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BUILDING INFORMATION MODELING (BIM): FRAMEWORK FOR PROACTIVE CONSTRUCTION MANAGEMENT

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Abstract

Building Information Modeling (BIM) is relatively recent in construction procurement management. Tremendous improvements are reported since BIM was introduced. The technology which accommodates software packages to execute diverse construction management tasks witnessed rapid development and functional applications. However, it was observed that the BIM technology is still developing and therefore, still lapses in managing construction projects in a proactive manner. There's a gap to inquest to know key weaknesses of this technology. This work aims at assessing key weakness of BIM in view to developing a framework for its improvement as a more proactive tool in managing construction projects. Extant literature has recommended best practices at various milestone in a procurement practices. These may include -effective knowledge management, process flaws prediction, culpability indicator, forecast quality results of end products and modelling cost changes at different milestone in a project procurement process. These are tenets of proactive management and models to achieve them are still in dearth. Three subsystems namely- best practice modules, knowledge management mechanism and mathematical forecasting model were developed and synthesized into a proactive model that improves proactive management in BIM. This framework improves BIM proactive management capability and recommended for application.

Key words: Building Information Modeling (BIM), Construction procurement, forecasting model, Framework, Proactive management

Introduction

Construction procurement has a history of being notorious in management glitches. Most often, challenged by its complex nature (Fidelis, Stanley, Kaetonna and Nathan, 2018), thus, defiling fervent managerial efforts. The results of these have been poor quality work, persistent claims, extended completion periods and excess cost. The advent of BIM has improved performance over most of these anomalies (Kong, Lau, Wong and Phan 2020) having tinkered with the construction complex nature. The benefits of BIM in construction procurement are many, well acknowledged and documented in literature (Crotty, 2012; Masood, Kharal and Nasir, 2013, Zichen and Riazi, 2024). Vilutiene, Hosseini, Pellicer and Zavadskas (2019) described the BIM technology as currently the most innovative methodology across the construction sector. It is a game changer in the working pattern of the built environment sector work, changing from bungling processes to a practice that is more dynamic and intelligent (RICS, 2017, Yang and Wang, 2020). Notably, it improves stakeholders' collaboration across organizational boundaries and providing intelligent digital representation of facilities in support of diverse activities all through the life cycle of projects (Vilutiene *et al.*, 2019). Estimate by the European Construction Industry Federation puts it that 15-25% cost savings on global infrastructure market is possible by 2052 if a wider global adoption of BIM is attained (Kjartansdóttir and Snæbjörnsson, 2017). Many governments like the US, UK, Germany have strong policies on BIM implementation in construction (Kalfa, 2018). It is not gain saying that BIM technology has come to stay in the construction sector and is already performing marvelous jobs.

The numerous benefits in adopting BIM in construction explain why the technology has witnessed wide and quick acceptance into the production system in contrast to the previous trend of resistance to change and slowness to innovations (Gholizadeh, Esmaeili and Goodrum 2018). Many countries have adopted BIM in construction procurement because of its importance (Kalfa, 2018). The degree of adoption and success level of BIM from different countries are narrated on positive notes, with the US, UK and Germany at the leading positions (Kalfa, 2018).

Mbarga and Mpele (2019) described the BIM technology as not being software itself but an ICT platform where different software packages are hosted to interact and offer management solutions. The platform hosts CAD, information management and collaboration technologies to address architectural, structural, and electrical and HVAC work tasks (Wierzbicki, de Silva and Krug, 2011)

The way BIM started and its developmental pattern from a simple 2D to n-D package was documented by Masood et. al. (2014). The varying software packages being hosted in BIM related to Architecture, Engineering and Construction (AEC) were also listed. The relevance of BIM to the varying stakeholders in the construction supply chain was discussed (RICS, 2017). According to Kong et al. (2020), the BIM technology development has reached a stage that enables its application by stakeholders in managing all the phases of construction life-cycle (i.e. the pre-construction, construction and post-construction phases). Within these phases, domicile the many software packages hosted on the platform that aid in the management of diverse construction activities such as designs, modeling, quantities take-off and estimating, electrical and mechanical services, structural designs, etc.

BIM and procurement of construction infrastructure

Construction procurement passes through stages as the product idea develops into real existence. The stages may include pre-design (pre-planning), design (planning), bidding (contractor selection), construction (assembly) and handover (closing) (Aung, 2018; Ismail, Zulkifl, Baharuddin, Ismail and Mustapha, 2021, Umar, Waziri, Samuel and Yahaya, 2022). Each of these stages is not without constraints that prevent successful completion. BIM has been applied at various stages to improve the procurement success level. For example, an investigation into the level of applications of BIM in construction planning process was carried out in Lagos State, Nigeria. It was found that BIM has mostly been applied in design, drafting and visualization within the study area (Opoko, Sholanke, Joel, Caiafas, Fakorede, & Oyeyemi, 2019). Quantitative research by Umar et al. (2022) pin pointed the most beneficial stage in BIM application in the Nigerian construction processes. Twenty-four benefits of BIM covering four construction stages (Pre Design, Design, Construction and Post Construction Stage) were investigated. The Design Stage was ranked highest as most beneficial. It mainly allows early collaboration which minimizes errors and omissions, allows consistency of all working drawings as per design intent, automatic corrections when changes are made in the design process and opportunities for review and options (Umar et al., 2022). Matos, Cruz and Branc (2024) sought for an enhanced BIM-based procurement processes and the successful BIM implementation in construction projects. The motivation was the absence of BIM-specific procurement guidelines, standards and regulations to integrate with conventional construction procurement methods. The research introduced a systematic approach for integrating BIM requirements into traditional tendering processes for construction works, applicable to both the public and private sectors, serving as a reference guide for contracting authorities.

