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Assessing BIM Needs and Perceived Benefits in Building Lifecycle

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Abstract

This study explored the pressing necessity for the adoption of building information modelling (BIM) within the Architecture, Engineering, and Construction (AEC) sector, highlighting its potential to address challenges related to increased construction costs, productivity challenges, and difficulties in carrying out operation and maintenance (O&M) practices. Despite its acknowledged advantages and benefits, BIM implementation in the AEC domain is yet to achieve significant maturity across the building lifecycle, particularly in developing regions. Employing a case study, this study evaluated the application of BIM in the Adolescent Girls' Initiative for Learning and Empowerment (AGILE) World Bank construction project in Nigeria. Furthermore, it conducts a systematic scoping review of BIM benefits alongside a bibliometric trend analysis, emphasizing the global relevance of BIM. The findings highlight the urgency of the widespread acceptance of BIM and offer valuable insights for industry practitioners, clients, and researchers, enriching the understanding of BIM indispensability, advantages, and worldwide patterns to foster BIM integration during construction project execution.

Keywords

BIM adoption, Building lifecycle, Construction projects, Project management, Sustainable practice.

1. Introduction

Recent research in the construction industry has increasingly focused on innovative technologies within the built environment, contributing to what is commonly referred to as the fourth industrial revolution (Ebekozien & Aigbavboa, 2021). Consequently, there is a growing need for innovative technologies, owing to advancements in digital technology in construction. Construction 4.0 represents a paradigm beyond mere technological integration; its adoption is geared toward addressing the industry's prevailing challenges through the utilization of innovative technologies (Sawhney et al., 2020). The capacity to address these challenges by adopting digital technology in conjunction with Construction 4.0 has led to a significant transformation in the construction industry globally (Toyin et al., 2024). Therefore, technologies such as building information modeling (BIM), the Internet of Things (IoT), robotics in construction, virtual reality (VR), wearables, 3D printing, data collection applications (DCA), cyber-physical systems (CPS), and artificial intelligence (AI) have a considerable influence on construction project execution (Seyman Guray & Kismet, 2023). Among these technologies, BIM stands out because of its ability to complement other technologies, facilitating automated connections aimed at enhancing the execution of construction projects. The integration of BIM with IoT and other CPS sensors enables the monitoring of facility performance and the establishment of an effective system for preventive maintenance management (Dave et al., 2018). Nevertheless, although BIM has proven to be a valuable intelligent tool in the construction industry, its impact has been predominantly felt in developed countries, with slower adoption rates observed in developing countries. For years, the World Bank projects in Nigeria have relied solely on traditional design and construction methods. However, recognizing the impact of Construction 4.0, and the imperative for innovative transformation within the global construction industry, reveals the importance of accepting BIM tools from the design stage to the maintenance stage of subsequent projects. This realization was evident in the 2022 AGILE tender bid, involving six states in the northern region of Nigeria. Despite scholarly efforts to document the benefits derived from the adoption and integration of BIM, there remains a gap in the literature regarding a concise evaluation of why BIM is essential throughout the building lifecycle and the benefits driving its acceptance in developing regions. In addition, bibliometric mapping has been absent from this discourse.

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BIM can enhance collaboration, increase efficiency and effectiveness, manage the material supply chain, and reduce interoperability costs (Babatunde et al. 2018). At the conception and design stages, Gamayunova & Vatin, (2014) reported that architects saw the need to adopt innovative technology, out of which they realized the suitability and compatibility of BIM in their task role. This enabled them to produce drawings within hours and allowed visualization of the proposed building(s), unlike traditional methods, which may take months to achieve (Babatunde et al., 2018). Gamil & Rahman, (2019) noted that a lack of awareness of BIM benefits is a significant challenge discouraging the adoption of BIM in the Architecture, Engineering and Construction (AEC) industry. Olanrewaju et al., (2022) opined that it could contribute to the slight setback experienced in developing countries, which obstructs the quick adoption of BIM in their construction industry. The more readily available and regularly updated BIM benefits are, the more professionals and clients will be motivated to implement the technology (Silverio et al., 2023). However, this study aims to fill these gaps using the World Bank's AGILE proposed project as a case study and a systematic scoping review of published articles sourced from selected academic databases supported by bibliometric network analysis. Based on this, the following research question was proposed:

(I) What are the current bibliometric trends related to the benefits of BIM adoption in the construction industry?
(II) What benefits does BIM offer in the various stages of the building lifecycle?
(III) What justifies the necessity of BIM in various stages of the building lifecycle and who are the primary users with defined roles in its implementation?

2. Methods

One unique way to conduct reliable scientific research involves reviewing existing knowledge in the proposed area of study (Mewomo et al., 2023). This will serve as a guide for the debate on new ideas. In this study, a bibliometric analysis, systematic scoping review, and case study were adopted to triangulate the state-of-art BIM needs and its benefits in the building lifecycle. Scoping reviews are commonly used when a literature frame is yet to be broadly reviewed, or exhibits an extensive, complex, and systematic review. This may be carried out to determine the extent of the research available on a topic and how it was conducted. This may be studied to check a body of literature relevant to location, time (e.g., context or country), source, and origin. Based on this concept, this study was supported by bibliometric trend analysis. The Scopus and Web of Sciences (WoS) academic databases were used to source relevant documents for this study. The case study adopted for this study was the World Bank's proposed project in six selected Northern states in Nigeria, with a focus on the tendering phase. Figure 1 shows the flow steps used in the study..

