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Integrating BIM technology in construction for effective knowledge management: case studies and methodological insights

Eman Elalwani*[1], Ekrem Bahadır Çalışkan[2]

[1] *Ankara Yildirim Beyazit University, Department of Civil Engineering, Türkiye, 225113405@aybu.edu.tr*
[2] *Ankara Yildirim Beyazit University, Department of Architecture, Turkey, bahadir.caliskan@gmail.com*

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Abstract

Integrating Building Information Modeling (BIM) technology for effective knowledge management (KM)in the construction industry is a crucial aspect of modern construction. The construction industry is susceptible to losing its qualified and knowledgeable workers, and there are no certain plans to address this issue. The construction industry often relies on personal knowledge and experiences rather than certain analytical methods or textbook guidelines. Although various knowledge management approaches and researchers have given many perspectives on knowledge management, this study explores and compares previous management systems practices in the construction field. It investigates the implementation of BIM technologies and discusses the challenges, benefits, and potential strategies for enhancing knowledge-sharing and management processes. Knowledge management is furnished with significance through various decision-making processes, innovation, and constant learning that ends in progressing project delivery and collaboration among project teams. With regards to the implementation of the technology that involves building information modeling and knowledge management of construction projects, the analysis and comparison of some case studies that related to definite locations was conducted to discuss how cultural and development factors affect BIM involvement in construction projects. For concluding purposes, it emphasizes the importance of implementing BIM into each phase of projects not merely during the design and the construction operations but in all phases of project development. This research investigated novel ideas for improving (KM) and the application of (BIM) and also expressed that cultural and developmental characteristics have a noticeable influence on knowledge management systems based on BIM.

1. Introduction

"Knowledge Management" (KM) is mentioned in this sense as the techniques used by organizations to accumulate, coordinate, develop, exchange, and transfer knowledge [1]. The transfer of knowledge from those who are working as engineers and specialists on a project could boost the building process as well as the control of the time and the costs for solving problems [1].

KM allows businesses to exactly collect, transmit, and use the sum of their competence, information, and experiences [2]. Knowledge management systems can benefit organizations through better decision-making, promotion of innovation, facilitation of continuous learning, and avoidance of unnecessary work duplication, ultimately improving performance. Moreover, it eliminates the loss of intellectual capital and optimizes productivity, and outdoor competition in an environment that is volatile for companies to operate in. In the construction industry, KM avoids repetitive errors, improves project delivery, enhances collaboration among project teams, and maintains a repository of valuable knowledge for future projects. Effective knowledge management enables construction companies to optimize operations, promote innovation, support industry standards, and enhance the quality of construction projects [3]. Various characteristics set construction apart from other sectors. One significant aspect is that construction businesses create and oversee projects, which include temporary collaborations between many entities to achieve certain objectives within a predetermined duration [4]. Due to the temporary nature of projects, knowledge cannot be easily transferred across teams; it is even more difficult to acquire, retain, and leverage this knowledge because of the frequent changes in these groups [5]. Moreover, if it is assumed that one of the fundamental goals of companies is to survive, then it entails gaining a competitive edge. Thus, knowledge is an important source for organizations. According to [6], knowledge is a crucial asset for companies as it may give them an advantage in the market. The construction sector may be described as knowledge-demanding since dealing with the challenges professionals face in its operations requires a high level of specialist knowledge [6].

However, companies' ability to compete relies on individual knowledge and team experiences. They should create an ideal environment for knowledge to be properly collected so employees and collaborators can easily refer to it when required. The importance of knowledge management to a company's competitiveness, intellectual capital, and intangible assets makes it a challenging obstacle for modern businesses. These firms must incorporate the information obtained by their team members through regular procedures to foster learning, knowledge coherence, and, as a result, the organization's sustainability [7].

This study intends to outline the integration of knowledge management and BIM technology in the building industries. It will focus on identifying the obstacles, advantages, and viable approaches to improving information sharing and management practices. The study's primary objectives are to a). Examine the scientific community's contributions to construction knowledge management, b). Examine how building information modeling technology can improve knowledge sharing, c). Investigate the advantages and challenges of BIM technology, and d). Discuss how cultural and development factors affect BIM involvement in construction projects.

