greater understanding of the challenges involved in its construction. By integrating 4D capabilities, the contractor also can simulate the construction process, which significantly increases the contractor's ability to evaluate and optimize the construction sequence. The interaction between scheduling software and the model also can be used to evaluate construction delays and errors [22].

Reduced Fabrication Costs and Errors: The ability to use information in the model to directly create fabrication drawings avoids a problematic and difficult step in the construction process. In a traditional workflow, the fabricators must review the plans and specifications, prepare fabrication drawings, compare them to other fabrication and design drawings, have them reviewed by the design team, and eventually release the drawings for fabrication. Errors can occur at any stage. By using the data in the model, dimensional errors, conflicts, and integration errors can be avoided or significantly reduced. In addition, the model can be updated with as-built information, allowing accurate fabrication of custom components, such as building facades [22].

Facilities Management: If the model is properly maintained during construction, it becomes a tool that can be used by the owner to manage and operate the structure or facility. Modifications and upgrades can be evaluated for cost-effectiveness. Data contained in the model can be used for managing remodeling, additions, and maintenance [22].

Functional Simulations: The 3D and conflict-checking mechanisms can be used to simulate and evaluate emergency response and evacuation. For example, NavisWorks was used at the Letterman DigitalArts Center to assure that fire response vehicles could navigate the parking structures. Building information modeling is the most powerful tool yet conceived for integrating design, construction, and management of facilities. It allows designers to explore alternative concepts and iteratively optimize their designs. Contractors can use the model to rehearse construction, prepare cost data, coordinate drawings, and prepare shop and fabrication drawings. Owners can use the data to manage maintenance and facility renovation. Together, the parties can use building information modeling as a basis for collaboration [22].

3. METHODOLOGY

The adopted mixed design approach. That's it involves both quantitative and qualitative approach. The study employed the use well-structured questionnaire and interview. The essence of the questionnaire is to capture a wide range of opinions concerning the collaborative potential of knowledge management professionals in Nigerian construction Industry. Likewise, the population for the study consist of knowledgeable workers in the construction industry such as Engineers, Estate Surveyors and Valuers, Quantity Surveyors, Architects, and Builders in Nigeria construction firms. Therefore, the population of the study comprises of these professional's resident and practicing the study area. Furthermore, sampling concerned with the selection of a subset of individual, from within a statistical population to estimate characteristic of the whole population. The objective of sampling is to provide a practical means of enabling the data collection and processing components of research to be carried out whilst ensuring that the sample provides a good representation of the population [23]. In identifying the appropriate sample size, the, the research will use the following equations in each of the construction professionals' body in order to make findings that are generalizable and applicable to the entire population. The formula used was advanced by Howard [24]. From the computation a sample of 50 was selected from each professional group, since the research is dealing with 5 major construction professionals a sample of 250 was used.

Data generated were analysed using relative importance index to rank the application of BIM as a knowledge management tool for collaboration among professionals in the construction Industry. The formula is show below:

$$\text{RII} = \frac{\sum fx}{\sum f} \times \frac{1}{k}$$

Where,

∑fx = is the total weight given to each attribute by the respondents.

∑f = is the total number or respondents in the sample.

K = is the highest weight on the likert scale.

Ranking of the items under consideration was based on their RII values. The item with the highest RII value is ranked first (1) the next (2) and so on. Ranking of the items under consideration was based on their RII values. The item with the highest RII value is ranked first (1) the next (2) and so on. The ranking of all the factors for extent of significance was based on the value of their respective relative importance index (RII). The guide for the ranking is given in Mbamali and Okotie (2012), as follows: RII <0.60, item is assessed to have low significance. 0.60 ≤ RII <0.80, item assessed to have high significance. RII ≥ 0.80, items assessed to have very high significance.

4. RESULTS AND DISCUSSION

The demographic data collected indicated that, 250 questionnaires were administered and 50 was given to each of the professionals in the construction industry. Table 1 represents the number of questionnaires administered to professionals. A total of 250 questionnaires were administered and 235 were properly completed and returned representing a percentage response of 94%. According to Moser and Kalton [25] the result of a survey could be considered significant if the response rate not lower than 30-40%. Therefore, the response rate is considered to be adequate.

Table 1. Demographic data of the respondent

Questionnaire distributed	Frequency (No.)	Percentage (%)
Returned	235	94.0
Not returned	15	6.0
Total	250	100

Source: Field Survey, (2018)

Majority of the construction industry's professionals are familiar with the concept of BIM as indicated in the Fig. 1, where 94% are aware of the concept, while 6% are not aware of the concept of BIM. This therefore establishes the basis of which the professionals can respond adequately to the research questions.

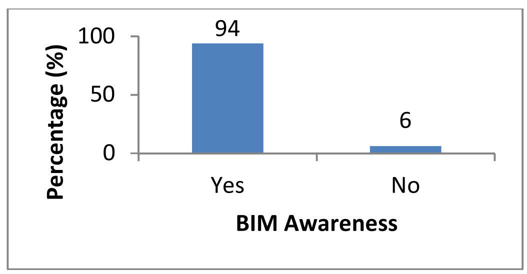

Fig. 1. BIM awareness
Source: Field Survey (2018)

From Fig. 2, it is obvious that majority of the construction professionals, don't apply BIM in their field of operation. Based on the three-point likert scale 94.47% never applied BIM, 4.68% rarely apply BIM, while 0.85 often apply BIM.