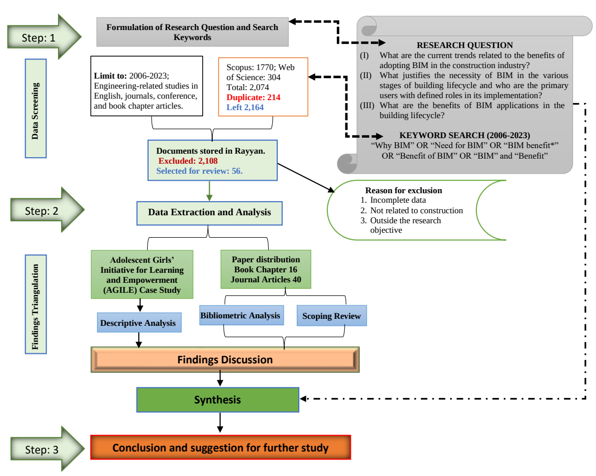

Fig. 1. Study flow steps.

3. Bibliometric

This section presents the findings and discussion of the bibliometric mapping analysis. Bibliometric analysis is a crucial research technique that reveals various fields of network mapping and trends over the years based on published articles. It seeks representations of logical links within a constantly evolving scientific knowledge system. The data analysis and findings of the study are presented using tables, figures, graphs, and charts.

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3.1 Discussion of total retrieved documents

From both Scopus and WoS a total of 2,108 bibliometric manuscript data records were retained in Zotero located through the defined keyword for this study. Figure 2 shows a chart of publication frequency per year from 2006 to 2023. This indicated that significant publications started in 2011 with 51 publications, and the highest peak was in 2019, due to covid19, there was a slight drop from the peak; thereafter, there was an improvement until 2023. The most critical year of publication falls between 2018 and 2023, and each year has more than 160 publications.

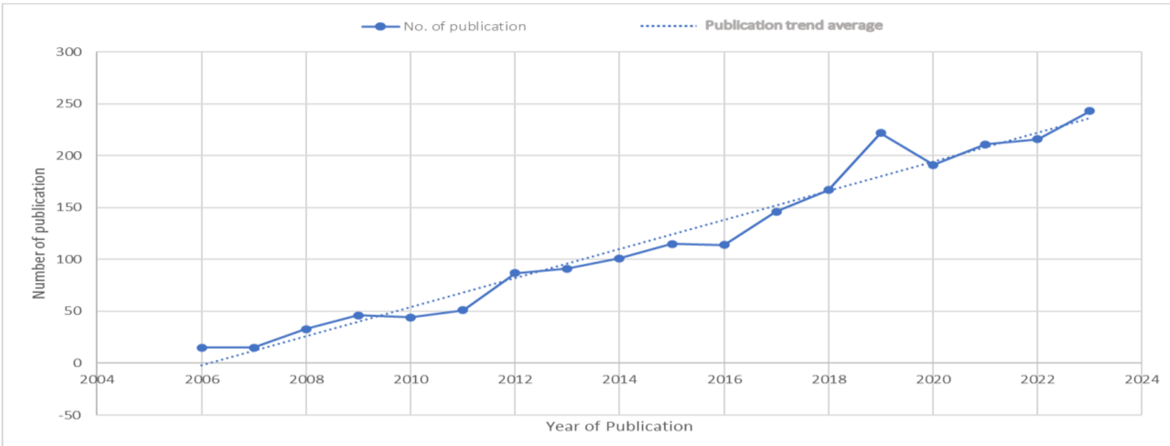

Fig. 2. Publications per year

3.2 Co-occurring keywords network

Keywords are terms, nouns, and phrases, which are the core contents of an article/publication and show the advancement of research topics over time. There are two types of keywords: (i) "author keywords," which are provided by authors, and (ii) "index keywords," which are recognized by journals. A network of co-occurring keywords was built using the keywords of the authors from the 2,108 bibliometric data. Co-occurrence might also comprise likely keywords based on the same topic but not the same meaning; the closeness of keywords is precisely related to the degree of co-occurrence (Toyin & Mewomo, 2023).