However, it is imperative to inquest on the level of BIM's technology development? To what extent is it actually addressing construction glitches? What are the weaknesses evident in it deserving improvement to enhance its performance? These are fundamental and pertinent inquests this research attempted to address. Deficiencies in BIM software packages relating to tools and information interchange format have already been noticed (Ustinovicius, Puzinas, Starynina, Vaišnoras, Cerniavskaja, and Kontrimovicius, 2018). Anumba (2020) pointed out that BIM's proactive capacity needs enhancement. BIM requires enhanced capabilities in predictive analytics and automated decision-making (Emmanuel, Danquah, Ukpoju, Obasa, Olola and Enyejo, 2024). Suggestions on how BIM can be proactive have also been made. These suggestions are still in disarray. This work therefore, is an appraisal concern that raised the need to underscore the stage of BIM technology development towards clear articulation of what aspects deserving research attention for its improvement, with special focus on proactive management. Most researchers have discussed the benefits, the developmental pattern and adoption levels, but focus on appraisal concern seems under-stated. This research therefore sets out to:

i. Assess the BIM context along its developmental pattern
ii. Identify key management flaws and BIM's weaknesses in addressing them
iii. Discuss proactive management conception
iv. Synthesis, existing models into a framework for BIM proactive responses to construction flaws during procurement process.

LITERATURE

The BIM context, development and application

The present BIM technology was a revolution which came in a pattern extending over time. However, it was described as rapid and its adoption by the construction sector wide **(**Gholizadeh, Esmaeili, and Goodrum, 2017, Akadiri, and Omisakin, 2020). This deviates from the general notion that construction is resistant to change and slow to innovation thrust.

The BIM concept was birthed by Professor Charles Eastman from Georgia in the late 1970s (Latiffi, Brahim and Fathi, 2014). Within a span of 50years it has broadened its perspectives via inputs from other scholars, and is now applied all through the building life cycle including conception, design, estimation, construction assembly, occupation, and performance management (Latiffi, Brahem and Fathi, 2014, Aung, 2018).

The technological progression of BIM and key area of application at each milestone of its development as in Table 1 indicate that the Building Description System (BDS) which was its cradle in the 1970s, was initiated mainly to coordinate designs. Later in 1989 the Building Product Model (BPM) came up. BPM was an improvement that brought in estimation, construction process and involvement of players in the construction process into BDS(the BDS which centered mainly on design applications only).

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Table 1: BIM developmental account

Year	Packages/ Application	Design application	Estimation	Construction process	Involvement of construction players	Concepts, technologies, standards and projects	Constructability and construction management	Corporate and construction activities	Physical information and architecture of building	Building life-cycle	Use of computer software	Tool to control projects	Methodology of interacting projects	Use of technologies	Increase effectiveness and efficiency	Project simulation using 3D	Modelling	Proactive management
1970s	**BDS**	✓																
	GLIDE	✓	✓															
1980s	**BPM**	✓	✓	✓	✓													
1990s	**GBM**					✓	✓	✓	✓									
2000s	**BIM**									✓	✓	✓	✓	✓	✓	✓	✓	
2010 to date																		?

Source: Adapted from Latiffi et al. (2014)

However, communication under BPM focused entirely on information that aid product and didn't integrate information and knowledge required for design and construction management. The Generic Building Model (GBM) improved on these bringing projects information which enhanced incorporation of construction activities. It was further noticed that the more complex and challenging construction requires a wider adoption of ICT for better performance and expectation that was lacking in GBM. The BIM technology was achieved for this purpose. By 2013, BIM has expanded to become a technology revolution that transforms the way buildings were conceived, designed, constructed as well as operated. BIM has performed excellently as a tool for construction cradle to grave management. Nevertheless, how proactive is BIM managing each stage of the construction process flow is an issue requiring attention. In Table 2, Kalfa (2014) documented the firms that developed or improved BIM software packages from its cradle up to 2010, and also took note of major contributions of BIM at each stage of construction lifecycle.

Table 2: Contributors to BIM Development

	Organizations	Date founded	Major contribution of the software developed
1	Tekla	1966	Structural software
2	Autodesk	1982	Architecture, engineering and building construction, manufacturing, and media and entertainment software
3	Benitley	1984	Solutions in the scale of the building, plant, civil and geospatial vertical markets for architecture, engineering, construction, and operations.
4	Nemetschek	1985	In the field of architecture, engineering, and construction; entertainment; landscape design; and manufacturing software
5	Onuma	1995	Internet address created and developing Onuma Planning System (OPS) as an internet server model.
6	Solibri	1999	Market solutions that improve the quality of BIM and making the design process more efficient; optimizing BIM processes and allow the user to analyze the models for integrity, quality, and physical security; checking for clash detections and code verification, with a function locating the error on the original model.
7	Gehry	2002	Software that provides technology and services to owners, developers, architects, engineers, general contractors, fabricators, and other building industry professionals
8	Innovaya	2006	Solutions on the BIM environment and specifically to the building construction and looks at interoperability issues between the Autodesk solutions and other construction management software
9	Vico	2007	Software that link the design of the project with the construction phase, that allow to create the model from scratch and simulate construction process inputting cost, creating earn value analysis and "what if" scenarios
10	Synchro	2010	Solutions to the project management area and specifically to project schedule, linking the geometry of the project to many scheduling software and allowing the simulation of the project as well as resource management.

