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BIM Implementation for PMBOK Enhancement in the Construction Industry

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The construction industry has made significant improvements in adopting and integrating emerging technologies. One example is the wide use of Building Information Modeling (BIM), which offers numerous benefits to the construction industry. BIM assists project teams in achieving better quality with lower risk, shorter timeframes, and reduced costs. Meanwhile, the Project Management Body of Knowledge (PMBOK) defines the required discipline to meet stakeholders' needs. PMBOK aims to facilitate the achievement of predefined project deliverables and improve project goals through effective communication and decision-making processes. This paper presents a questionnaire-based investigation to measure whether BIM implementation enhances the PMBOK in projects and whether BIM positively affects Project Management Knowledge Areas (PMKAs) on a global scale. The questionnaire consisted of 7 general questions, 37 PMBOK-oriented questions, and 4 questions targeting BIM advantages and obstacles. 95 experts participated in the survey based on the LinkedIn search and survey invitation. The results showed that BIM dramatically influences the quality of execution of PMKAs, specifically in Project Integration Management. Additionally, the study examined the effect of BIM on the product lifecycle that BIM improves project coordination and discovers clashes during the engineering phase. In the construction phase, BIM facilitates as-built drawings and enhances communication, and during the post-construction phase, BIM enhances facility and components' lifecycle management. The research also found that the most significant obstacles to implementing BIM are the lack of experts, value propositions, and efficient training.

Key Words: BIM, Knowledge Areas, PMBOK, PMKA, Project Management

Introduction

Achieving project goals timely and cost-effectively has been a primary challenge of traditional construction management approaches while managing every aspect of project management through contract documents and addressing the dynamic needs of employers. In response to this challenge, the Project Management Body of Knowledge (PMBOK) offers an integrated project management

framework. PMBOK aims to cater to the satisfaction of all stakeholders, encompassing not only project owners but also project teams and end-users (Project Management Institute, 2021).

At the project's outset, stakeholders often possess a limited understanding, which can lead to errors or oversights. To enhance their comprehension, stakeholders can utilize walk-through applications that integrate BIM and Virtual Reality (VR) (Alizadehsalehi, Hadavi and Huang, 2020). Additionally, during construction, stakeholders may have an ambiguous vision of the consequences of their decisions on the final deliverables. As an nD digital model, BIM provides a realistic and futuristic perspective, which aims to render the final deliverables (Yang et al., 2021). Additionally, BIM employs automatic change-interdisciplinary tools to measure and represent the effects of any alterations, thereby enhancing project deliverables (Luo and Chen, 2018). BIM can improve project outcomes throughout the entire lifecycle of a construction project. During the engineering phase, engineering teams can intelligently manage changes (Luo and Chen, 2018), detect clashes (Liu and Zou, 2021), identify workforce interferences (Kim and Grobler, 2009), and provide reliable cost estimations (Zhang and Man, 2018),. The construction team can then benefit from enhanced communication (Sharma, Sawhney and Arif, 2017), resulting in fewer defects, lower costs, and shorter timelines (Yang et al., 2021). Simultaneously, BIM proves instrumental in risk discovery, enabling project teams to make a predictive decision before any issues arise (Yang et al., 2021). Upon project handover to maintenance teams, BIM can help maintain critical information that affects continuous operation, including equipment and components lifecycle (Pour Rahimian *et al.*, 2020). Furthermore, in times of crisis, BIM can facilitate efficient management (Yang *et al.*, 2021). Through circular economy implementation, elements could be reused, thereby reducing greenhouse gas production levels (Akbarieh et al., 2020). Therefore, to amplify the positive impact of BIM on projects' deliverables, this paper measures the cumulative effect of BIM and PMBOK.