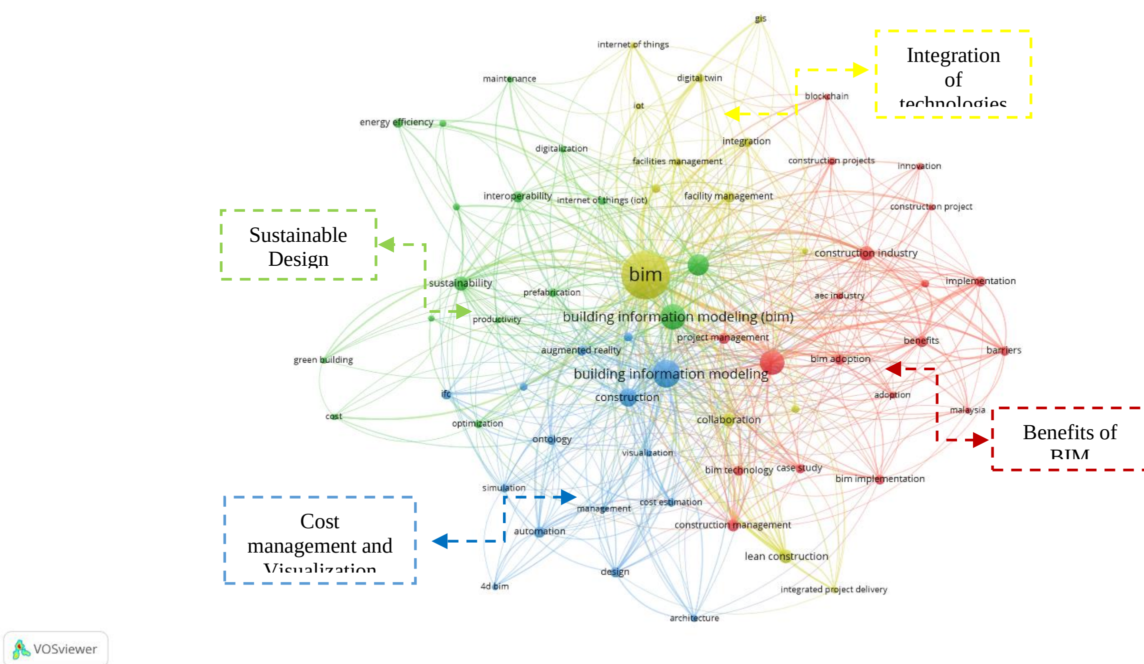

Fig. 3. Network of keywords in the documents

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A total of 3574 keywords were identified using the VOSviewer software. Subsequently, the inclusion criteria were set to a minimum of 10 occurrences of a keyword. A total of 64 keywords met this threshold. Figure 3 shows the network of co-occurring keywords with 541 links and a total link strength of 1430. The keywords were grouped into four (4) clusters identified using different colors, as shown in Figure 3. Each cluster set was named according to the specified variables. Hence, cluster 1 (red zone) items are named [Benefits of BIM adoption], cluster 2 (green zone) are named [Sustainable Design], cluster 3 (blue zone) are named [Cost management and Visualization improvement], and cluster 4 (yellow zone) are named [Integration of technologies with BIM]. Each cluster contained 19, 16, 15, and 14 keywords, respectively.

4. Systematic scoping reviews

Scoping reviews may be performed to evaluate the extent of existing research on a topic and how the study was conducted. Decades ago, during the initial realization of BIM, the Cooperative Research Council (CRC) for Construction Innovation (Innovation, 2007) saw the key benefit of BIM as an accurate geometrical representation of building parts in an integrated data environment. This benefit has been the driving force behind BIM adoption. Moreover, BIM is still new in the construction industry, and Azhar et al. (2012) noted seven significant benefits derived from adopting BIM in building production. The authors also realized five significant benefits acknowledged by the Center for Integrated Facilities Engineering (CIFE), such as: up to 40% elimination of unbudgeted change, cost estimation accuracy within 3%", up to 80% reduction in time taken to generate a cost estimate, savings of up to 10% of the contract value through clash detections and up to 7% reduction in project time. These benefits were realized based on 32 projects in which BIM was adopted. Moreno et al. (2014) investigated the perceived benefits of using BIM to design and construct educational facilities. The authors found that BIM use increases client engagement, clarifies the design, serves as an innovative marketing tool for firms, and improves collaboration and communication among professionals. In addition, it lowers risk and better predicts outcomes owing to the discovery of errors, omissions, and conflicts before the construction and automation of documentation. A similar benefit was recorded in the findings of Bryde et al. (2013), who collected secondary data from 35 construction projects that utilized BIM to explore the benefits of BIM implementation in their project, although BIM adoption was still in its early stages. Currently, these benefits have motivated the adoption of BIM globally. These benefits are further discussed below.

4.1 BIM Model-based benefit check

In their research, Lu et al., (2013) developed a model to measure the benefits of BIM construction. The authors noted that BIM offers both practical and academic value, including enhancing project management activities, improving people's understanding of BIM, and helping to rationalize their investment in it. The authors' findings justify the capacity of BIM in academic settings, value for money, and managerial activities. Moreno et al. (2014) investigated the perceived benefits of using BIM to design and construct educational facilities. The authors found that BIM use increases client engagement, clarifies the design, serves as an innovative marketing tool for firms, and improves collaboration and communication among professionals. In addition, it lowers risk and better predicts outcomes owing to the discovery of errors, omissions, and conflicts before the construction and automation of documentation.