The research examines the technological benefits of managing information in the building business. It also discusses how important KM is in Building, the problems it causes, and how BIM technology might help solve these problems. It uses the literature review, case studies, and the execution phase information to develop a plan for improving knowledge management and using BIM technology in the building business. Furthermore, it discusses how KM and BIM technology can be used together in the building industry. It summarizes the problems, the benefits, and possible ways to improve sharing and managing knowledge.

1.1. Knowledge management in the construction industry

KM is a topic that affects all industries [8]. The construction sector, on the other hand, has been widely proven and examined in the scientific literature. Construction projects have become increasingly complex, dynamic, and interactive in recent years. Where project managers are continuously under pressure to make quick and reflective decisions. As a result, Knowledge gathering is a crucial tool that helps with decision-making and gives firms a competitive edge when they do these kinds of initiatives [9].

When it comes to the construction sector, heuristics rule the workplace. Employees and businesses in the construction industry often rely on personal knowledge and experiences while managing projects rather than relying on certain analytical methods or textbook guidelines [10]. The construction industry risks losing skilled personnel, worsening the problem. The solution to certain management challenges is not clear. Identifying knowledge use and sharing best practices is one of the greatest ways to increase organizational and industrial competition [10]. Indeed, the researchers give many perspectives on knowledge management and various knowledge management approaches [10]. According to Hartmann and Fischer, KM is the continual managing set of all knowledge in a corporation to meet multiple variables. The studies [11] characterize knowledge management as "an umbrella." It serves as a comprehensive framework encompassing several interrelated actions, including the creation of knowledge, the assessment of its worth, the organization and categorization of information, the transfer, storage, and dissemination of knowledge, and the act of sharing knowledge. From the view of [10], Knowledge management is a growing set of practical and organizational designing concepts, processes, structures, devices, and technology that give knowledge workers the tools they need to make the company valuable. [12] Described managing knowledge as the procedure of unlocking and exploiting information. Employing knowledge management enables a firm to use its institutional knowledge, facilitate information sharing, and identify its competencies, thus fostering a proactive and knowledge-driven organizational culture. Many writers have proposed further benefits of KM in project management within this framework. According to [12], excellent knowledge management has a clear role in enhancing quality, promoting creativity, decreasing project duration, and increasing customer satisfaction. Following [13], knowledge management enables an organization to use its intangible assets effectively to generate value. This requires leveraging interior and exterior knowledge to benefit the organization.

Involving BIM in a built environment may enhance work collaboration and facilitate the exchange of well-informed information. This may be accomplished via disseminating exemplary documentation, insights gained from experience, effective project management and system engineering techniques, illustrative package samples, and the rationale behind strategic decision-making. [14] Argue that (KM) offers several advantages, including increased productivity, improved activities, enhanced intelligence, storage of intellectual capital, strategic planning, flexibility acquisition, best practices collection, increased chance of success, and constructive cooperation. Figure.1. illustrates the systematic way of defining KM in most of the reviewed research.
Nevertheless, difficulties in understanding and managing organizational knowledge have led to numerous challenges in successfully implementing and sustaining organizational knowledge management initiatives. [15] Emphasize that the project-oriented nature of

construction organizations requires the inclusion of cultural concerns to achieve effective knowledge management. Engaging in short-term, task-oriented work has been shown to impact continuous learning. In construction projects, the perspective on knowledge management is commonly described by identifying the main points: gathering project information and knowledge, knowledge acquisition, creating a database of knowledge on best practices, and providing knowledge-based decision support for project implementation [16].

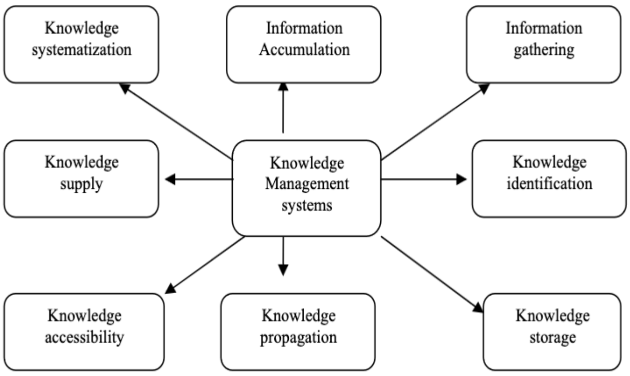

Figure 1. A systematic way of defining KM [14].