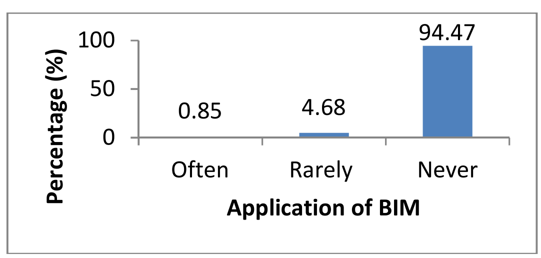

Fig. 2. BIM application
Source: Field Survey (2018)

Table 2. BIM as a knowledge management tool for collaboration

S/no	Collaboration	Frequency of response 1	2	3	4	5	∑f	∑fx	Mean	RII	Position
1	**Single Data Entry:** Multiple Uses; consolidating information into a unified data source, the likelihood of data entry, translation, or versioning errors is greatly decreased.	0	15	45	115	55	230	900	3.91	0.78	10th
2	**Design Efficiency:** Using data-rich elements instead of drawn objects accelerates creation of contract drawings	8	5	82	93	47	235	871	3.71	0.74	13th
3	**Consistent Design Bases:** BIM modeling ensures that all parties working from the model share the same base.	2	10	35	78	110	235	989	4.21	0.84	2nd
4	**3D Modeling and Conflict Resolution:** The BIM model can render the design in three dimensions and does not require separate software to explore the model visually.	5	7	43	93	87	235	955	4.06	0.81	6th
5	**Conflict Identification and Resolution:** Conflicts that are identified are brought to the designer's attention through the request for information process, where solutions can be developed and clarifications issued	0	14	20	115	86	235	978	4.16	0.83	3rd
6	**Take-offs and Estimating:** The model contains information, or can link to information, necessary to generate bills of materials, size and area estimates, productivity, materials cost, and related estimating information	5	16	35	97	82	235	940	4.00	0.80	8th
7	**Shop and Fabrication Drawing:** Models can provide construction details and fabrication information.	6	11	20	109	89	235	969	4.12	0.82	4th
8	**Visualization of Alternative Solutions and Options:** Because it is inherently a 3D process, models are excellent methods for evaluating alternative approaches.	0	15	45	115	55	230	900	3.91	0.78	10th
9	**Energy Optimization:** Information for energy analysis, such as lighting design and options.	2	5	82	93	53	235	895	3.81	0.76	12th
10	**Constructability Reviews and 4D Simulations:** visualize the entire structure and simulate the construction process.	2	3	35	85	110	235	1003	4.27	0.85	1st
11	**Reduced Fabrication Costs and Errors:** Directly create fabrication drawings avoids a problematic and difficult step in the construction process	5	11	43	89	87	235	947	4.03	0.81	6th
12	**Facilities Management:** Manage and operate the structure or facility	0	14	30	113	78	235	960	4.09	0.82	4th
13	**Functional Simulations:** The 3D and conflict-checking mechanisms can be used to simulate and evaluate emergency response and evacuation.	5	16	35	97	82	235	940	4.00	0.80	8th

Source: Field Survey (2018)

The research identified thirteen (13) key areas where BIM can be used as a KM tool for collaboration among construction professionals. From Table 2, constructability reviews and 4D simulations ranked first with RII of 0.85, indicating a high significance. Consistent Design Bases ranked second with RII of 0.84 also indicating a high significance. Conflict Identification and Resolution ranked third with RII of 0.83, which is indicative of a very high significance, Shop and Fabrication Drawing as well as Facilities Management both ranked fourth with RII of 0.82, indicating a very high significance. Reduced Fabrication Costs and Errors as well as 3D Modeling and Conflict Resolution both ranked sixth with RII of 0.81 which has a very high significance. Take-offs and Estimating as well as Functional Simulations both ranked eight with RII of 0.80 with a very high significance. However, Single Data Entry: Multiple Uses and Visualization of Alternative Solutions and Options both had a high significance with RII of 0.78, while Energy Optimization had an RII of 0.76 which also have a High significance. Design Efficiency had a high significance of 0.74 with a high significance.

It is obvious that all the thirteen areas for the application of BIM as a KM tool for collaboration are all of varying significant ranging from very high to High significance. Constructability reviews and 4D simulations was identified to be the most important. This involves providing an interface to visualize the entire structure and simulate the construction process. This is seen by construction professionals as the basis for which they can share knowledge relating to the project, based on their individual skills.

5. CONCLUSION AND RECOMMENDATIONS

Based on the research finding, it is evident that BIM has great prospect as a knowledge management tool for collaboration among construction professionals, especially as seen in the thirteen (13) key areas. Constructability Reviews and 4D Simulations which involves providing an interface to visualize the entire structure and simulate the construction process stood out as the most important. However, irrespective of the immense benefit and capacity of BIM to pull together and house every professional's knowledge, it is still minimally used in construction. This obviously indicates a gap, which can be attributed to several factors. Therefore, this research recommends that the built environment professional bodies in Nigeria should undertake a proper sensitization programme in-order to train and retrain professionals in Nigerian construction industry as regards BIM tools and its applications. This is because, there is a need for a clarion call for professional body to focus intently on integrating BIM as their primary work tool. Also, BIM should be introduced as an integral part of the school curriculum for the training of future construction professionals so equipped them with the requisite BIM knowledge.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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