Yang & Chou, (2019) focused on BIM benefit evaluation. The authors designed an overall BIM benefit evaluation structure for its implementation through the evaluation of BIM project-based benefits. Seven benefits were identified based on which a subjective BIM benefit evaluation model was developed. Li et al. (2018) found that the robust control of physical and functional digital presentations of BIM is a helpful tool for enabling on-site assembly services for prefabricated buildings. Li et al. (2019) see the need to implement BIM in prefabrication housing production (PHP) to manage inefficiency and collaboration issues resulting from heterogeneous means of storing information by various stakeholders involved in the production. The authors noted that the adoption of the BIM model enabled the recognition of the following key benefits: it serves as a collaborative working platform for working efficiency, enhances decision-making, and facilitates the interoperability of smart PHP objects, smart work packages, and smart BIM platforms. These enhance the facilitation of communication and interaction with the central database, improve production time, eradicate delays, and reduce material wastage. Dave et al., (2018) developed an open standards-based model for connecting BIM and the Internet of Things (IoT); the authors concluded that the BIM model provided a significant benefit, such as a hosting platform for storing necessary information for the smart campus project investigated.

4.2 BIM Benefit Check: A Case Study.

Dowsett & Harty, (2016) examined the link between BIM benefits and implementation by focusing on two case studies. The benefits of using BIM derived from the case study are the automation of manual processes, improved

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understanding of design intent, and improved consultation meetings. Nepal et al., (2014) research also focused on two documented case studies of BIM implementation. In both case studies, BIM benefits were reported and grouped under benefits to the owner and benefits to the general contractor and subcontractors. From the real-life case examined, it was realized that BIM implementation in these projects adds fantastic value and benefits to the interests of the client and contractor. Evidence proved that the achievement of these benefits would encourage parties to adopt BIM in their next project. Lu et al., (2015) compared the project with real-life BIM and non-BIM projects based on “time-effort distribution curves” at the design and building production stages. The findings show that BIM use enhances the project design phase by reducing the time spent on design. Compared to those without BIM, it improves the design efficiency and makes it easier to conduct quantity surveying. Barlish & Sullivan, (2012) studied how BIM benefits could be measured. The author validated the measure through three case studies. Case 1 focused on “returns” based on two BIM pilot projects and two non-BIM historical projects in similar functional areas. The authors found a 42% difference in change orders and a 67% difference in scheduling when non-BIM- and BIM-based projects were compared. Case 2 focused on “design and construction investment, ” calculated based on design and contractor costs. The findings also revealed a significant difference between BIM-based and non-BIM-based projects. Case 3 combined “returns and investment” based on current non-BIM and BIM projects. The author acknowledges that the success of BIM depends on the BIM proficiency, project size, and level of communication among the project team members.

In Saudi Arabia’s construction industry Al-Yami & Sanni-Anibire, (2019) identified the benefits of BIM implementation through a focused case study approach. Nineteen BIM benefits were identified and thus grouped into four sub-groups, namely: design-related benefits, performance-related benefits, business-related benefits, and construction-related benefits. Doan et al., (2021) conducted a semi-structured interview among industry experts in the New Zealand construction industry; the interview’s outcome affirmed substantial benefits accruable with successful BIM adoption. As reported by the authors, most interviewees noted time-saving, improved collaboration and coordination, improved visualization, clash detection, variation reduction, and risk reduction as significant benefits realizable with successful BIM adoption. They also felt the importance of additional benefits such as improved efficiency, improved cost management, and client satisfaction. The interview findings were in tandem with the available documented BIM benefits reported by scholars. Therefore, the benefits in Table 1 are acceptable globally, depending on the BIM adoption level and BIM manager’s knowledge.

4.3 BIM benefit check: Countries-based focuses

Decades ago, Eadie et al., (2013) evaluated the benefits of implementing BIM throughout the construction project lifecycle in the United Kingdom (UK) and found that stakeholders identified financial benefits as the most significant benefit, thus concluding that clients and facility managers benefit the most financially from BIM adoption. Babatunde et al., (2018) research study in Nigeria identified 14 benefits derived from using BIM. Information was sourced from the perspective of academia and students, focusing on two selected universities offering quantity surveys. However, these reported benefits are not well actualized in the country, as the government and lawmakers are yet to incorporate BIM as a requirement for building production (Toyin & Mewomo, 2021). Enshassi et al., (2018) studied the benefits of BIM in Palestine’s Gaza Strip construction industry. The authors identified 19 benefits derived from using BIM in Brazil, which were further classified into four groups. The findings revealed that the essential separate BIM benefits among the four main components are improved operation and management of buildings, lifecycle cost control, reduced change orders, increased coordination between contract parties, improved communication, improved safety, improved quality, and improved decision-making process (Chahrour et al., 2021). These findings are in tandem with various authors’ assumptions about BIM benefits, which makes the results valid and buttresses more validation of BIM capacities.