1. Literature review

1.1.Project Management Body Of Knowledge (PMBOK)

PMBOK is a standard that provides a platform for professionals to define project goals, enhance communication between stakeholders, reduce risks, improve quality, and prepare project management tools (Project Management Institute, 2021). This standard is based on ten knowledge areas, as shown in Figure 1. The standard encompasses the entire lifecycle of a project, from inception to completion (Faraji *et al.*, 2022). Hwang et al. (2018) showed five knowledge areas have the most effect on megaprojects and general project cost control, including communication, procurement, risk, time, scope, and human management knowledge areas. The survey also showed that the scope has the most significant effect on managing megaprojects due to the complexity and added interfaces (Hwang *et al.*, 2020). Investigating the project delay, Sepasgozar et al. (2019) found that PMBOK is one of the factors that should be considered in delay analysis (Sepasgozar *et al.*, 2019). Two components commonly used to identify project success, successful project management, and successful deliverables. The first one focuses on three factors: scope, time, and cost. Successful deliverables concentrate on the application of deliverables or services during the post-construction phase (Varajão and Carvalho, 2018). A framework is proposed using PMBOK to identify and achieve a successful project. The framework aims to evaluate the conventional success factors including time, cost, quality, etc. through PMBOK (Takagi and Varajão, 2020). Artificial Intelligence (AI) is expected to influence cost, time, and risk within a decade. On the contrary, processes relying on human knowledge and experience will be less affected, for instance, team development and stakeholder satisfaction (Fridgeirsson *et al.*, 2021).

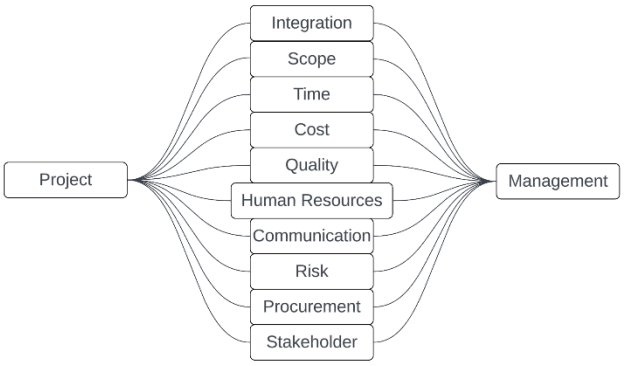

Figure 1- Project management knowledge areas

1.2.Building Information Modeling (BIM)

A construction project lifecycle typically comprises two primary phases: the preconstruction phase, which includes design and engineering, and the construction phase (Project Management Institute, 2021). The subsequent post-construction phase encompasses operations, maintenance, facility management, and asset management. BIM accurately represents the current state of design and facilitates precise estimation of time and costs in the engineering phase. Additionally, BIM expedites engineering and clash detection, enhances problem-solving, and facilitates reengineering when necessary (Zahedi and Sardroud, 2023). In the early stage of engineering, BIM could provide an accurate Life Cycle Cost Analysis (LCCA) (Ullah, Lill and Witt, 2019). Project teams relying on BIM can deliver improved conceptual designs and feasibility studies, leading to enhanced resource conflict resolution. Stakeholders will benefit from energy consumption optimization through BIM utilization(Ullah, Lill and Witt, 2019). (Crowther and Ajayi, 2019) discovered that BIM streamlines the predictive decision-making process by comparing planned and actual progression, asserting its ability to enhance time and knowledge management, ultimately improving understanding within the project lifecycle. On the other hand, employing BIM in construction projects will result in reduced material waste (Heigermoser et al., 2019). Project managers can effectively manage physical resources due to improved communication and find it easier to prepare accurate as-built drawings. Furthermore, BIM facilitates the control of Health, Safety, and Environmental (HSE) risks, enabling reliable predictive decision-making. During the operation phase, BIM facilitates efficient facilities and asset management. Operation teams, armed with a comprehensive archive of equipment and component information, can anticipate component lifecycles and plan for maintenance and replacements, ensuring continuous operation. In times of crisis, operation teams can also manage the situation efficiently with fewer injuries and less property damage, thanks to the wealth of information and data available through BIM (Figure 2) (Zahedi and Sardroud, 2023).