Obtaining project information and knowledge is an important part of every step of a construction project's life cycle, from planning the idea to buying materials to building the structure to running it and keeping it in excellent condition. It is critical to procure information and expertise from all pertinent stakeholders and organizations involved in the undertaking, such as inspectors, clients, designers, consultants, and contractors. This is necessary since communication across various disciplines is sometimes troublesome. Poor project performance may be attributed to the industry's lack of integration and coordination across many professions [17].

An efficient knowledge strategy is crucial for obtaining and handling explicit and tacit information. Explicit knowledge refers to readily accessible information inside an organization, often found in books or documented procedures, that can be effectively stored and retrieved as required. Tacit knowledge is deeply embedded in the established practices and protocols of an organization, as well as in the thoughts of its staff. This understanding is very advanced and intricate. An organization's leadership, vision, strategy, incentive structures, and culture are intangible human variables that may make or break knowledge management efforts [18]. Both academic and industrial organizations acknowledge the need for knowledge management. However, the lack of clarity about precise definitions of knowledge and knowledge management within construction enterprises may result in misguided KM projects, ultimately failing to fulfill their objectives. It is imperative that the whole business fully understands the meaning and significance of KM. Organizations must examine the work cultural environment, behavior, political thought, practices, and the intended advantages of managing KM projects to synchronize with corporate objectives and strategy. The related work reviewed in the literature stated that the business is susceptible to losing its trained workers and lacks a solution. Personal experience is typically valued above analytical procedures or textbooks. Knowledge management promotes industrial and organizational competition. Knowledge management techniques vary, and workplace heuristics are common. Systematic knowledge identification and innovative methods or tools, such as integrating BIM, may improve construction project decision-making and competitiveness.

1.2. BIM application in construction

Building Information Modeling (BIM) digitally depicts a building's physical and functional attributes. It provides a collaborative approach to working, allowing different stakeholders to combine their knowledge and information into a single model. This technology improves communication, collaboration, and efficiency throughout the building's lifetime [19].

Many studies have extensively explored various dimensions of BIM within the construction industry. This work encompasses various contributions, each addressing specific challenges and opportunities associated with BIM technology. From addressing CO2 emissions calculations to integrating BIM into facility management and exploring its impact on sustainable design and construction, these studies collectively contribute to a deeper understanding of the diverse applications and potential benefits of using BIM in the building industry. Some of these studies have advised the construction industry to use BIM technology and addressed the main obstacles. Using building information modeling, in [20] developed a technique using BIM technology to compute carbon dioxide emissions from residences of varying dimensions, architectural styles, and construction materials.

The study in [21] integrated the information modeling to generate a central database for the owner's facility data. [22] Examined existing standards globally and presented the BIM concept as a starting point for industry-wide research and project delivery. Building information modeling (BIM) enabled tools were created by [23] so on-site workers can access design information and record job quality and progress data using mobile tablets. Automatic code-checking processes and a water distribution system were developed using building information modeling (BIM) [23]. To prevent fall-related accidents before construction starts, an automated safety-checking platform was created and connected with BIM [24]. This platform alerts construction engineers and managers. Critical efforts were identified by [25] based on an analysis of BIM deployments in six countries, including both public and private sectors.

The study by Bryde [26] investigated the impact of Building Information Modeling (BIM) on various building projects. Sebastian and van Berlo [27] developed an evaluation tool for BIM achievement to assess the performance of design, engineering, and building firms. Bynum explored how designers and builders perceive BIM as a tool for environmentally friendly projects, focusing on space planning and energy analysis. Wang

[28] examined how building modeling can assist site managers during the planning phase. In comparison, Zhang [29] utilized a visible information model based on Industrial Foundation Classes to demonstrate data-sharing capabilities in virtual building systems.

In addition to the studies listed, Fischer; conducted relevant research on the subject of BIM, focusing on the potential of BIM to improve construction project performance through increased communication and coordination. The research emphasized the advantages of BIM implementation in minimizing rework and improving project delivery efficiency [30].

One aspect that could be further explored in the previous research is the specific challenges or barriers faced during the implementation of BIM in building projects. Understanding these challenges could provide insights into organizations' practical issues when adopting BIM. Additionally, the impact of BIM on the cost and schedule performance of building projects could be more extensively studied to provide a comprehensive assessment of its benefits and limitations. These research gaps could lead to a more nuanced understanding of the factors influencing the successful use of BIM in the construction industry.