Hosseini et al., (2018) researched the need for BIM for an existing building. The authors clarified that there are numerous benefits of using BIM in an existing building, but these could not be achieved because of barriers hindering BIM adoption. The author documented these barriers in a broader review (Toyin & Mewomo, 2021). It was also established that this barrier caused a setback in appreciating BIM’s benefits of BIM. Ahankoob et al., (2022) study in Australia elicited information from experienced BIM users in Queensland. The findings show that their experience with BIM directly influences their ability to judge BIM capacity based on its possible benefits. Fourteen crucial benefits of BIM were identified. The survey findings revealed that, as building contractors in the country became more experienced in BIM applications, their understanding of the business values realized with BIM use improved. Jin et al., (2017) documented the following highly ranked benefits of BIM: providing new working areas, reducing rework, errors, and omissions, enhancing product quality, controlling costs and improving project quality. According to experts in the Chinese AEC industry, these were rated mostly from developed regions where BIM was used (Ding et al., 2015). Similar research was recently conducted by Liu et al., (2019), who focused on professional perceptions of BIM. Practicing professionals in Chongqing, China were contacted. Thirteen possible benefits of using

BIM were identified. Al-Ashmori et al., (2020) studied the benefits of BIM and its influence on BIM implementation in Malaysia. The authors noted seven (7) essential benefits that encouraged Malaysian construction companies to implement BIM.

Charlesraj & Dinesh, (2020) research on 4D-BIM adoption focused on the Indian construction industry. The authors identified the following as the most realized benefits of 4D-BIM: visualizing the construction flow, validating the time schedules by simulations, and communicating the construction plan. These are the most appreciated benefits of BIM in the 4D context of Indian construction. Habib & Kadhim, (2020) researched the 6D-BIM model, focusing on assessing its features for building sustainability. The authors identified seven (7) crucial benefits accruable with 6D-BIM. In their study, Khajavi et al. (2019) identified the key benefit of adopting a BIM model with digital twin to expand visualization management, which enables them to monitor the sensors quickly and take appropriate readings. Musa et al., (2019); Sanchez et al., (2016) studied the benefits of BIM integration in building production projects from the design stage to the construction stage. The expected benefits derived from BIM are time management, clash detection, easy takeoff, resource and data management, easy communication, and collaboration among professionals.

Shibani et al., (2020) research on the Iraqi construction industry focused on the benefits of adopting BIM in small and medium enterprises in the country. This study identified five important benefits of using BIM in Iraq. Othman et al., (2021) research in Malaysia identified the following vital benefits, prompting firms to adopt BIM in their projects: increased productivity and design efficiency, reduced time and cost associated with design change, integration of construction scheduling and planning, elimination of clashes in design, improved multiparty communication and synchronized communication, monitoring, and tracking of progress during construction, and identification of time-based clashes. Dowsett & Harty, (2019) focused on the benefits of BIM applications. The authors reported that the application of BIM can improve decision making, enhance the sustainability of buildings, reduce engineering conflicts, save resources, reduce design and construction changes, and help manage cost control. However, the contributions of various authors in this study provide a clear roadmap based on the focus of this study. Olawumi and Chan (2019) investigated and evaluated the primary benefits of BIM integration and sustainability practices in the built environment. The authors generated constructive information from built environment stakeholders in 21 countries, which identified the key advantages of green BIM as increasing project efficiency and productivity, enabling real-time sustainable design and multi-design possibilities, allowing the selection of sustainable materials and components, and decreasing materials.

4.4 BIM benefit summary and grouping

This section comprehensively summarizes the BIM benefits that have gained significant recognition over the years, based on the researchers' findings. These benefits were grouped into established stages in the building production life cycle, a method used in the BIM-related studies by Toyin & Mewomo, (2023). Figure 4 presents a summary of the benefits extracted from the literature.