Source: (Adapted, Kalfa, 2014)

The first set of software developed was by Tekla in Finland for structural designs (Kalfa, 2014). After then, it took about 16 years before Autodesk and then other organisations followed suit to add value as indicated. The significance of both Latiffi (2014) and Kalfa (2014)'s account lies not only on the presentation of a brief developmental pattern of BIM, but the scholars agree that the technology grew over a time frame. Each stage addressed varying aspects of construction challenges depending upon the scientific breakthrough in the software technology introduced. Currently, the application of BIM in solving construction glitches covers all stages in the entire construction whole-life-cycle (Kong et al. 2020). Activities, including early design, design and detail, construction, fit-out and handover, and facilities management and operations are achieved (Adujar-Montoya, Galiano-Garrigos, Rizo-Maestre and Echarri-Iribarren, 2019). Table 3 summarises a typical application of BIM in managing key construction stages in the case of Malaysian construction sector.

Table 3: BIM application in Malaysia

Phase	Stage	Uses of BIM
Pre-construction	Existing conditions modeling	Enhances accuracy of existing conditions documentation
	Planning	Identifies schedule sequencing or phasing issues
	Design	Facilitates better communication and faster design decision Performs clash detection and clash analysis -increases design effectiveness
	Scheduling	Enables project manager and contractor to see construction work sequence, equipment, Materials and tract progress against logistics and timelines established.
	Estimate	Enables generation of take-offs, counts and measurements directly from a 3D project model
	Site analysis	Decreases costs of utility demand and demolition
Construction	Construction	Enables demonstration of construction process, including access and exit roads, traffic flows, site materials and machines. Provides better tracking of cost and cash flow. Enables tracking of work-in real time, faster flow of resources and better site management.
Post-construction	Operation facilities management	Keeps track of build asset Manages facilities proactively Enables scheduled maintenance and provides review of maintenance history.

Source: Aung (2018)

BIM Tools and Technology in construction

The development of BIM encompasses a history of add-ins. Software packages were developed and added to **BIM** platform. Kalfa (2014) classified BIM software into six groups as those related to- architectural, structural, construction, mechanical/electrical/plumbing (MEP), sustainability, and facility management. Each subgroup focuses on a specific discipline in the sector. Philip and Mordue (2017) identified some tools with relevant software packages in a procurement system as in Table 4. BIM tools often cover, but not limited to architectural, structural, electrical, mechanical, management and site work 3D modeling software (Ugochukwu, Akabogu, and Okolie, 2015). It is imperative noting that the BIM technology which began as a tool for a particular construction profession to undertake specific task (Kalfa 2014) is now a package used by all the professionals in the sector (Saad, Ajayi, and Alaka, 2023). Adujar-Montoya et al. (2019) discussed the relevance of the BIM technology to the Architecture, Engineering and Construction (AEC) industry where the function as mere information exchange and clash detection transformed into a larger field of management applications.

Table 4 BIM enabled tools and technologies

Tools	Purpose	Relevant software
Design Authoring Software	Provides the ability to aid the design and construction by generating data for multiple uses, in 2D and 3D. Tools may be specific to a discipline and use parametric capabilities using a combination of graphical information and data.	● Revit (Autodesk) ● Tekla Structures (Trimble) ● MicroStation (Bentley) ● Archicad (Graphisoft).
Scheduling software	Provides ability to schedule works by contractors on a project. Some software integrate the graphical model with time based capabilities to provide construction sequencing (often referred to as 4D Modeling)	● Vico Office (Trimble) ● Synchro Pro (Synchro Software) ● Navisworks (Autodesk).
Cost tools	Provides for quantity takeoff and estimating. Costing capabilities may be linked to Design authoring tools via plug-ins.	● Solibri (Solibri) ● Navisworks (Autodesk) ● Vico Office (Trimble).
Model Review Software	Provides ability for project team members to view, navigate and interrogate model information. Some software also offer additional functionality such as model checking for clash detection	● Solibri Model Viewer (Solibri) ● TeklaBIMsight (Trimble) ● Trimble Connect (Trimble) ● Rendra (Rendra O) ● Dalux BIM viewer (Dalux)
Field Management Software and Field BIM Software	Provides the ability to collaborate, report and feedback to a project model, using a combination of mobile and cloud technologies.	● BIM 360 Field (Autodesk) ● Trimble Field Link (Trimble)
Computer-Aided Facilities Management tools (CAFM)	Provides the ability to manage, report, track and plan facilities functions. May include or interface with CAD systems, Information models and Computerised Maintenance Management Systems (CMMS)	● YouBIM ● Mainmanager ● FM: Systems

Adopted: Philip and Mordue (2017)

Along this trajectory, a good BIM application should have 6 key characteristics (Dace, 2006 and Campbell, 2007 in Liu *et al.* 2013) as:

i. digital (capacity to simulate design and construction phases),
ii. spatial (3D representation of complex construction conditions),
iii. measurable (with quantifiable and query-able data),
iv. comprehensive (building performance, constructability, project schedule, etc.),
v. accessible (enabling information sharing to the whole project team through an interoperable platform), and
vi. durable (reflections of as-built conditions throughout the life cycle of a building).

Ten aspects of BIM application suitable for diverse professions were also listed by Campbell, 2007 in Liu *et al*., 2013 which are as Tale 5: While the foregone discussions explicitly present the developmental pattern of BIM and what the technology does in the construction sector, the functional list seems to abstract the mention of some key construction requirements.