BIM exerts a positive effect on project management knowledge areas (PMKAs) of the Egyptian construction industry, significantly enhancing various facets of project management. This influence extends to project risk management, communication management, cost management, and schedule management (Figure 3) (Shaqour, 2022). Similarly, a 2014 study illustrated substantial improvements in PMKAs' overall project management quality attributable to BIM's contribution to managing project activities, goals, and deliverables, with a focus on the Iranian construction industry (Fazli et al., 2014). Despite the well-documented advantages associated with BIM, numerous studies highlight persistent challenges hindering its widespread implementation. Recent research identifies five major universal

BIM implementation barriers: the lack of experts, lack of awareness, high initial investment, absence of rules and regulations, and lack of employer demands (Zahedi, Sardroud and Kazemi, 2022).

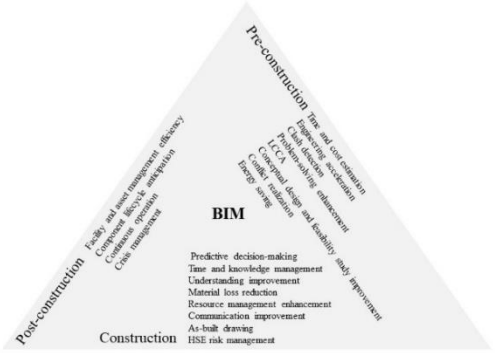

Figure 2- Effect of BIM on project phases

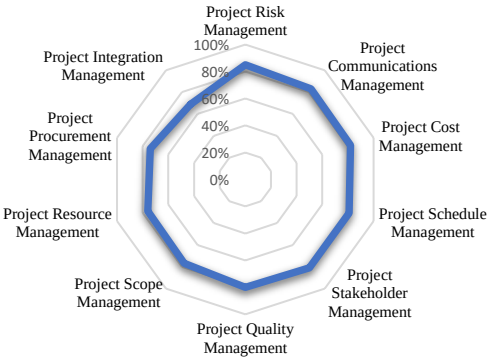

Figure 3- Effect of BIM on PMKAs

2. Research Method

A questionnaire was meticulously designed and distributed to decision-makers, experts possessing specific expertise, and individuals known for their reliable judgment to comprehensively address the impact of BIM on PMBOK knowledge areas implementation quality. The opinions gathered were verified using a Delphi-based method, heavily relying on participant input. However, a noteworthy challenge in this approach is the absence of an established criterion for selecting participants and evaluating their qualifications. Studies suggest collaborating with anywhere from 10 to over 2000 people. Consensus can be achieved with a more modest group, typically 10 to 20 respondents when the participants share similar characteristics (George et al., 2010). In cases where participant homogeneity is lacking, it is suggested that a broader range of 15 to 30 respondents should contribute to reaching a consensus (Martino, 1993). The questionnaire consists of 48 questions organized into 12 sections that merge PMBOK tasks. The initial section aims to collect general information about the respondents. Subsequent sections, numbering ten, correspond to each PMBOK knowledge area. The final section encourages participants to identify notable BIM accomplishments in construction projects.

The questionnaire included the following structure:

- Seven questions gather general information such as contact information, experience, job, and education through short answer and check mark questions
- 37 5-point questions measure the effect of BIM on PMKAs and subtasks
- Four multi-choice questions measure the effect of BIM on the project and obstacles to implementing BIM