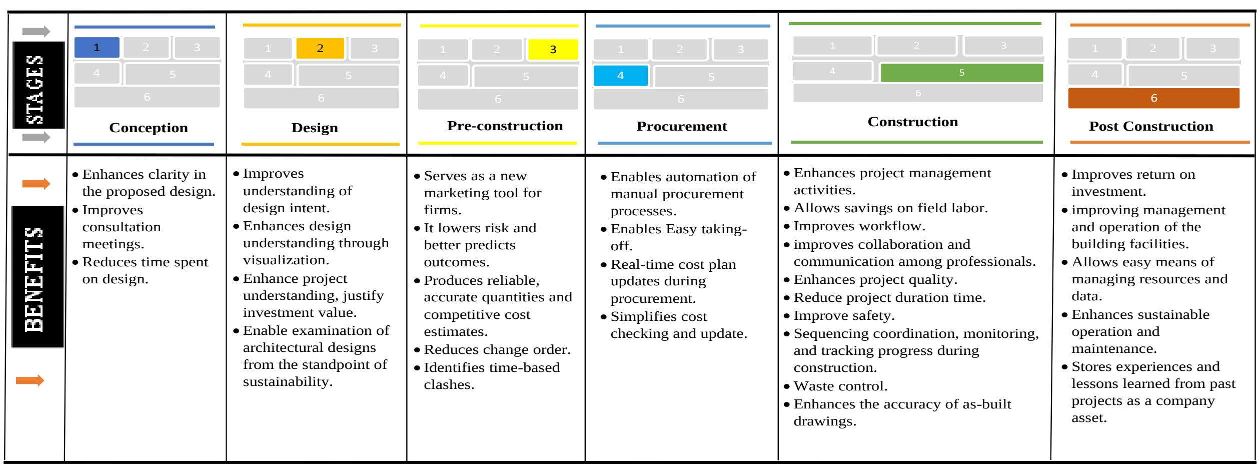

Fig. 4: BIM Benefits across the building lifecycle

4.4.1 Conception stage

This stage refers to the initial phase of a project, where the idea or concept for the construction project is conceived and defined and usually starts with the client and consulting professional. The client's proposed dream is documented, and the project's purpose, scope, objectives, and feasibility are outlined. Hence, the search for the right location, specifications, or standards to actualize the dream. Key activities include conceptualizing the design, defining the project goals, considering budgetary constraints, and assessing the overall viability of the construction project. The conception stage sets the foundation for the entire construction process and guides subsequent phases. Adopting BIM at this stage will aid in visualizing and simulating project concepts in 3D, thereby facilitating better communication among stakeholders. This visualization enhances understanding and helps in decision making and collaboration from the project's earliest stages. Thus, it reduces the time spent on the design, improves consultation meetings, and provides a clearer understanding of the proposed design.

4.4.2 Design stage

The design stage entails harmonizing the client's dream with what can be pictured by the AEC team in charge of the design through architectural, structural, mechanical, and electrical drawings. The design team must ensure that all environmental requirements and necessary building codes are satisfied, while preserving the client's vision and ensuring that the proposed structure is usable and sustainable. At this stage, BIM allows for detailed 3D modelling, enabling architects and designers to create a comprehensive digital representation of the project. This not only improves the design accuracy but also facilitates clash detection, reducing errors and revisions during the design process.

4.4.3 Pre-construction stage

The pre-construction stage follows the design stage; at this stage, the contractor is selected from either an open or selective tender and thereafter prepared to obtain the required construction documents, materials, and workforce to the site. BIM adoption can help prepare the site before work begins by identifying time-based clashes and reducing change orders while preparing to move the workforce to the site. BIM will also assist in accurate quantity take-offs and cost estimations during the pre-construction stage. It enables real-time updates to cost plans, enhances coordination among various project elements, and supports effective planning and scheduling, leading to improved project outcomes.

4.4.4 Procurement stage

At this stage, the project team orders labor, materials, equipment, and other utilities needed on-site. The application of BIM at this stage will benefit the team as the procurement process will be automated. BIM supports procurement processes by providing detailed models and specifications. This aids in creating more precise and comprehensive procurement documents, improving the accuracy of bids, and reducing misunderstandings among stakeholders.

4.4.5 Construction stage

The construction stage is the most delicate and highly capital-intensive. This stage determines the reliability of all efforts put in place. At this stage, the goal is to organize everything so well that everything works out without a problem. This rarely occurs because something always goes wrong during a building project. The application of BIM at this stage is vital as it assists in averting most of the issues that could arise. BIM enhances construction efficiency by providing a detailed 3D model that can be used for on-site coordination and communication. It supports better project sequencing, resource allocation, and clash detection, leading to efficient construction processes and reduced likelihood of rework.

4.4.6 Post-construction stage

This can be regarded as the last significant stage of every construction project. This entails commissioning of the project, owner occupancy, operation and maintenance, and project closure. The facility manager in charge of the project would need a series of details regarding the construction of the project, which will assist them in performing their duties diligently and effectively. BIM continues to be valuable during the post-construction phase of facility management. The digital model, enriched with data on components and systems, aids in ongoing maintenance, renovations, and facility management, ensuring that the building operates optimally throughout its lifecycle.

5. Case study: Nigeria

5.1 The need for BIM in Building lifecycle

Before the advent of innovative digital technology in the construction industry, built environment professionals worked solely. This process prolongs project delivery and limits sector growth (Succar et al., 2013). Presently, digitalization has reformed a broad range of architectural engineering and construction (AEC) sectors, causing a significant increase in productivity, product quality, and the availability of sophisticated infrastructure. This requires the construction industry to source highly skilled and competent construction managers capable of handling the innovative technologies that impact the industry. Digital tools are increasingly used in the AEC sector to design, construct, and maintain building facilities. Recent studies have reported that the AEC and facility management sectors are yet to develop a unique bond in utilizing BIM throughout the building lifecycle in developing countries (Olanrewaju et al., 2022). This may be because BIM is yet to reach a significant maturity level in the design and construction stages of these regions. In the process, essential pieces of information are lost, even though the information is primarily distributed in the form of drawings, whether in digital or physical printed form on paper in a restricted format. Such interruptions in information dissemination may occur throughout a building facility's lifecycle, including the design, construction, and operation phases as well as critical handovers between these phases (Borrmann et al., 2018). The scheduling and accomplishment of building facilities is a complicated procedure that involves diverse stakeholders with specialized knowledge. A constant understanding and frequent information interchanges between stakeholders are essential for successful building projects. This usually entails the handover of diagrammatical technical drawings of building projects in detailed drawings, vertical and horizontal sections, and various views (Sacks et al., 2010). The BIM tools used to create these drawings were designed to mimic the traditional method of using a drawing board. Computers, however, cannot comprehend line drawings completely, although computational methods can only partially process and interpret the information they contain. The great potential of information technology for project management and building operations is overlooked by relying solely on drawings for information flow. In traditional methods, the uniformity of various engineering drawings can only be checked manually, which is a major issue. Thus, it is a potentially significant source of error, especially because experts typically create drawings from multiple engineering disciplines and across different firms. It is challenging to manage design changes if they are not regularly recorded and conveyed to all relevant stakeholders. Inconsistencies are common and may go unreported until the building is complete when they incur considerable extra expenditures for ad hoc resolutions on site. Another significant problem with little information on engineering drawings is that downstream applications cannot directly use building design information for simulations, calculations, or analyses (Borrmann et al., 2018). However, it must be re-entered manually, which adds more labor and increases the possibility of error. The same applies to transferring information to the facility manager or building owner when construction is completed. They must devote considerable time and effort to gathering essential information for facility maintenance from accessible building documentation. Data previously accessible in digital form may be lost at each information-exchange point and must be carefully recreated. The BIM approach enables a more comprehensive use of computer technology in the design, construction, engineering, and O&M of building facilities (Olanrewaju et al., 2022; Seyman Guray & Kismet, 2023). BIM manages, saves, and transmits information using sophisticated digital representations known as BIM models, rather than drawings. Figure 5 presents a graphical representation of the main users of the BIM model and the flow of information from the users to the project and back to the model. This method significantly improves design activity coordination, simulation integration, construction process setup, and management and information transfer to facility managers (Lee et al., 2021). The green arrow represents the extraction of information stored in the model during the design and construction stages for use in the operation and maintenance stages of the project.