Table 5: BIM application

	Application	Explanation
1	Design visualization	visualize and communicate design intentions
2	Design assistance & constructability review	assists the design team and helps perform constructability review
3	Site planning & site utilization	study and estimate site conditions
4	“4d” Scheduling and sequencing	visualize and optimize construction sequences
5	“5d” Cost estimating	facilitate the quantity survey of building components for cost estimation
6	Integration of subcontractor and supplier models	incorporate detailed data from subcontractors and vendors into BIM models
7	Systems coordination	identify and resolve conflicts between different systems prior to the installation
8	Layout & fieldwork	facilitate the layout of materials and systems on site
9	Prefabrication	assist in the prefabrication of building components
10	Operations & maintenance	support facility maintenance and management

Adapted: Liu *et al.,* (2013)

These include guide on best practice, flaws predictions as well as stakeholders’ management culpability which relate to proactive functions. These were not clearly document suggesting a gap in the BIM technology that deserves keen attention.

Improved BIM Technology

Research work is on -going to improve the BIM technology. Waqar, Othman, Hayat, Radu, Khan, Galatanu, Almujibah, Hadzima-Nyarko and Benjeddou (2023) set out to identify key gaps in BIM practices and undertook a comprehensive examination of the current state of adoption and implementation in construction projects. The researchers noted some deficiencies and obstacles that impede its widespread implementation and efficient utilization.

Emmanuel, Danquah, Ukpoju, Obasa, Olola, and Enyejo (2024) in a review of the application of BIM in the construction sector highlighted the specialized functions of BIM that are particularly beneficial to construction management in the U.S. which included clash detection, 4D scheduling and cost estimation. In attempt to clearly explain how the technology enhances project outcomes, dominant challenges were identified and a critically examination in addressing them using of the BIM were analyzed. The research recommended enhance capabilities in predictive analytics and automated decision-making in future advancement.

The diminishing productivity of construction projects due to increase complexity and the lack of adoption of novel technologies led to identification of features of BIM helpful for enhancing the capabilities of project managers in applying knowledge areas in the Construction Industry. Ten key knowledge areas including procurement, cost, risk, stakeholders, quality, communication, resources, schedule, scope and integration and sixty-six features of BIM helpful in enhancing the capabilities of PMs in application of knowledge areas were found (Raza, Tayeh, Aisheh, and Maglad, 2023). Kong, Lau, Wong ad Phang (2020) in a quantitative study identified lack of standards and frequent design changes causing poor effectiveness of BIM in terms of time and cost in the Malaysian construction sector. In contrast however, there are reduced project timelines and enhanced cost efficiency in the US construction sector by virtue of BIM implementation. It is believed that the poor success level in Malaysia is due to the relative recent BIM adoption. (Kong et al., 2020).

Construction Flaws and BIM Flaws

Construction flaws: identifying the perennial flaws that bedevil construction procurement in view to better understand how BIM has or can address them is essential at this level. Construction flaws that impede project success are classified into two broad aspects identified as the direct and indirect impediments (Shane, Molenaar, Anderson and Schexnayder, 2009; Kanchana and Sukumaran, 2018) or internal and external risks factors in projects (Tanhankar, Gupta and Desai, 2018). The BIM technology must act/react against them in a proactive manner to be efficient and effective for an improved procurement result. The internal flaws originate within the construction organization. These are mainly human factors relating to actions, poor actions and inaction of stakeholders (Liu et al. 2016). Construction project stakeholders do influence and have some degree of control over internal flaws. The external flaws are those that originate from outside the construction organisation and stakeholders have less influence on them. Issues like inflation and government policies are among these kinds of flaws that affect construction success level. Still, the strong fragmentation of activities in the traditional project delivery approach (Kia, 2013), the ad-hoc nature of its supply chain leads to difficulty in project coordination, communication and collaboration. Construction is beleaguered with complex flow of data during project life cycle (Masood, Kharal and Nasir, 2013), poor collaboration, weak exchange of technical information in the supply chain and large multiplication of errors (Mbarga and Mpele, 2019). There's high waste profile, knowledge capital flight and slow adoption to innovations such as the ICT (Mohandes and Omrany, 2015). Both internal and external flaws disrupt construction budgets, quality as well as process flow leading to unsuccessful projects implementation (Gandu, Musa-Haddary and Zaki, 2021). As part of a solution, managing projects proactively becomes necessary (Song *et al*., 2017). Knowledge management was identified as key element in a proactive response to the identified internal and external risks (Gandu *et al.* 2021). Knowledge must therefore be expressly managed to be sufficiently proactive in addressing construction risk and uncertainty (Liu *et al.,* 2013, Gandu *et al*. 2021). This involves organizing, creating, sharing and the flow of knowledge within organizations (Lin and Lin 2006).

The BIM technology flaws: There are certain construction management aspects that BIM is yet to satisfactorily address (Saad, Ajayi, and Alaka, 2023), and most of the factors relate to proactive management. A proactive BIM should be able to manage the identified construction challenges. However, despite the tremendous breakthrough in the application of BIM in construction business, Anumba (2020) stated clearly that "we are not there yet and more needs to be done regards BIM advancement". Cha and Jiang (2020) asserted that new trends in BIM are still emerging, thus, accepting a paradigm continuum. Yang and Wang (2020) was very concerned about how to accelerate the development of informationization and intelligentization, and improve productivity. Furthermore, BIM maturity isn't sufficient to generate and capture knowledge, i.e., knowledge management is still a stand-alone process separated from BIM implementation (Liu, Jallow, Anumba and Wu, 2013). The scholars then highlighted the importance of the proposed Building Knowledge Modeling (BKM) as an integrated multimedia technology process to capture potential knowledge in BIM process, collaborate and manage knowledge throughout the life cycle of a facility. This involves the integration of knowledge capture, sharing, reuse and maintenance with passing of formation to stakeholders from planning to design, construction and operation phases. The research then concluded by proposing a framework with its constituents to facilitate BKM.