A total of 95 experts were identified through a targeted search on the LinkedIn platform using keywords such as BIM, PMBOK, Project Management Body of Knowledge, and Building Information Modeling/Modelling. All invitees are actively engaged in the industry or academia, boasting a solid background. The invitees prove a reliable professional experience, certification, or education pertinent to the survey subject. Despite extending invitations to 95 experts from diverse countries, only 12 professionals from eight countries actively participated in the research. Recognizing that achieving consensus typically requires input from 15 to 30 respondents (Martino, 1993), the results were discussed with three decision-makers through face-to-face interviews to verify

the outcome. The decision-makers included a megaproject project manager, a CEO of a consultant engineering firm, and a Project Management Office (PMO) manager from a corporation specializing in the oil and gas industry. The interviewees not only confirmed the gathered opinions but also validated them against practical experiences. Ultimately, the study concluded that BIM plays a pivotal role in enhancing the adoption of PMBOK, contributing to the achievement of its targets and goals. Specifically, the Project Integration Knowledge Area, responsible for integrating all knowledge areas from inception to deconstruction, experienced the most positive effects. Given that the survey aimed to collect expert opinions to measure the impact of BIM on PMBOK and motivate the construction industry, a single-round survey was deemed sufficient.

Among the participants, the majority (67%) were master's graduates, followed by 17% PhD graduates and 8% bachelor's or other certification (Figure 4). Based on Figure 5, While 50% of the respondents worked in consulting firms, none worked in client organizations or manufacturing. Additionally, over one-third of the participants worked in contracting firms, while only one respondent was a researcher, and another had an occupation that was not predefined. Figure 6 illustrates the diverse professional backgrounds of participants in construction and BIM. Most respondents boasted between 5 and 10 years of experience, accounting for 42% and 50% in construction and BIM, respectively. An equal amount of 33% of participants had less than five years of experience in BIM and the construction industry. Furthermore, 8% of respondents possessed over ten years of experience in BIM.

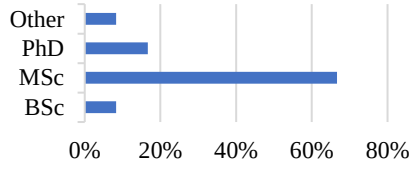

Figure 4- Participants' education level

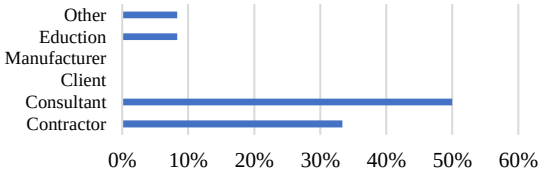

Figure 5- Participants' occupation

3. Findings and discussion

The present study collected data through an international survey to gauge the impact of BIM on PMBOK implementation in construction projects. The participation of experts in the study yielded valuable insights into the topic, revealing that the adoption of BIM in construction projects can lead to improvements in the quality of PMBOK implementation. Table 1 showcases the five achievements derived from BIM and PMBOK integration, ranked in order of consensus among the experts.

As depicted in Table 1, the study found that BIM and PMBOK integration is expected to improve all knowledge areas. Notably, the findings emphasize that project integration management stands out as the knowledge area poised to gain the most significant advantages from the incorporation of BIM. Consequently, BIM has the potential to streamline the project integration process, fostering more efficient and effective project management practices. These results underscore the capability of BIM to elevate PMBOK implementation in construction projects and stress the importance of recognizing BIM as a valuable tool in achieving project management goals. Beyond assessing the impact of BIM on PMBOK implementation, the study also sought to identify which tasks in the pre-construction phase would see the most improvement through the adoption of BIM. Figure 7 presents the results of this analysis, indicating that BIM would primarily enhance project understanding and detect clashes before construction commences. Approximately 58% of respondents believed that BIM would enhance accuracy in cost estimation, which can significantly influence project planning and budgeting. Additionally, 50% of participants accepted that BIM would result in better communication

between stakeholders, a vital element for ensuring stakeholders' involvement in project communications. The study posits that BIM can play a pivotal role in improving preconstruction tasks, ultimately contributing to more successful project outcomes. Effect of BIM on PMKAs is depicted in Figure 9.