2. Method

This research investigates how building modeling improves the construction industry. It reviews existing research and uses a grounded theory approach to analyze two case studies from different countries to dissect how cultural factors may affect creative techniques in knowledge management enhancement. These case studies scrutinize the benefits and disadvantages of knowledge management in construction industries and their operations. The central topic of the research is developed to offer an insight into critical elements of Knowledge Management systems and their effect on the reduction of construction errors.

3. Case studies

3.1. Case study A: "Construction of a 3D BIM-based knowledge management system in Taiwan"

The presented work is a handy tool for bringing together BIM data collected during construction projects into a comprehensible and easy-to-use presentation. The central topic of this article is the application of building information systems for the establishment of data management in projects at every stage of building development. Using a customized Construction. The article suggests a three-dimensional (3D) BIM-based knowledge management system for general contractors, which uses building information modeling. The application of the CBIMKM platform in Taiwanese construction projects when offering the solution is the best example of how to achieve the aforementioned approach. Apart from that, it draws attention to the fact that an effective information-sharing process occurs in three dimensions. The integral component of this study is to assess how knowledge has been managed in Taiwanese construction projects by applying the CBIMKM approach. Figure 2 highlights the results of this investigation. This essay and the discussion about it to some degree are centered on knowledge management and its role in building projects. The present paper tries to achieve a well-structured system as an interactive tool for user-to-user knowledge translation and experience exchange with the use of the CBIMKM system, which enhances construction knowledge management. Implementation of clear 3D CAD descriptions of the problem and its solutions in a BIM Framework into the CBIMKM system uses a visual data place. Building information modeling (BIM) is an approach gaining in popularity that can bring significant benefits to the building industry if it is utilized effectively. It has an important role in enhancing knowledge management during the phase of construction of a project. The BIM approach employs the currently available data sets that enable the construction of a 3D knowledge map to access relevant information irrespective of the disciplines. Furthermore, BIM produces 3D data with visual representations that are accompanied by knowledge and development skills. Integrating information from various projects and synthesizing relevant solutions to problems is a process that is made possible with the help of the CBIMKM system [31, 32]. As to field testing as well as a lens for construction information management expertise, the CBIMKM tool has proven to be a tool that makes sense. To have a knowledge management system like CBIMKM and establish a BIM technology to be included in the building process is the main point of the case study. This article puts forth the idea of a CBIMKM system as the platform for data sharing and getting information among the participants of building projects. (BIM) is a technique that may be used to set up the system information visualization in CAD three dimensions [33]. The experts in the project could access the relevant information with much ease due to the incorporation of a three-dimensional knowledge map in the Building Information Modeling strategy. A system of centralized business information management and knowledge management (CBIMKM), suggested in this paper, has a lot of advantages. It is quite clear that the first feature that made this platform outstanding was its solution for knowledge management tasks that were based on a 3D CAD environment.

This included performing a web-based system creation enabling training and awareness campaigns aimed at building projects. After all, it not only allowed newcomers to enjoy the expertise of veterans but also made it easy for them to minimize the mistakes of the rockers [33]. According to the CBIM/KLM system architecture, the technological gaps were filled through research projects and standards that were developed in the architecture, engineering, construction, and building information modeling fields. The appropriation of the results of the investigations furthered the BIM technology research and development, with improvement in information representation and easier installation by the time of the visual knowledge management during the building process [33].