Cha and Jiang (2020) reviewed results of research works from 19 publications on BIM application in construction to present more recent advances in the development of BIM technology and application in the field of Architecture, Engineering and Construction (AEC). Several aspects of AEC including BIM and Lean Constructions or Last Planner System (LPS) were reviewed. The flaws identified with BIM related to lack of integration with the last planner system, weaknesses in work efficiency, project management, health and safety management and fire safety in both the construction and operation stage. A review of plug-in publications by (Saad et al., 2023) was aimed at availing hidden areas where BIM capabilities can be expanded. The researchers developed a framework for easy plugins of innovations into BIM platform, the plugins enabling expanding BIM abilities to reach tasks that are less acknowledged. Saad et al. (2023) stated that BIM is developing, and their research found progression in custom-based plug-ins along construction automation, health and safety and lifecycle assessment. In similar research earlier, Vilutiene, Hosseini, Pellicer and Zavadskas (2019) presented five research themes in the expanding BIM capabilities, relating to inter-organizational and cross-disciplinary collaboration, BIM adoption in SMEs, benchmarking the BIM use level, BIM technology integration with web technologies and augmented reality technologies, BIM-based digital fabrication and BIM applications.

Furthermore, Yang and Wang (2020) were more specific that the application of BIM to risk management is less effective-being an aspect viewed as still developing. The authors listed a wide range of risks that are concerned. Anumba (2020) posited that the User Behaviour Modelling, Building Knowledge Modelling and Proactive Process Control are either still emerging or lacking in BIM model. Improvement along this line therefore becomes important as well as fundamental need to embed knowledge modeling, last planner integration, fire, health and safety management into BIM (Liu *et al*., 2013, Cha and Jiang, 2020). However, success in every management effort begins with best practice (Gandu *et al.*, 2021) and the BIM technology further seem to lack a compass to direct users on best practices, or dos and dons at varying construction process milestones. A proactive BIM seems less attended to in research efforts. Fundamentally, BIM should improve on the direction of being more proactive than its present status (Anumba, 2020).

Proactive Management Concept

The "proactive" concept is not new in construction. Terminologies like forecasting, predicting, estimating and anticipatory management has been long in construction management and connote proactive management but that robust models to attain a more feasible proactive demand is lacking (Gandu, Mbamali, Zubairu and Musa-Haddary, 2018). To be "proactive" entails being predictive and preventive on flaws, including quick detection and resolution of anomalies (Kim *et al.,* 2011). It exploits a prior knowledge about uncertainties to generate a baseline solution (Song, Kang, Zhang and Xi, 2017). The proactive system is a forward looking concept (Song *et al*., 2017) aided by formal exchange of information, proper documentation, tracking and reporting of project events well-structured consistently, and presented in a recognised and common language (Arrow, 2008). This facilitates a preemptive response in management process (Johnson, 2010; Kim *et al.,* 2011, Song *et al.,* 2017). In a summary, proactive rudiments include:

i. Best practice of process implementation (Gandu *et al.*, 2021)
ii. Managing knowledge by documenting, tracking and reporting flow systems in right manner (Arrow, 2008).
iii. thinking ahead, anticipating and planning for exceptions (Kim *et al.,* 2011).

iv. availing at hand the culpability of risk factors and user behaviour (Song *et al.*, 2017)
v. laying down clear mechanism for preventive and quick response (Kim *et al.*, 2011, Song *et al.*, 2017)
vi. acting rightly in preventive manner (Johnson, 2010)
vii. responding quickly to exceptions before any damage impacts ((Kim *et al.*, 2011).

Anumba (2020), Cha and Jiang (2020) and Yang and Wang (2020) submit that the BIM technology is yet to sufficiently meet the proactive demands of construction management. Chan and Jiang (2020) foresee making technology more adaptable to the development of the industry in the future research focus. Meng (2020) also presented the importance of developing a proactive and collaborative culture in construction.

METHODOLOGY

The gathering, evaluating and analyzing existing literature has been recognized as popular and used severally in addressing research questions (Saad *et al.*, 2022). This work established a gap related to the topic from literature and identified key models to develop a proactive framework. Key words including BIM, Framework and Proactive construction management were searched from Google Scholar, Science Direct, ResearchGates and Academia. The result gave 147 articles which were screened and 30 were identified for consideration. Models which are still in disarray were identified and subsequently synthesized into a framework for a proactive BIM. The models identified relating to proactive management as below are also discussed:

1 Best practices — Gandu *et al*. (2021)
2 Managing knowledge — Liu *et al*. (2013)
3 Managing exceptions
  a. culpability factor — Johnson 2010
  b. cost-time relationship — Gandu *et al*. (2018)
  c. Quick and adequate response to flaws occurring — Kim *et al.* (2011)

Best practices

Success in production begins by ensuring best process implementation. The bedrock of proactive management is using best approach and guide in process implementation. Monitoring and control brings back deviations to plan in process flow. Each construction stage has recommendations on best implementation steps (Gandu *et al.*, 2018). Being largely an assembly process, most construction components come with established guidelines and instructions manuals. Twelve modules with itemized best practices for a typical construction process flow were collated by Gandu *et al.* (2018). The stage of implementation in the flow process and key stakeholders answerable were identified. The modules covered key management functions as Table 6:

Table 6: Procurement best practice modules

Sn.	Best practice Modules	Stage of implementation
1	Supply chain management	Inception
2	Process design and management	Planning & Execution
3	Contract placement	Planning
4	Cost estimating	Planning
5	Cost advise to client	Planning
6	Cost control	Planning & Execution

7	Process monitoring	Inception, Planning & Execution
8	Lessons learning	Inception, Planning & Execution
9	Continues process improvement	Planning & Execution
10	Change management	Planning & Execution
11	Stakeholders management	Planning & Execution
12	Strategic initiative	Planning & Execution

Source: Adapted from Gandu *et al.* (2018)

Details of each module are intended to guide on proper implementation of projects so as to mitigate flaws. However, where flaws occur, quick and adequate response become inevitable (Kim *et al.*, 2011). The modules can be broader to include health and safety management and fire safety in the construction or operation stage which seems to have been left out by the scholars (Liu *et al.,* 2013, Cha and Jiang, 2020). The proactive BIM technology therefore, should guide the stakeholders on best implementation of work modules in the process flow and act sufficiently on exceptions.

Managing knowledge (The BIM learner)

Learning brings about knowledge and knowledge in construction comes overtly or covertly through instructions or personal experiences obtained within and outside the construction environment. The knowledge of pattern and frequency are used in predicting the future (Gandu *et al.,* 2021). Persistent construction flaws in Egypt were blamed on knowledge gap (Hafez, Aziz and Elzebak, 2015). The BIM technology should learn from successes and failures of construction procedures. Failure should not be repeated. Hafez *et al.* (2015) and Liu, Zhao and Yan (2016) presented some human and natural factors in a risk profile that impedes construction success which should form a key learning domain. Li, Fang and Sun. (2016) used quantitative method to estimate the probability distribution of risks attributes and their criticality to project success. The research collated experts' opinion and used the Monte Carlo simulation and Kolmogorov-Smirnov test to avail risks' probability of occurrence and the level of impact. This availed knowledge from data. Yu, Yang, Tseng and Yu (2007) developed a knowledge management model that is proactive. The components are:

1. Knowledge expert map that captures and present knowledge that is critical to knowledge management
2. Automatic problem answering (APA) - uses historic problem-solving cases and lessons learned to solve new problems by searching into a solution database to provide most appropriate answer to problems.
3. Automatic problem dispatch (APD) - sends unsolved problems from APA to appropriate domain for possible solution.
4. Lessons Learned Wizard (LLW) - accumulates historic lessons-learned as new lessons for future use.

Capturing construction knowledge prevents the loss of critical knowledge capital due to retirement, downsizing, and outsourcing, or discards of experts and professionals at the end of projects- failure of which is great loss of assets. Developing an appropriate strategy to capture construction project knowledge through appropriate technology, techniques, concept and tools becomes inevitable. Knowledge and experiences are often lost in many construction sites due to poor management, but user friendly technology can easily manage such knowledge. Knowledge which could be from external and internal domain, covert or overt in nature should encompass everything relating to a project. It covers but not limited to human traits (Yu *et al*., 2007**),** act of God (Hafez et al., 2015), market forces (Gandu *et al.*, 2021) and statutory policies (Liu *et al.*, 2016). To predict and proactively act against such uncertainties learning must happen by data collating and analyses. Gandu *et al*. (2021) recommended that lessons should be deliberately captured, processed, stored and retrieved when needed. A process flaw culpability management system was then proposed, the model which essentially captures flow inefficiencies from internal and external factors and the data used to predict future occurrences (Table 4). Table 4 is a sample of risk profile in which project participants assess the likelihood of occurrence and possible impact. Each mean indicates a culpability test of an item and its source. Thus, the culpability of stakeholders as well as that of each risk factor avail (Table 7). This assessment continues periodically all through the procurement process. The mean values documented as knowledge repository.

Table 7: Risk occurrence scorecard

	Obligation	Risk profile	Likert's Scale					Probability of occurrence or impact factor
			1	2	3	4	5	
	General factors	Site condition						
		weather conditions,						
		natural disasters,						
		government actions						
		material supplies						
		Inflation						
		Bureaucracy						
		Accident						
	Client related	Adequate brief						
		Project funding						
		Commitment to project success						
		client's interruptions						
		Delays						
	Contractor related	Experience,						
		Poor planning						
		Contractor's commitment						
		Work quality						
		liquidity						
		staff qualification						
		response to site instructions						
		Site accidents						
		client's interruptions						
		Health and safety measures						
		Fire safety measures						
		Delays						
	Consultants related	Project cost estimate						
		Variation order						
		Site instructions						
		Constructability of design						
		Designs detailing						

Source: Li *et al*. (2016), Gandu *et al.* (2018)

Cost-time relationship

Predicting cost changes in construction is necessary. Even though difficult, cost management is inevitable in attaining construction success. Cost Change cannot be captured and managed through opinions, but better achieved by collating historical cost data. Time series have been used to predict how future cost of labour, materials or entire buildings will be. A mathematical model was developed to monitor cost changes of building elements at different milestone within a construction process (Gandu *et al*. 2018) as follows:

$$T_p \quad = x_1(1 + pr_1) + x_2(1 + pr_2) + x_3(1 + pr_3) + \cdots + x_n(1 + pr_n) \quad - eqn. 1$$

$$= \sum_{i=1}^{n} (1 + pr_i)\ x_i \qquad - - - - - - - - - - - - eqn. 2$$

***T_p** -total cost of a project at a particular point. x_i -is the estimated cost of an element in a proposed construction facility, the variable x_i is obtained by first principle of estimating method. r_i -is the yearly rate of change in cost of element x_i computed using historical cost data (HCD) over a long period. The value, r_i can be expressed quarterly by dividing r_i by 4 or in any other timeframe.*

The model accepts three variables- cost, time and cost change to avail current project cost implication at a particular milestone. It also means that the model can proactively avail the future cost at any point within and outside contract period.

