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Building Information Modelling (BIM)-Based Quality Management System (QMS) for Mitigating Building Failures and Collapse: A Case Study of Nigeria

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Abstract

Building collapses have become a serious issue in developing countries due to the rapid growth and concentration of people in urban areas. Nigeria has been particularly affected, with over 115 building collapses in Lagos alone over the past decade. To address this issue, the study evaluates the potential use of Building Information Modelling (BIM) as a tool for Quality Management Systems (QMS) to mitigate building failures and collapses in Nigeria. The study conducted a comparative analysis of BIM implementation and processes in the UK and Nigeria through a literature review, and the survey of QMS of 23 Architecture, Engineering, Construction, and Operations (AECO) companies in Nigeria. The survey found an alarming lack of QMS practices in Nigeria, with only 39% of respondents indicating that their organization has formal quality management in place, only 50% of respondents indicated that they have an up-to-date quality management training manual, while nearly half of the respondents (48%) do not have an effective QMS reporting structure. These findings suggest that there is a significant need for greater implementation of QMS practices in Nigeria's AECO industry, particularly in the context of building collapses. The potential use of BIM as a tool for QMS represents a promising avenue for mitigating building failures and collapses in Nigeria and other developing countries.

Key Words: Building Information Modelling (BIM), Quality Management System (QMS), Building Collapse, Training, Quality Control, Certification,

1. Introduction

The fact that building collapse is becoming a more frequent occurrence within developing communities in Africa and Asia is worrisome (Boateng, 2019). For example, The Rana Plaza building collapse in Dhaka, Bangladesh, on 24th April 2013, led to the loss of a minimum of 1,132 lives and over 2,500 injuries (International Labour Organization, 2017). In the city of Kampala, Uganda, as reported by Alinaitwe and Ekolu (2014), there were 54 building collapses and 122 injuries between 2004 and 2008. Countries in sub-Sahara Africa have experienced the highest number of cases of building collapse associated majorly with human errors in building design, neglect and lack of tools and capacity to deter building collapse and structural failure (Asante and Sasu, 2018). The media reports also several building collapses, e.g., a 7-story building collapse in the capital of Kenya, Nairobi, on June 13th, 2017, and another 6-story building collapse a year earlier (BBC Africa, 2017). In Lagos, Nigeria, 115 building collapse cases occurred between 2012 and 2022 (Punch, 2022). According to Oyedele (2018), no city in Nigeria was without a major building collapse incident, e.g., Windapo & Rotimi (2012) list building collapses in Port Harcourt, Abuja, Enugu and Ibadan.

The most detrimental result in the construction business is the loss of lives and properties, workers injured on the job site owing to poor safety planning, insufficient economic resources, and time pressures (Ibrahim, Suleiman, & Bello 2019). Carnage and mega losses resulting from the devastating consequences of building collapses have become a silent feature of present-day cities worldwide (Khazaee, Mohamadi, & Ghoohestan 2017). The present study seeks to explore the role of Building Information Modeling (BIM) as a potentially vital tool for a Quality Management System (QMS) that can generate and maintain information produced during the lifecycle of building projects. The study seeks to draw lessons from the UK BIM implementation plan for the construction sector in Nigeria.

2. The concept of QMS and BIM

QMS points to the quality of planning, quality assurance and quality control within the construction industry (Mane & Pathi, 2015) and quality inspection (Dale, 1999). Quality inspection focuses on identifying and correcting defects after they have occurred while quality control considers preventing defects from occurring in the first place by implementing strategies and procedures that help to ensure quality (*Key Difference Between,* n.d.). QMS is also viewed as a broad approach by organizations in directing, controlling and coordinating building quality, assuming preventive measures to identify and mitigate risks (CIOB, 2021). Recently, quality management in construction has also been viewed as the 3P system (policy, process and procedure) set in place by administration to boost the institutions' proficiency to deliver quality to the client, be it owners, contractors or subcontractors, always and effectively (Sitemate, 2018).