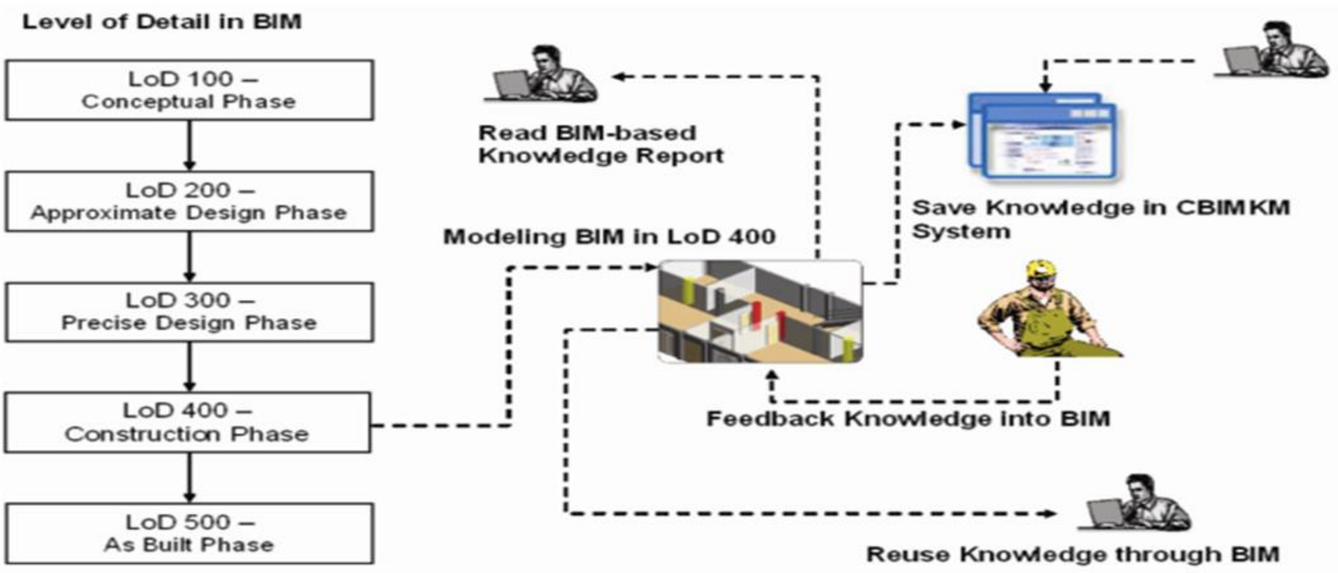

Figure 1. Integration of BIM in Construction Knowledge Management [33].

3.2. Case study B: Prefabricated Construction enabled by the Internet of Things (IoT) in Hong Kong

The examination concentrated on the utilization of construction BIM in prefab factories in Hong Kong and its influence on public housing projects of the Hong Kong Housing Authority. The points were to review BIM and share its merits and demerits, build a unified system that will be driven by IoT ensure the system to be real-time visibility as well as traceability, and show a demo of the system applications in real-time construction projects. Given the tri-level structure of the MITBIMP, such development was easily brought into the DHI's functional structure. Stacked at the first level was the level containing the Data Source Management Service (DSMS), Infrastructure as a Service (IaaS), and Decision Support Service (DSS) platform level. At each stage, stakeholders will see a new set of management services that cover different processes of development [34, 35].

The integrated IOT BIM platform that provides the following dimensions is presented in Figure 3.

A significant improvement in the delivery time of homes in Hong Kong has been noticed due to the utilization of prefabricated building technologies. The ten-year public housing initiative of the Hong Kong Housing Authority (HKHA) has featured several prototype prefabrication-based construction projects that have used contemporary technologies. Examples of such technologies include radio frequency identification (RFID) and BIM tools. By making information more accessible and traceable, BIM also guarantees quality control and safety in construction projects. To help find and fix problems quicker, the multidimensional IoT-enabled building information modeling platform (MITBIMP) has been put into place.