DISCUSSION

This research was set to appraise BIM as a construction projects management system in the view to developing a framework to make the technology more proactive. BIM disrupted not only the way construction management is being handled but the negative views about its response to innovations was changed. The technology is being deployed to solve many construction challenges in the entire life cycle of projects. However, the question on whether the BIM technology has attained its zenith of development was addressed. Literature established that BIM is not sufficiently proactive in managing construction projects. Key among its poor proactive rudiments identified relate to guide on best practices in the process flow, management of knowledge capital and the predictive tendencies which might encompass predicting cost changes, the culpability of both risk factors and the associated stakeholder as well as the human traits that impact projects success. Figure 1 summarises management expectations from a proactive BIM system. The figure depicts the performance requirement of the proactive BIM system which addresses the identified anomalies. The management domain manages all events relating to success or failure. Knowledge domain receives cost data from market conditions, and from process flow and individual's traits. The best practice and preemptive/reactive domain positively impact on the management of market forces, process flow and the human traits.

The performance expectation is that the proactive BIM should enable lessons learned from the knowledge management domain. The knowledge domain captures successes and failures for lessons learning process. The preemptive and reactive domain checkmate process flow inefficiencies. This is achieved by predicting what risk might occur and who is responsible which makes possible for contingency plans to contain beforehand. When risk occurs, it should guarantee quick and right reactions to minimize the negative impact on the project.

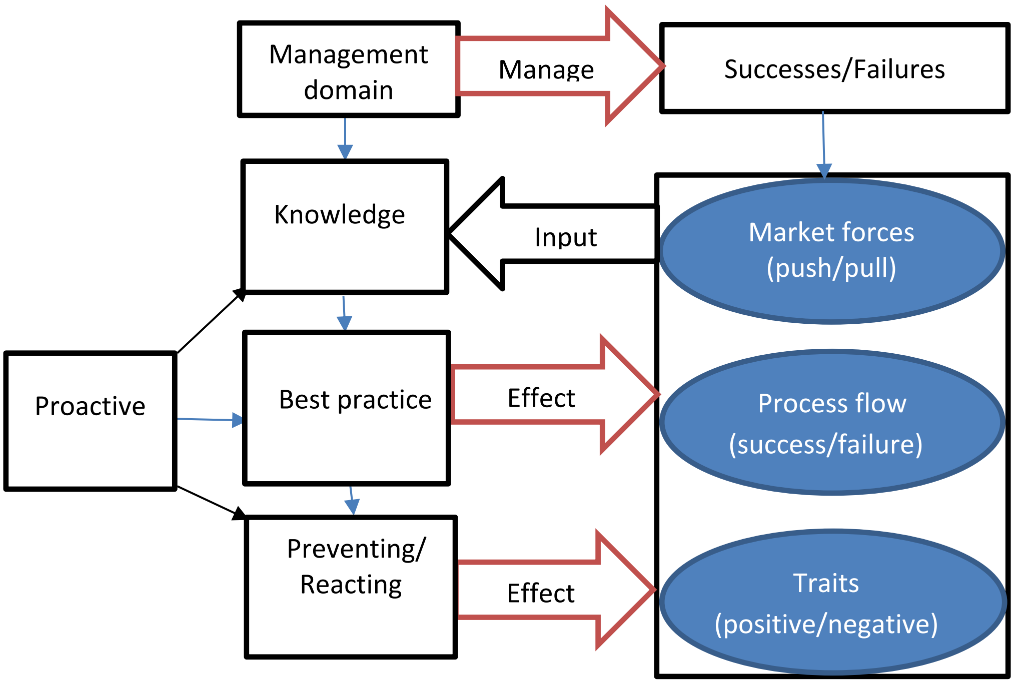

Figure 1: BIM performance

Managing knowledge and predictions of risk factors that might occur is carried out at each milestone from inception throughout the project period. Preventive action impacts on the team members, market conditions and process flow. Any anomaly from any domain should receive quick and right responses during the project. The anomalies are those coming from market forces, process flaws and disruptive human traits. However, there must be best practices relating to cost-time relationships, process implementation and right behaviors of team members involved in the implementation of the project. Table 8 summarises the key content and responsibilities of each subsystem.

Table 8: Expectations from proactive components

	Subsystem	Key content	Responsibility
1	Best practice	Collate best activities relating to: • Supply chain • Planning • Change management best • Resource control, etc.	Provide instruction manual for each factor on how best to implement.
2	Preventive actions	• Cost management models • Exceptions culpability indicator • Participants' culpability indicator	Predict market changes, flow inefficiencies like chances of risk occurrences and failed actions or inactions of participants likely to harm the projects process implementation
3	Reactive mechanism	• Quick identification of flaw that occurred • Clear response procedures	Smart flaw indicator of flaws Contingencies against predicted or impromptu flaws

4	Knowledge management	• Intrinsic and extrinsic lessons learning • Successes and failures capture	Lessons captured, processed and stored

THE PROACTIVE BIM FRAMEWORK

Figure 2 is the framework for a proactive BIM management. It consists of three subsystems synthesized into a proactive model. The first subsystem consists of twelve management modules that cover the entire construction process. Each module contains steps for best implementation. From project conception to closing, the modules guide each milestone. It is a prompting subsystem that queries if a particular action has been achieved or certain procedures followed. Each stakeholder ticks yes or no. For example, regards the supply chain management, the system asks all viable questions in achieving best practice.