On the other hand, BIM means several things to several professionals. Some professionals consider BIM as a "A modelling technology and associated set of processes to produce, communicate and analyse building models." (Eastman et al., 2008). The UK BIM Task Group defined BIM as essentially "value creating collaboration through the entire life cycle of an asset, underpinned by the creation, collation and exchange of shared three-dimensional (3D) models and intelligent, structured data attached to them" (BIM Task Group, 2013). BIM is the process of generating and managing information about a built asset over its whole cycle HM Government (2013). There seems to be a common consensus that BIM is a process for fusing technology and information to produce a digital representation of a project. BIM incorporates information from several sources, changes throughout the course of the actual project, and includes design, construction, and operating data while in use (Mordue, Swaddle, & Philp 2015).

2.1 *Implementing a BIM-Based QMS to Mitigate Building Failures and Collapses*

Several factors cause buildings to fail or collapse. A building would collapse if at least one or more of its critical structural components fail (Khazaee, Mohamadi, & Ghoohestan, 2017). The roof, slab, beam, column and foundation inclusive of the sub-surface foundation and even the walls constitute the critical building components (Ejiofor, 2018). The causes of building collapse can be segmented into two major groups which include human-influenced collapse and natural causes (Okagbue et al., 2018). The human-influenced actions responsible for building collapse include the use of poor-quality materials (Ede et al, 2018 & Joshua et al, 2017), structural defects (Adewoyin et al, 2017; Oyeyemi & Olofinnade, 2016 and Oni, 2010)), lack of effective management of construction processes (Onungwa, Uduma-Olugu, & Iqwe, 2017 & Fayemi and Adepelumi, 2012), corrupt practices (Bamigboye, et al, 2017), legal and regulatory failures (Ojukwu-Ogba, 2011). Regional geophysical and geotechnical issues (Oyediran & Famakinwa, 2015 and Orazulike, 1988) fall under the category of natural cause of building collapse. The human-influenced collapse is primarily caused by human actions and inactions. BIM aims to address specification, design, and structural usage problems caused by non-compliance with building specifications, failure to consider building load, and improper structure utilisation. However, failures are still likely to happen. (African Surveyor, 2022). In recent years, the construction industry has faced challenges related to a lack of interoperability, security, and universal standards, exacerbated by the increasing size and complexity of data requirements needed to meet evolving sustainability management needs (Mahamadu et al., 2013). Chong et al. (2014) proposes integrating building information modelling (BIM) and facility management to improve maintenance quality and performance. Lin et al. (2017) propose a framework for productivity and safety monitoring using BIM. Despite the potential benefits of innovation and effective data management, the construction industry has adopted such practices conservatively (Ding et al., 2020). One of the key benefits of BIM is its ability to identify potential safety hazards early in the design phase and model safety equipment in a virtual environment (Sadeghi, et al 2016). Such capabilities allow safety professionals to visualise potential safety hazards and assess the effectiveness of safety equipment in preventing accidents. BIM can serve as an effective tool for QMS when integrated into the quality assurance, control, planning and inspection processes, ensuring the following:

- Information consistency from the design through the construction phase - BIM is a parametric modelling effort that offers tabular representations of components and distinctive interactions with their parts, such as name, type, characteristics, relationships, and metadata (Zollinger, et al 2010). Automated analysis using construction product data can replace manual examination of drawings and modification orders, enabling the identification and assessment of differences between design and as-built conditions.
- Consistency in process management during construction - The percentage of each activity's completion on the construction timetable may be continually monitored (Chen & Luo 2013). Hence, quality inspections may be planned right away once one activity is finished, before the start of the following task, ensuring that the quality inspection procedure is timely and consistent with the building process (Park & Kim, 2015).
- Participant collaboration - Using BIM technology on building projects can enhance the construction process, thus enabling all team members to cooperate more precisely and effectively than when utilising traditional techniques (Xin, 2011).

BIM data may be paired with other cutting-edge technology such as the Internet of Things, and artificial intelligence (Wang et al., 2013). Furthermore, BIM can also be paired with augmented reality (AR) for quality defect control, such integration allows for enhanced visualisation and improved quality management in construction projects (May et al., 2022).