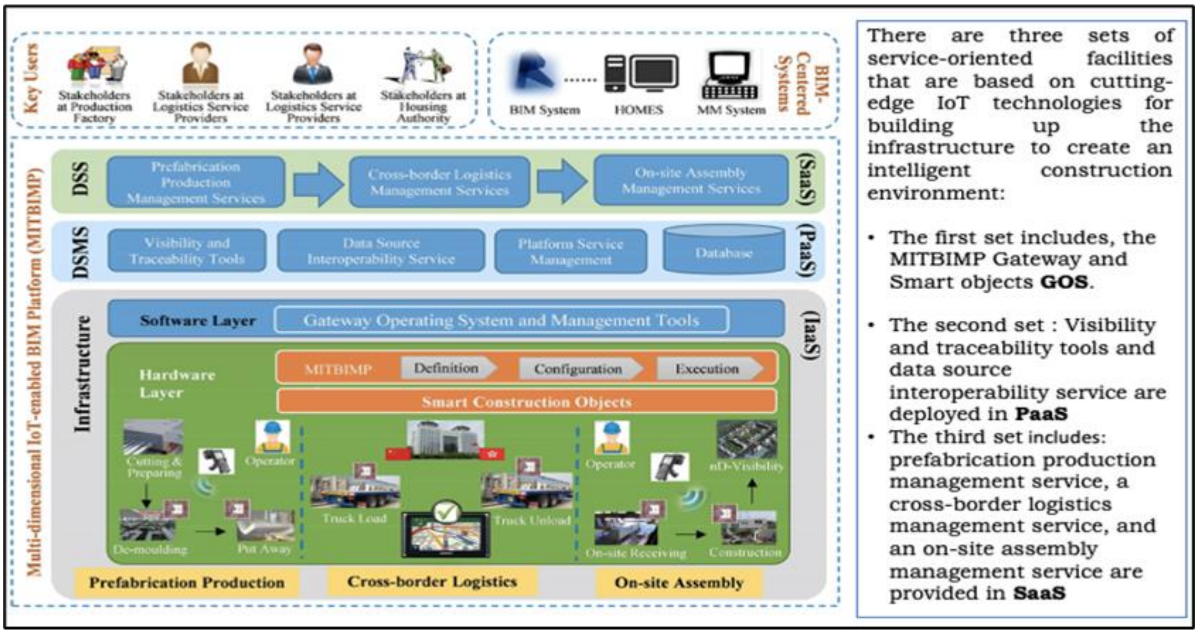

Figure 3. A multidimensional IOT BIM platform [34].

To demonstrate the benefits of BIM in prefabricated construction, this paper used a literature review and a case study. These advantages included better project management, faster housing delivery, and more information visibility. Two challenges are the high Installation cost and the need for specialized expertise. The main findings show that the MITBIMP successfully integrated new dimensional data into real-world construction projects [36].

4. Discussion

Existing research on knowledge management in the construction industry indicates a lack of a specific strategy to mitigate the loss of qualified employees. Personal knowledge and experiences are often relied upon over analytical methods or textbook guidelines. Knowledge management is crucial for strengthening industrial and organizational competition. There are various approaches to knowledge management, and heuristics are prevalent in the workplace. Systematic identification and utilization of knowledge can enhance decision-making and strengthen organizations' competitive advantage in construction projects. The study highlights that knowledge management and utilization techniques are crucial in building projects [30, 33]. Based on similar research conducted in Taiwan, the aim was to enhance the sharing and administration of visual information by developing a knowledge management system that utilizes 3D building information modeling for local construction projects. The system was tested using a case study and surveys. The researchers aimed to employ Building Information Modeling (BIM) in their knowledge management system owing to its features such as data storage, collaboration, management of database updates, and preservation of information for reuse. BIM improved construction project productivity by enabling automatic revisions and transfers of information inside the 3D CAD environment. Some benefits were better knowledge sharing, faster tracking, and automatic adjustments. Some problems were the need for BIM models, the fact that PCs needed much power, and that using BIM tools took time and effort. The method worked well to make sharing and keeping track of information easier, but it might have trouble handling contracts and items that are too complicated. The advantages of using BIM in project planning, design, construction, operation, and physical structure maintenance are causing it to be more useful in the construction industry, particularly for prefabricated building projects. BIM facilitates the exchange of information and enhances the productivity of all project stakeholders. It can also expedite home delivery, especially in crowded areas like Hong Kong, by reducing time and money spent on Building. BIM also ensures quality control and safety in building projects, making information more visible and traceable. To help find and fix problems quicker, the multidimensional IoT-enabled building information modeling platform (MITBIMP) has been put into place. Investigating two cases concerning location variation, it was discovered that how 3D BIM-based knowledge management systems are used varies from region to region because of cultural differences and how the construction industry develops. Developed countries with a strong culture of innovation and technology adoption, a highly developed construction industry, and a more conventional methodology may better accept these systems [35].

Table 1. A comparison of two case studies implemented BIM-based knowledge [30, 33].