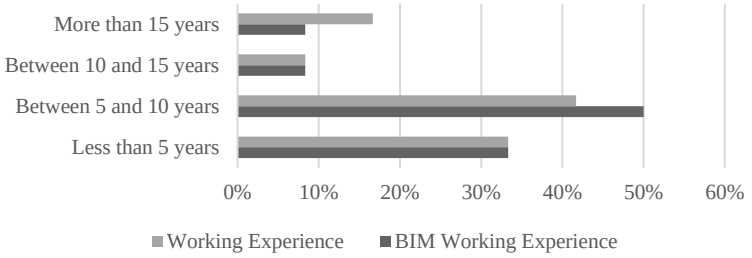

Figure 6- Participants' Working Experiences

The study further evaluated the effectiveness of thirty specific items in project management to elucidate how BIM can enhance project outcomes. The results presented in Figure 8, reveal that more than 65% of the respondents believed that BIM facilitates the creation of accurate as-built drawings- a crucial component of project documentation. Additionally, around 60% of the participants acknowledge that BIM improves communication among stakeholders, highlighting its potential to enhance collaboration and coordination throughout the project lifecycle. Half of the respondents also expressed that BIM implementation leads to improved sequencing accuracy, a vital aspect in ensuring that project tasks are carried out in the correct order and on schedule. Concurrently, BIM aims to detect interferences among the workforce, offering project managers valuable insights for implementing corrective actions. These findings provide nuanced insights into how project management can be enhanced using BIM, emphasizing its potential as a valuable tool for achieving project goals.

Table 1. *The five most important PMKAs improvements through BIM*

Grade	Effect	Knowledge Area
1	Detecting interferences before happening	Project resource management
2	Approving required plans, policies, and procedures relying on a 3D virtual model	Project integration management
3	Monitoring and controlling project activities (time, cost, control, quality, etc.)	All knowledge areas
	Change management	Project integration management
	Improvement of project understanding	Project scope management
	Managing and accelerating communication between stakeholders	Project communication management
4	Completing the project in a shorter time, with less cost and higher quality	Project schedule management Project cost management Project quality management
	Finding the best way of communication between stakeholders	Project communication management
5	Using current knowledge and creating new knowledge	Project integration management
	Storing project information for project handover	Project integration management

The study also aimed to pinpoint the tasks in the post-construction phase that experience the most positive influence from the adoption of BIM. Participants were asked to share their opinions, presented in Figure 10. Notably, eight out of twelve participants believed that BIM would enhance facility management, showcasing the potential to elevate the maintenance and long-term upkeep of buildings. Moreover, over 41% of respondents believed that BIM would lead to effective tracking of component lifecycles, a critical aspecn for ensuring timely replacements of building

components. Furthermore, 41% of respondents indicated that BIM could be used to prepare realistic and reliable building system analyses. Finally, a quarter of the responses emphasized the potential of BIM to enhance asset management, improve warehouse management, and facilitate component performance tracking, suggesting that BIM can play a valuable role in a range of post-construction tasks.