2.2 *BIM Implementation in Nigeria and UK*

Several studies conducted on BIM within the Nigerian context primarily focused on specific areas such as the obstacles to incorporating BIM into the undergraduate curriculum for Quantity Surveying students (Babatunde and Ekundayo, 2019), identification of measures to improve the usage of BIM in the Nigerian building industry (Onungwa et al., 2017), assessment of the BIM training gaps (Oyewole and Dada, 2019), the impact of BIM on collaboration (Onungwa and Uduma-Olugu, 2016), BIM awareness (Olapade and Ekemode, 2018), barriers to BIM in SMEs (Saka and Chan, 2020), benefits (Olawumi and Chan, 2019), and drivers/barriers for BIM implementation (Babatunde et al., 2019). More so, the higher levels of BIM awareness in Nigeria do not necessarily translate into implementation (Saka and Chan, 2019). Nigeria, like most developing nations in Sub-Saharan Africa, lacks a government initiative or strategy to promote the use and understanding of BIM (Olanrewaju, et al., 2020). Such a situation contrasts with the more developed countries like the UK, China, the USA, etc. (Ibrahim and Bashir, 2012; Aluhofai, 2012). As the Nigerian government continues to be the primary customer for projects, the absence of such government policy may deter other private investors from taking BIM adoption initiatives seriously as the government is expected to lead by example (Chewlos et al., 2001). Other factors include the frequent client demands for the use of traditional methods to design buildings (Ibrahim and Bashir, 2012), lack of BIM training and certifications (Olanrewaju et al., 2020), lack of constant electricity supply and lack of internet connectivity affecting the output of office workers (Abubakir et al, 2014).

In the UK, the government has implemented a range of policies and initiatives to support the adoption of BIM in the construction industry, as follows:

BIM Level 2 Mandate: The BIM mandate was introduced in the Government Construction Strategy and the Industrial Strategy in 2013 and came into effect in April 2016 (HM Government, 2013). Since then, all centrally procured government projects require the use of BIM Level 2, which involves the creation and sharing of 3D models and other data between project stakeholders (HM Government, 2013).

BIM Task Group: The UK government established the BIM Task Group in 2011 to provide guidance and support to the construction industry on BIM adoption (Cabinet Office, 2011).

BIM standards and guidance: The UK government has adopted a range of standards and guidance documents to support the implementation of BIM, including the BIM Level 2 standards, the Digital Plan of Work, and the BIM Execution Plan (HM Government, 2015).

BIM Level 3: The UK government has set a target of achieving BIM Level 3 by 2025, which involves the use of open data and integrated project teams (HM Government, 2015; Infrastructure and Projects Authority, 2022).

Based on the presented evidence, when considering the main points in the UK and Nigeria BIM implementation key considerations are the Level of BIM adoption, Awareness, Training & certifications, Technology & Infrastructure, Policies & standards. Although the implementation of BIM in the UK has also suffered some setbacks, such as the lack of clients' demand (NBS, 2022), many benefits are realised using BIM on UK construction projects. Examples of such benefits include increasing total project quality (Bynum, Issa & Olbina, 2013), improving design quality by increasing efficiency, communication and precision (Cheng & Wang, 2010), reducing errors due to better coordination between documents and the entire team, thus minimizing conflicts (Popov et al., 2006), simulation and optimisation for better performance, lower costs, and shorter lead times (Kim et al., 2012).

3. Methodology

The study relied on a literature review to (1) understand building collapse and failures and associated effects in Nigeria, (2) explore the basic concepts of QMS, BIM, the role of a BIM-based QMS in attenuating building collapse in Nigeria, and (3) explore key issues for comparative analysis between the UK and Nigeria BIM implementations. Subsequently, the quantitative method involved carrying out a survey of construction Architecture, Engineering, Construction, and Operations (AECO) companies in Nigeria against their QMS, essential to address the goal of the research. The study surveyed 23 AECO construction companies in Nigeria, out of the 33 initially reached to complete the survey, representing a 70% response rate. One response per company was received, and out of the received survey responses 16 (70%) came from limited liability companies, 1 (4%) from a public liability company with foreign ownership and 2 (9%) from the public sector or government-owned companies from different parts of Nigeria such as Lagos, Federal Capital Territory (FCT) Abuja, Kaduna, Bauchi state, etc. To justify the sample size, Creswell & Creswell (2018) opine that no hard and fast rules specify how many persons to survey in research; 10-50 participants may be sufficient depending on the type of research and research question. The survey administered a questionnaire with 24 questions divided into 6 categories: (1) demographic information, (2) indication of formal quality management standard, (3) QMS documentation, (4) leadership commitment to QMS, (5) QMS implementation and challenges, (6) process evaluation. The respondents included Project Managers, Project Architects, Project officers, Project lead, and Project coordinators from the surveyed companies, in order words one representative from each company. In a bid to protect the participants and their organizations, the respondent identities were anonymized. The survey was carried out online using Microsoft Forms and exported into Excel for statistical analysis.