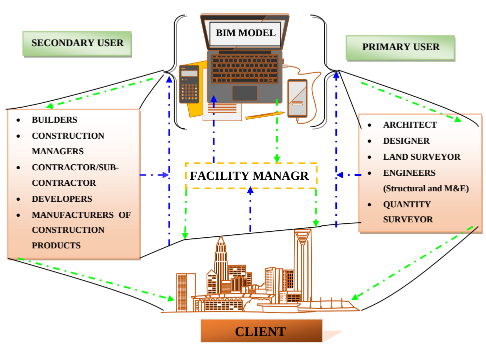

Fig. 5. Main users of the BIM model and information flow

Simultaneously, the flow of the blue arrow represents the return of updated information to the model, which can be used for future operation and maintenance. As communication and information management are essential among the stakeholders involved in the project lifecycle, the BIM technology model is required to harmonize the information and data generated from the conception stage, design, construction, and maintenance of the project closeout (Liu et al., 2019).

The section denoted as primary users contains the project stakeholders whose inputs are required during the initial project preparation, primarily during the design stage, after which they can visit the site to check the builder/construction manager's and contractor's conformity to their design. The proposed World Bank AGILE project comprises Lot 1-7; each lot has the following similar projects: block of four classroom bungalow, block of six classroom story building, block of eight classroom story building, block of administrative Block B, multipurpose hall, laboratory block, and gender-separated toilets. This project was spread across senior secondary schools (SSS) and junior secondary schools (JSS) in the selected state's local governments. Figure 6 shows the architectural frame design proposed by the architect team using the Revit-BIM authoring tool for one of the AGILE projects (a block of eight classroom-story buildings). From the model, the section denoted as secondary users comprised the project stakeholders responsible for bringing the drawings and documents produced by primary users into reality. The data and information generated and stored in the model within the project's five years of building and operation will help the client's facility manager to make an appropriate maintenance plan, as comprehensive information will be available.

Fig. 6. Building component architectural design using BIM tool.

Figure 7 shows the working drawing, which will be used on-site, and the necessary information will be updated on the BIM model as the construction progresses. The extent of the projects warrants the use of the BIM, as each lot has more than 20 projects spread within the states that require handling per contractor. The full project drawings- architecture, structural, mechanical, and electrical (M&E), land surveyor plan, and bill of quantity (BOQ) prepared by the quantity surveyor were combined as the project documents, which were then submitted for tender by interested contractors. The project adopted BIM technology to manage information flow throughout the design stage, and the contract required a successful contractor to build and operate the project for five years using the BIM model. As such, they were required to integrate the BIM from the design phase to the maintenance phase. Thus, it assists in properly managing the information and data generated during the design, construction, and O&M stages.

Fig. 7. Working drawing.

The contractors deemed qualified to submit for the project tender were required to submit comprehensive 4D BIM-related documents that could be used to track project progress while they took over the site. This was integrated into the BIM model. Figure 8 shows the preliminary mobilization schedule prepared by one company as part of the bid document. The essence of this schedule is to track important dates, comprehend information from the mobilization schedule with the main construction schedule to monitor work progress, and know the expected milestones where the client is likely to receive substantial project completion.

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Figure 9 shows the use of the BIM in the lifecycle of a BIM-based building project. The three most significant stages in the building project lifecycle were analyzed using BIM activities. The design stage captures four essential activities: planning, specification, law and regulation, and documentation.

