Building Information Modelling and Project-Lifecycle

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The Architecture, Engineering, Construction and Operations (AECO) industry constitutes a cornerstone of a country's economy and is predicted to account for circa 15% of the World's Gross Domestic Product (GDP) by 2030. Construction outputs create critical infrastructure and buildings that cumulatively constitute the built environment which provides the basis for society and other industries to flourish; hence, the economic contribution is perhaps greater than the estimated "direction" contribution to the GDP. Annually, the AECO industry is responsible for nearly 40% of the total energy use, 32% of CO2 emissions and 25% of the generated waste in Europe. Furthermore, in many developing countries, the construction industry has undergone substantial fluctuations to accomplish its local economic objectives. As a result, many developing countries' financial procedures are in the process of improvement. In these countries, construction projects frequently face several time-schedule delays. Furthermore, the industry is faced with numerous productivity issues stemming from the lack of adoption of emerging technologies or concepts such as Building Information Modelling (BIM), blockchain, Internet of Things (IoT) and Industry 4.0. As a result, the construction industry in developing countries does not achieve government goals for society and clients, and a need for developing "overall success construction projects" that are resource-efficient has been underlined in the literature.

Keywords: building information modelling ; drivers ; Awareness

1. Introduction

BIM implementation continues to gain exponential momentum among global construction professionals [1]. For example, the National Building Specification (NBS) [2] revealed that there is a high level of BIM awareness in the UK, Canada, Finland and New Zealand. Consequently, BIM awareness and adoption have grown expeditiously from 10% in 2011 to nearly 70% in 2019 [3]. McGraw-Hill [4] revealed the implementation rate of BIM in Australia to be 64% while Rodgers, et al. [5] indicated a 48% level of adoption among Small–Medium Enterprises (SMEs). However, Tookey [6] revealed that there are doubts about the advantage of BIM in New Zealand's construction industry.

In sub-Saharan Nigeria (as an exemplar of a developing country), Anifowose, et al. [7] indicated the adoption level of BIM as 50% while Ogunmakinde and Umeh [8] recorded a 58% level of awareness. Olanrewaju, et al. [9] also reported a high level of BIM awareness at the design stage which concurs with the findings of Onungwa and Uduma-Olugu [10] where client satisfaction and drawing improvement were identified as the major reasons for BIM usage at the design stage. However, Olapade and Ekemode [11] reported that there is very low awareness of BIM implementation for facility management practices in Nigeria. Literature suggests that many Nigerian construction professionals are aware of BIM and its potential benefits. For other developing countries, Gamil and Rahman [12] highlighted that 38% of Yemen's construction practitioners are aware of the benefits of BIM while 8% are already implementing it. Similarly, Ismail, et al. [13] assessed the level of BIM uptake in Asian developing countries including China, Malaysia, India, Indonesia, Thailand, Myanmar, Sri Lanka, Mongolia, Vietnam and Pakistan. The study reported a low level of BIM implementation in the region. Nonetheless, China is at the forefront of BIM adoption due to its hybrid system, i.e., it has attributes of both a developed and developing country. Mehran [14] reported that the use of BIM in the United Arab Emirates (UAE) is gathering momentum while Shibani, et al. [15] indicated a low level of BIM awareness in Lebanon.

Recently, there has been positive feedback regarding BIM awareness in some developing countries such as South Africa [16]. This connotes that much work has been done regarding promoting the use of BIM in developing economies. Conclusively, construction professionals in developing countries are becoming aware of the benefits BIM offers, and the major problem lies in implementing BIM for construction projects. For instance, Olanrewaju, et al. [9] stated that only the Eko Atlantic City project has fully implemented BIM (i.e., from design to operation stage) in Nigeria.

2. BIM and Project Lifecycle

Raouf et al. [17] proffered that BIM has transformed traditional construction-project-management practices which in turn impact the project lifecycle. BIM usage varies across this lifecycle which is periodically punctuated by inputs from diverse professionals at various stages of development—defined for brevity as design (e.g., designers and architects), construction (e.g., contractors) and operation stages (e.g., facility managers) [9][18]. The BIM usage at different project lifecycle stages is shown in **Table 1** which was adapted from our previous study.

Table 1. BIM usage and awareness in project lifecycle.

Constructs	Code
Design stage	
Cost Estimation	**AW1**
Construction Planning	**AW2**
3D Coordination	**AW3**
Prefabrication	**AW4**
Visualization	**AW5**
Constructability Analysis	**AW6**
Sequencing	**AW7**
Construction stage	
Construction Monitoring	**AW10**
Maintenance Scheduling	**AW11**
Fabrication	**AW12**
Operation stage	
Asset Management	**AW13**
Building System Analysis	**AW8**
Record Modelling	**AW9**

Note: Adapted from Olanrewaju, et al. [19].

2.1. Design Stage

The design stage often involves a virtual collaboration between the architect/designer, structural engineer and mechanical and electrical services engineer to ensure design clashes are minimised in a federated model [20]. In addition, depending on the country's legalizations, BIM models are implemented using different software (ArchiCAD, Revit or SketchUp, CYPE MEP, DDS-CAD,). These models are imported into simulation software packages (e.g., Ecotect or IES-VE) to assess building features and sustainability. After the successful design, the quantity surveyor is responsible for using BIM tools such as costX, Navisworks or Vico to generate thorough cost analysis and Bills of Quantities. The final designs and cost details are then presented to the client for contractor selection and project commencement. In summary, BIM in the design stage not only enables visualisation of the project and design but also enhances the project by reducing the cost without affecting the quality. Chahrour, et al. [21] expressed that BIM offers cost savings through early clash detection in design before the project execution. It has also been viewed as a tool that facilitates a smart contract-automation process and effective collaboration among team members [22][23]. Cheng, et al. [24] argued that BIM has the potential to enhance the efficiency of facility maintenance management for MEP components (mechanical, electrical and plumbing) in building projects.