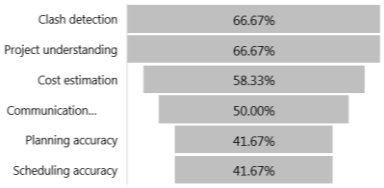

Figure 7- Effect of BIM on pre-construction tasks

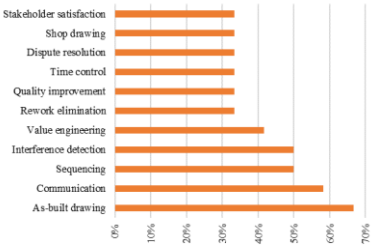

Figure 8- Effect of BIM on construction tasks

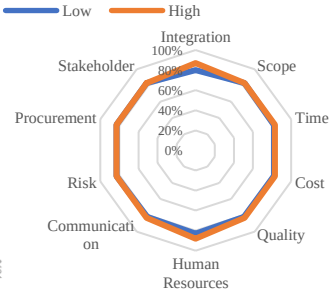

Figure 9- BIM effects on PMKAs improvement

Figure 11 outlines the percentage of agreement among the participants concerning various factors that could impede the adoption of BIM in construction projects. Among the identified factors, the lack of experts was the most commonly reported issue, with 58.33% of respondents agreeing. Other potential barriers to adoption included a lack of employer demand and inadequate training, with 41.67% agreement. One-third of experts voted that high initial funding, the absence of rules and regulations, resistance to change, complications with team building, and lack of awareness hinder successful BIM implementation in construction projects. 25% highlighted conflicts over data ownership and prolongation of the engineering phase as potential hurdles. Overall, these findings underscore the range of factors that can influence the implementation of BIM in construction projects, emphasizing the need to address these challenges for widespread adoption of the technology.

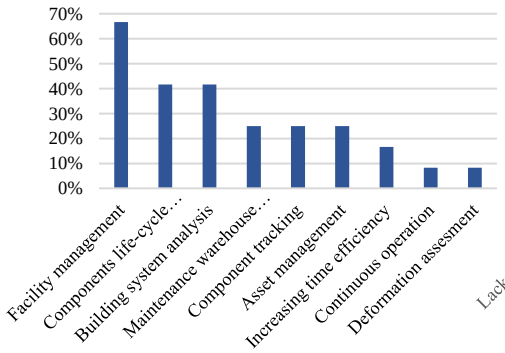

Figure 10- Effect of BIM on post-construction

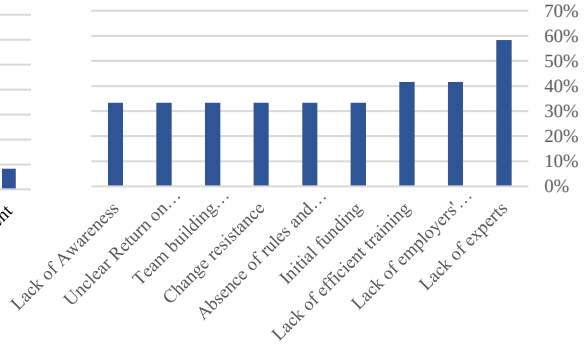

Figure 11- Obstacles to BIM implementation

4. Conclusion

This study utilized a questionnaire-based methodology to assess the impact of BIM on the effectiveness of PMBOK implementation in construction projects. The questionnaire was distributed to 95 global experts, garnering responses from 12 professionals. These results were further validated through face-to-face interviews with three local experts, confirming the alignment of high-level

managers' views with our findings. Research revealed a notably positive influence of BIM on Project Integration Management, significantly enhancing the implementation of PMBOK in construction projects. BIM equips employers with vital insights for informed decision-making regarding project risks and outcomes and facilitates project teams in adapting to project changes.

The study extensively investigated the impact of BIM implementation across different aspects of PMBOK in various phases of construction projects. Four targeted questions were formulated to assess these effects, revealing BIM's substantial role, particularly in the pre-construction phase, where clash detection proves instrumental in averting rework. The 3D virtual modeling and walkthrough capabilities of BIM empower teams with a comprehensive understanding of project environments and deliverables, leading to more accurate cost estimations. This clarity is pivotal for owners to establish a concrete vision of the project and for tenderers to submit realistic financial proposals. BIM also plays a pivotal role in generating precise as-built drawings. BIM remarkably enhances communication among stakeholders, optimizes the sequencing of project activities, and enables real-time identification and resolution of conflicts among workforces and teams. Moreover, BIM proves beneficial for maintenance teams in managing facilities and tracking component performance to facilitate timely replacements, thus ensuring continuous operation.

The study encountered limitations in information gathering, as some experts declined to participate in the survey. Therefore, a minority proportion of invitees cooperated. A framework can expedite the leverage of PMBOK integration with BIM. In addition, case studies may inspire and propel the construction industry toward the implementation of BIM-PMBOK practices.

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