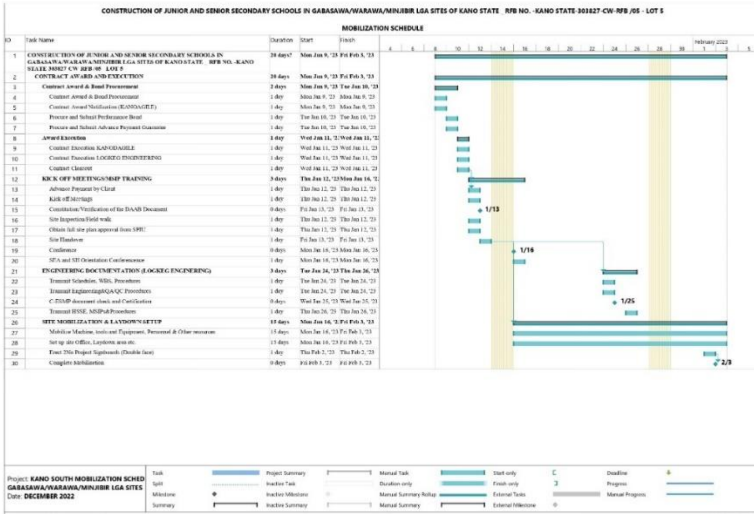

Fig. 8. Preliminary mobilization schedule using BIM tool.

The planning phase entails conceptual design, comprehensive design of the drawings, visualization, and 3D modeling of the designs. The specification phase necessitates the accurate detailing of the building components and elements in conformity with the design team agreement. The law and regulations cover the collection of necessary legal approvals that would allow the erection of the project, as stipulated by the country's building regulatory body before the project commences. The documentation phase involves reviewing and validating all the documents required to initiate the project.

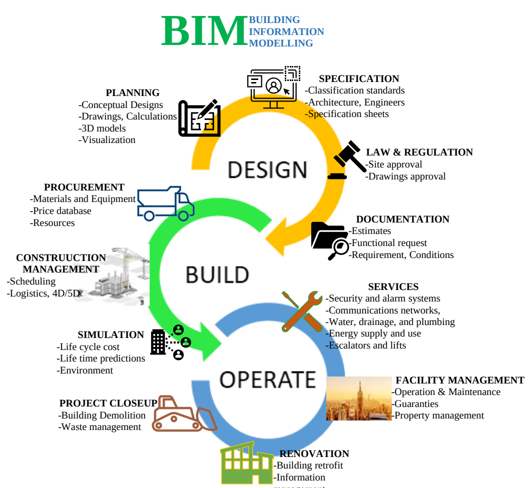

Fig. 9. Uses of BIM model during building lifecycle.

After completing the design stage, the next step was to move to the site to actualize the drawings. The building stage entails three significant activities: procurement, construction, and simulation. During the procurement phase, the resources required for the project are purchased and mobilized to the site. This activity likely spans the construction phase of a project. The construction phase deals with the project's on-site erection, focusing on available building documents. The simulation phase involves the final evaluation of the building components and elements in correlation with the designs; the final cost of construction is known at this stage. In addition, the expected lifetime of a project can be predicted and known with imputes from various stakeholders involved in the project. The last stage, known as the operating stage, entails four activities: services, facility management, renovation, and project closure. This phase

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of the building lifecycle involves the operation and maintenance of the building facility. The facility manager uses the information and data stored in the BIM model to design a comprehensive maintenance schedule and an adequate renovation plan when necessary. In addition, this information will assist in planning the best method of demolishing buildings and managing demolition waste during project closeouts.

6. CONCLUSION, RECOMMENDATIONS, AND FUTURE RESEARCH

The implementation of BIM in building projects has resulted in transformative changes to the traditional design, construction, and maintenance models. This study specifically focused on the AGILE World Bank project in Nigeria, conducting a preliminary evaluation of the need for BIM and documenting the extensive benefits associated with its adoption throughout the lifecycle of a building project. A bibliometric analysis of 2,108 retrieved documents with a brief discussion of 56 selected articles provided a comprehensive understanding of the prevalent recognition of BIM benefits by various scholars. The conclusions drawn from this analysis highlight the significant positive impact of BIM on building projects. Furthermore, a case study of the AGILE World Bank project revealed the recognition and initiation of BIM adoption by the World Bank in response to identified needs in the building lifecycle. The enforcement of BIM applications, particularly in Northern Nigerian projects, has been noted.

The scoping review identified the significant benefits of BIM adoption across the building project lifecycle. In the pre-construction stage, it enhances understanding, client engagement, and design clarity, and provides efficiency in design processes. During the construction stage, BIM improves project management, collaboration, safety, and decision-making and facilitates progress monitoring. In the post-construction stage, it ensures value for money, automates processes, and enhances building operations and maintenance.

Recommendations include encouraging BIM adoption in Nigeria, building on the success of the AGILE World Bank 2022 project, and urging other developing countries to integrate BIM swiftly for established benefits. The following future research is recommended: scholars may collaborate with the contractor awarded the project to document their experience with the BIM model. Scholars may try and discuss more BIM benefits through thorough research with BIM experts to draw the more crucial benefits that BIM offers in the building production lifecycle. Scholars may conduct research to seek the perspective of virtual design and construction (VDC) managers regarding the limitations of BIM at various execution phases and future expectations of BIM in the construction industry. Exploring the recommended gray area will contribute to the improved application of BIM.

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