2.2. Construction Stage

During the construction stage, the "as-designed" BIM model produced is used by the contractor and consultant to ensure appropriate cost and time management and track the project progress; however, changes will be needed to reflect the final "as-built" structure to cater to client variations [18]. Olanrewaju, et al. [9] also highlighted construction monitoring, maintenance scheduling and fabrication as the main uses of BIM during the construction stage. Similarly, Eastman, et al. [25] mentioned monitoring, modelling and fabrication as the major uses of BIM. The 3D models contain essential data related to building projects essential for BIM procedures, far better than usual construction methods [26]. BIM techniques deliver the chance to organize project data, such as building geometry, and construction typology that can be used in creating informed decisions [27][28]. Consequently, BIM represents an effective tool for obtaining an accurate model that reflects the "as-is condition" or "as-built" condition in a project [26]. Currently, key technological advances enabled detailed three-dimensional (3D) models to illustrate the "as-is condition" of buildings projects [29][30]. Three-dimensional laser scanning is a reality-capture technique that aims to collect the greatest and extremely accurate data about "as-built" or "as-is condition" [26].

2.3. Operation Stage

The operation stage is characterised by maintenance and facility management operations aimed at improving the building's lifespan. Comparatively, this area attracts less research, and general awareness is low (even in developed countries); however, some advanced applications in the industry are apparent [31]. Within the developing country of Nigeria, Olapade and Ekemode [11] expressed the low level of BIM awareness among facility management professionals. Additionally, Olanrewaju, et al. [9] reported a low level of BIM awareness at the operation stage in the Nigerian construction industry and potential applications that include asset management, building system analysis and record modelling. Elsewhere, Xu, et al. [18] also mentioned that BIM could be used for emergency management, lifecycle management and facility management. In addition, the implementation of the BIM concept in the building industry also belongs to the category of the digital twin approach for enhancement of building maintenance [32]. Digital twin has been the subject of various classic studies for increasing performance and decreasing operating costs in assets, machines, processes and specific applications with different integration and levels [33]. As a result, throughout the BIM implementation process, the design concept is turned into a three-dimensional model and then progressively into architecture for better performance maintenance procedures [32].

3. Drivers of BIM

The construction industry is characterized by poor document and information management which negatively impacts the project's lifecycle. Saka and Chan [34] also reported that the industry is notoriously slow to adopt modern digital technologies such as BIM which has stunted industry growth and modernity. In recent years, BIM has grown in popularity as a tool for design and construction in the built environment across the world [1][35]. BIM has developed as a solution, with significant promise for generating, consolidating and maintaining these connected databases, which contain essential information for a facility (or a portfolio of facilities) to assist operations and maintenance [36]. In addition, Nieto-Julián, et al. [37] agreed that BIM can support members of a multi-disciplinary team from the heritage field by providing data interoperability. Furthermore, the study (ibid) revealed four major drivers of BIM adoption in Nigeria, viz.: (1) construction-related; (2) process-digitalization- and economics-related; (3) sustainability- and efficiency-related; and (4) visualization- and productivity-related. Stransky and Dlask [38] suggested that BIM aids decision making during project execution and improves construction productivity. Similarly, Eastman, et al. [25] asserted that BIM improves collaboration among project teams. Studies also highlight the benefit of BIM in cost estimation and management processes [19][39].

BIM has also been considered as a crucial tool in promoting sustainable construction/buildings through the term "Green BIM" which aims to reduce the impact of construction activities on the environment [40][41]. Amarasinghe and Soorige [42] demonstrated the use of BIM for building Lifecycle Assessment (LCA) and made recommendations on how to improve BIM-LCA assessments. The innate visualization capability of BIM is another critical driver for its adoption as it enables the client to virtually preview their proposed structure before construction commences. This empowers the design team with the flexibility to adjust certain building features in line with the client's comments [19][25]. Lin and Hsu [43] adopted BIM to support problem visualization and management using a web-based API. This demonstrates the ability of BIM to visualize problems and work progress at an early stage. **Table 2** summarizes the BIM drivers extracted from existing literature reviewed and categorized based on the BIM drivers' groups identified in [19].

Table 2. Drivers of BIM implementation.

Drivers	Code
Construction-related driver	
Construction planning and monitoring	**D13**
Synchronized design and construction planning	**D12**
Facilities management record model	**D14**
Improved decision-making process	**D11**
Improved productivity and collaboration	**D10**
Process-digitalization- and economics-related driver	
BIM-enabled estimating capabilities	**D2**
Controlled whole-life costs and environmental data	**D4**
Potential economic benefits	**D3**
Lifecycle data	**D8**
Sustainability- and efficiency-related driver	
Green building standards incorporation	**D6**
Increased efficiency and coordination	**D9**
Improved customer service	**D7**
Visualization- and productivity-related driver	
Construction process visualization	**D1**
Improved quality and increased sustainability	**D5**

Note: Adapted from Olanrewaju, et al. [19].

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