In evaluating the results from the survey, the appraisals were done according to the standard ISO 9001 (ISO, 2015). The ISO 9001 management system documentation includes documented statements of a quality policy and quality objectives, a quality manual, documented procedures, and records required by the international standard, and other records deemed necessary to ensure effective planning, operation, and process control.

4. Results and Discussion

4.1 Comparative appraisals between BIM implementation in the UK and Nigeria

Results of the comparative analysis between UK and Nigeria BIM implementation are further presented. Figure 1 shows a summary of major issues that emanated from the review, such as the Level of BIM adoption, Awareness, training & certifications, Technology & Infrastructure, Policies & standards, and Industry collaboration, which are discussed within separate subsections.

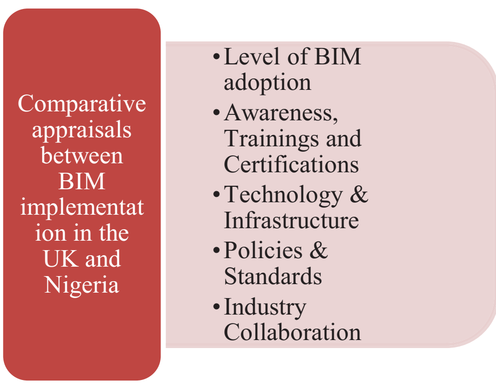

Figure 1: Major appraisal topics for BIM implementation in the UK and Nigeria

4.1.1 Level of BIM Adoption

UK BIM mandate in place since April 2016 necessitates all centrally procured government projects to require the use of BIM Level 2. In Nigeria, BIM adoption is still in its early stages and is largely limited due to the lack of a government initiative or strategy to promote the use and understanding of BIM.

4.1.2 Awareness, Training and Certifications

In the UK, there is a high level of awareness and education about BIM, with many training programs and certifications available. In Nigeria, a lack of awareness and education about BIM, with sparingly available training and certifications, often hinder BIM adoption.

4.1.3. Technology and infrastructure: The UK have advanced technology and infrastructure to support BIM implementation, such as high-speed internet, cloud computing, and 3D modelling software. In Nigeria, the technology and infrastructure are not as advanced, which can limit the effectiveness of BIM implementation.

4.1.4. Policies and Standards

The UK have established policies and standards for BIM implementation, such as the UK BIM Framework, BIM Task Group and PAS 1192 standards (BSI, 2013). UK government also set a target of achieving BIM level 3 by 2025. Nigeria does not yet have established regulations and standards for BIM implementation.

4.1.5 Industry collaboration

In the UK, there is a high level of industry collaboration and cooperation, with many public and private sector organizations working together to promote BIM implementation, whereas that is not so in the implementation of BIM in Nigeria

Summarily, the UK has made tremendous progress in BIM implementation, with a strong regulatory framework, advanced technology, and a high level of industry collaboration. Perhaps, Nigeria's construction industry could emulate such BIM successes to mitigate building failure and collapses. This could be explored through further collaborations that have occurred between the UK and Nigeria's construction industry over the years. Some of those collaborations have given rise to tremendous construction projects in Nigeria. For example, the partnership between Julius Berger Nigeria Plc and Bilfinger Berger AG, a German-based company with a strong presence in the UK (Bilfinger & Berger Bau A.G, n.d). Such partnership delivered several landmark projects in Nigeria, such as the Murtala Muhammed International Airport Terminal Two, Lagos, the National Assembly Complex, and the Abuja Stadium. Also, the collaborative efforts between Nigerian company Sujimoto Construction and UK-based firm Structurflex resulted in the construction of the iconic LeonardoBySujimoto luxury tower in Lagos, Nigeria (Leonardo by Sujimoto., 2023). Such collaboration can create an environment that fosters the exchange of ideas, methods, processes, and skills essential for the implementation of BIM.