Categories	Case Studies A	B
Publication Title & Year	Construction 3D BIM-based knowledge management system, 2014	Prefabricated construction enabled by the IoT, 2017
Country/ Region	Taiwan	Honk Kong
BIM Implementation	3D BIM-based, Collaborative Building Information Modeling and Information Management (CBIMKM).	Multidimensional (IoT) and (BIM) platform (MITBIMP) for prefabricated buildings.
Approach	For general contractors, enhance knowledge sharing and tracking efficiency among project participants in a 3D environment.	Focused on the Public Housing Authority in Hong Kong (HKHA). Examines BIM involvement in prefabricated building projects in Hong Kong.
Key Findings	Used BIM framework to visualize knowledge and experience sharing among users. Efficient in enhancing information sharing and optimizing tracking efficiency. Straightforward and precise depiction of things in 3D CAD	MITBIMP offered real-time visibility and traceability.
BIM Benefits	Improved knowledge sharing and tracking efficiency among project participants. Offers automated adjustments when information is modified.	Improved sharing management, faster housing delivery, and enhanced information sharing.
BIM Challenges	BIM models require construction management. High PC hardware requirements for BIM software. Required Substantial help to train managers to use BIM software for knowledge updating.	Need for specialized skills and training. High cost of implementing BIM technology.

Cultural elements like giving more weight to individual bonds and in-person interaction can cause additional problems in introducing digital tools for collaboration. Some possess such a culture that for them direct conversations are indispensable because remote communication is just a replacement. The incorporation and application of 3D BIM systems may be subject to variations in different parts of the world owing to these determinants.

For instance, the Hong Kong MITBIMP platform has been successful in countries like the UK, the UK, Japan, South Korea, and Singapore. Conversely, prefabricated construction techniques and building information modeling (BIM) technologies depend on cultural and development elements for their success. The public housing program conducted by the Housing Authority in Hong Kong is a good example of how the platform needs to be adapted to meet each project's particular requirements.

However, the case study in Taiwan looked at a knowledge management system for general contractors based on Building Information Modeling [36-38]. The case study in Hong Kong looked at the use of BIM in prefabricated construction projects, notably in public housing schemes. Both studies seek to enhance knowledge exchange and project management using 3D BIM technologies in different geographical regions. Both have proved effective and showed benefits and challenges during their applications.

Looking at Table.1 below, the two case studies were compared based on several categories that are believed to be very valuable to create a deep understanding of the possible challenges, and benefits of executing new creative insights to the construction industries. Despite the location variation of their geographical location, both have reached the main approach of improving KM and information sharing in this field.

5. Conclusion

BIM is gaining popularity in the building sector for prefabricated building projects. The reason for this is due to BIM provides several benefits in the areas of physical infrastructure planning, design, Building, operation, and maintenance. Building information modeling allows for better efficiency and productivity by facilitating the exchange of information and cooperation between all project stakeholders. Reducing construction time and expenses is important in speeding up house delivery, especially in heavily crowded locations like Hong Kong.

By making information more accessible and traceable, BIM guarantees quality control and safety in construction projects. Using a multidimensional BIM platform (MITBIMP) made possible by the Internet of Things has allowed for quick issue identification and resolution. However, according to cultural and developmental variations, knowledge management systems based on 3D building information modeling may differ among geographical locations. The use of BIM knowledge management systems is clarified by considering Taiwan and Hong Kong case studies. Although both studies showed that BIM improved information sharing and project management, they also described some of the problems that might arise from utilizing it, i.e., limitations or barriers recorded previously in Table 1, such as the fact that it requires specific skills, since it is expensive to deploy, and that BIM models are necessary throughout construction. Some innovative strategies for reducing the occurrence of repetitive errors in construction have been proposed as well.

In conclusion, the main contribution of the research is to examine KM in construction and emphasize BIM technology and its possible advantages, disadvantages, and significance. Strategies for enhancing knowledge management and using BIM technologies were developed via a literature analysis, case studies, and implementation stages. The research sheds insight on the challenges, advantages, and possible approaches to improving management and information sharing. Investigating two cases concerning location variation has revealed how 3D BIM-based knowledge management systems can vary from region to region because of cultural differences and how the construction industry develops.

Although BIM requires specific skills and is expensive to deploy further studies, can explore the way of integrating cloud-based platforms with Artificial Intelligence to trace not only the real-time project execution phases but also to monitor the in and after-use phases.

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Author contributions

Both authors contributed to methodology, original draft preparation, reviewing, and editing.

Conflicts of interest

The authors declare no conflicts of interest.

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