The second subsystem is a score card that assesses the frequency and impact of risks profile. It is a collation of impediments to success if they occur but grouped according to their sources. The origin may relate to either natural sources or from the stakeholders involved in the procurement process. Each stakeholder assesses the card in a Likert's scale and the culpability factors computed. For example, how can weather factor affect the project; is the contractor fully mobilized to site? Answers to these can depict the culpability and source. The queries are designed to capture both the external and the internal risk factors.

The card is assessed periodically from inception till the project closing. Accumulating the results of the assessment become valid data that offer clear culpability trend in each risk factor and the associated stakeholder. The stakeholder and the risk factors' performance are clearly depicted. Predicting which risk factor will occur, which stakeholder is associated to it or who will fail in his responsibility and whether the project as a whole will succeed or not become possible within the contract duration.

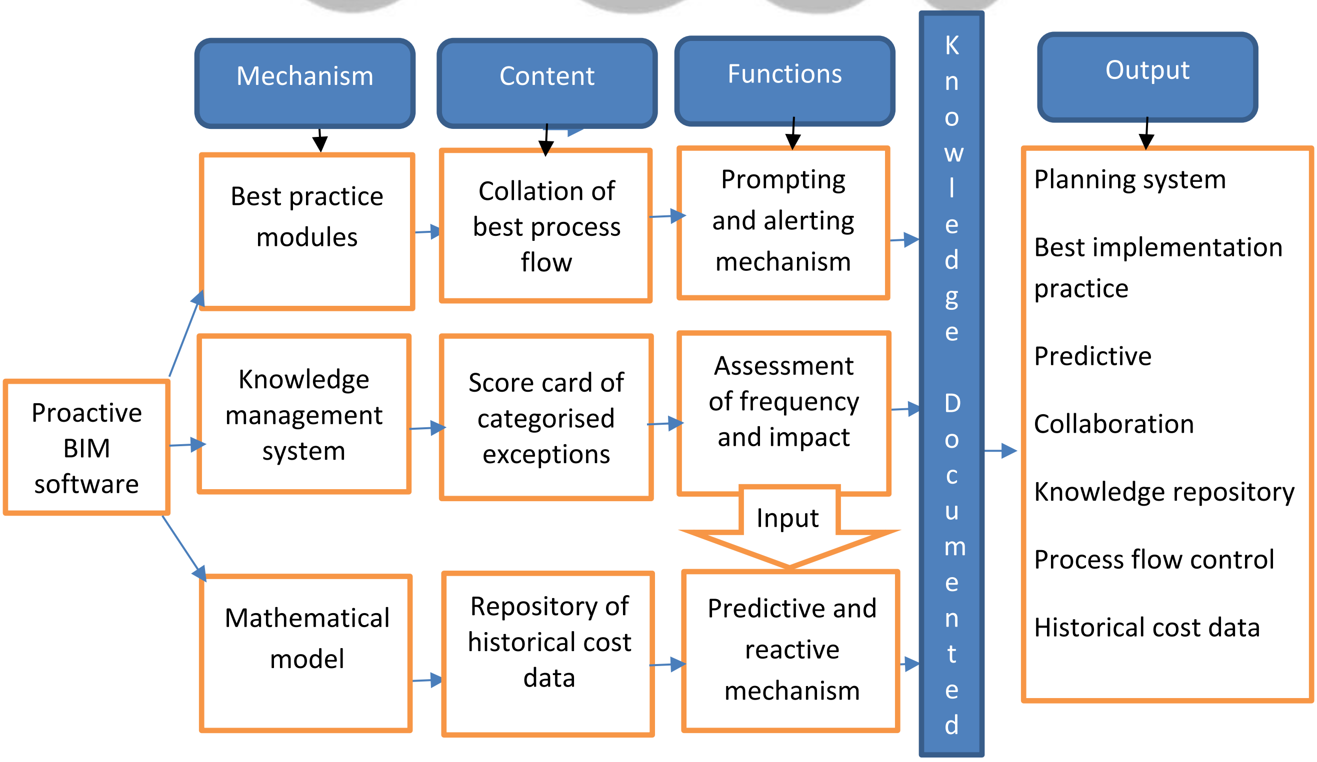

Figure 2: Framework for Proactive BIM software

The third subsystem is a mathematical model developed which addresses the cost changes that cannot be captured in a score card system. Historical Cost Data over a long period capture those forces that cause market cost movements. This is used to establish the yearly rate of change of the cost of the elements of a construction facility. It is keyed into the mathematical model along with value of each element, and the point in time as three variables to compute the total cost of the entire facility. Each value computed depicts the cost of the facility at a particular point with respect to the three variables input. This model can be used to avail the cost growth in every element at any milestone within and outside the contract period, the total which gives the entire cost of the facility. The software is expected to be both a guide, collaborative, predictive, knowledge managing, and planning system.

CONCLUSIONS AND RECOMMENDATIONS

The building information modeling (BIM) attained its present status over an expanse of time. It has revolutionized the construction procurement process, yet it is established that there are some aspects of services the technology is yet to address. This work has clearly identified the key weaknesses inhibiting the BIM technology bringing to fore areas BIM is lacking. Being proactive is one aspect desiring BIM attention. What proactive means and what a proactive BIM should do was also made plain. Thus, areas for research focus for scholars to dabble into are identified. A framework was developed for a proactive BIM. Software that will improve BIM performance along proactive tendency can be developed being guided by the framework put forward.

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