4.2 Survey Results

Considering some of the survey results, as seen in Figure 2, it was discovered that of surveyed responses 61% indicated that their companies do not have a formal QMS. Sixty-Five Percent (65%) of the organisations' QMS is not certified following the ISO 9001 (ISO, 2015) standard (which entails quality management principles such as the factual approach to decision making, leadership, involvement of people, process approach, system approach to management, continual improvement, mutually beneficial supplier relationships, and customer focussed organisation) or any other standard, such as the ISO 14000:2015 and related standards, or ISO 19011:2018 (ISO 2015; 2018).

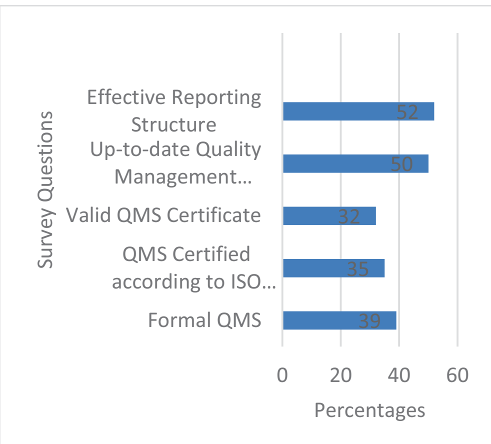

Figure 2: Evidence of formal Quality Management Systems

Thirdly, in considering the quality manual of the organisations that includes the scope of the QMS, the documented procedures and the interaction between processes (ISO, 2015), 50% of the companies surveyed do not have an up to date QMS manual for their operation.

Fourthly, the documented procedures and records required by the ISO 9001 standard (ISO, 2015) are mandatory and non-mandatory records. Examples of mandatory records include monitoring and measuring equipment calibration records, records of training, skills, experience and qualifications, product/service requirements review records, customer property, monitoring measurement results, etc. Examples of non-mandatory requirements include sales and warehousing procedures, the procedure for internal audit, management review, production and service provision, etc. (ISO, 2015). The companies were asked if their organisation's QMS have documented information (written document) that is required by the ISO 9001 international standard or any other standard. Seventy per cent (70%) of the surveyed construction companies do not have documented information that is required by the ISO 9001 (ISO, 2015) international standards and 48% of the companies indicated that their organisation's documented information is not effective for the implementation of its QMS.

Furthermore, in addition to the results presented in Figure 2, with regards to the documents including records, deemed by the organisation to be necessary to ensure the effective planning, operation, and controls of its process, 35% do not have a procedure for the quality control documents. Also, 39% of the companies surveyed do not conduct internal and external quality audits at planned intervals, and 48% do not have a preventive action procedure through risk-based thinking. The issues may be critical as the establishment of quality policies and objectives for the construction of buildings to meet customers' and regulatory requirements will be flawed without an effective QMS that includes quality planning and improvement activities. When this is not in place often companies resort to unprofessional means that can endanger lives and properties.

5. Conclusions

In conclusion, the study highlights the challenges the construction industry faces that lead to building failures and collapses. BIM can serve as an effective tool for QMS when integrated into the quality assurance, control, planning, and inspection processes. The integration of BIM into QMS ensures consistency in information and process management during construction, as well as participant collaboration. Therefore, implementing a BIM-based QMS can help to mitigate building failures and collapses and improve the construction industry's efficiency and performance. Perhaps, Nigeria can adopt the UK BIM implementation as an advisory while exploring indigenous ways to make progress in BIM implementation in the construction industry. Addressing the challenges of BIM implementation as described in the review may be vital for Nigeria to realize the benefits of BIM, such as improved project coordination, reduced costs, and increased efficiency. Stakeholders in Nigeria need to work collaboratively and prioritize the development of the necessary infrastructure, regulations, and educational resources to facilitate the adoption and effective implementation of BIM in construction. Most importantly, the government has a major role to play in establishing, building and prioritizing strong policies that will add to BIM implementation in the construction industry. Further studies could include the analysis of the impact of a BIM-Based QMS on project cost and schedule, investigation of the role of government policies and regulations in promoting the adoption of a BIM-based QMS and examining the potential for BIM-based QMS to enhance sustainability in the construction industry.

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