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KNOWLEDGE-ENABLED BUILDING INFORMATION MODELLING: A FRAMEWORK FOR IMPROVED DECISION-MAKING

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ABSTRACT

Purpose: The purpose of this study is to build an integrated framework that provides a methodical approach to managing the knowledge produced by Building Information Modelling (BIM) procedures.

Theoretical framework: BIM has revolutionized the approach to building design and construction projects; nevertheless, managing the vast amounts of heterogeneous data produced by the various BIM processes is a very difficult task. The need of knowledge management (KM) for successful BIM implementation is becoming widely acknowledged as it will allow organisational stakeholders to make strategic decisions, reduce errors, and improve results.

Methodology: Both primary and secondary data were collected in this research. This data was utilized to develop an initial version of the KM-based BIM framework, which underwent a thorough two-phase expert evaluation process via interviews with industry experts to enhance the framework's applicability and relevance.

Findings: The significant factors influencing KM in the context of BIM were identified. Moreover, through the expert evaluation process, it was determined that the proposed KM-based BIM framework provided valuable assistance in addressing these factors and in managing BIM organisational knowledge.

Research implications: The research has implications for the field of building design and construction projects. By promoting the adoption of a KM-based BIM framework, it seeks to address the challenges associated with managing heterogeneous data and information silos. The framework has the potential to improve the decision making process in the context of BIM.

Originality/value: This is the first research providing a methodical approach to managing BIM-related knowledge through KM, and that provides an expert-validated framework for improved decision making.

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MODELAGEM DA INFORMAÇÃO DE CONSTRUÇÃO HABILITADA POR CONHECIMENTO: UM FRAMEWORK PARA MELHORIA DA TOMADA DE DECISÃO

RESUMO

Objetivo: O objetivo deste estudo é construir um framework integrado que forneça uma abordagem metodológica para gerenciar o conhecimento produzido pelos procedimentos de Modelagem da Informação de Construção (BIM).

Referencial teórico: O BIM revolucionou a abordagem ao design de edifícios e projetos de construção; no entanto, gerenciar as grandes quantidades de dados heterogêneos produzidos pelos diversos processos do BIM é uma tarefa

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muito difícil. A necessidade de gerenciamento do conhecimento (KM) para uma adoção bem-sucedida do BIM está se tornando amplamente reconhecida, pois permitirá que os stakeholders organizacionais tomem decisões estratégicas, reduzam erros e melhorem os resultados.
Desenho/metodologia/abordagem: Foram coletados dados primários e secundários nesta pesquisa. Esses dados foram utilizados para desenvolver uma versão inicial do framework BIM baseado em KM, que passou por um rigoroso processo de avaliação de dois estágios, com entrevistas realizadas com especialistas do setor, visando aprimorar a aplicabilidade e relevância do framework.
Resultados: Foram identificados os principais fatores que influenciam a gestão do conhecimento (KM) no contexto do BIM. Além disso, por meio do processo de avaliação de especialistas, verificou-se que o framework proposto, baseado em KM para o BIM, oferece uma assistência valiosa na abordagem desses fatores e na gestão do conhecimento organizacional do BIM.
Pesquisa, implicações práticas e sociais: A pesquisa tem implicações para o campo do projeto de construção e obras. Ao promover a adoção de um framework BIM baseado em KM, busca-se enfrentar os desafios associados à gestão de dados heterogêneos e silos de informação. O framework tem o potencial de melhorar o processo de tomada de decisão no contexto do BIM.
Originalidade/valor: Esta é a primeira pesquisa que oferece uma abordagem metodológica para a gestão do conhecimento relacionado ao BIM por meio do KM, e que apresenta um framework validado por especialistas para melhorar a tomada de decisões.

Palavras-chave: Gestão do Conhecimento, Modelagem de Informações da Construção (BIM), Perda de Conhecimento, Framework Integrado, BIM Baseado em KM.

MODELADO DE INFORMACION DE CONSTRUCCION HABILITADO POR EL CONOCIMIENTO: UN MARCO PARA MEJORAR LA TOMA DE DECISIONES

RESUMEN
Propósito: El propósito de este estudio es construir un marco integrado que proporcione un enfoque metódico para gestionar el conocimiento producido por los procedimientos de Modelado de Información de Construcción (BIM).
Marco teórico: El BIM ha revolucionado el enfoque de diseño y construcción de edificios; sin embargo, gestionar la gran cantidad de datos heterogéneos producidos por los diversos procesos de BIM es una tarea muy difícil. Se reconoce ampliamente la necesidad de gestión del conocimiento (KM) para una implementación exitosa de BIM, ya que permitirá a los interesados organizativos tomar decisiones estratégicas, reducir errores y mejorar los resultados.
Metodología: Se recopilaron datos primarios y secundarios en esta investigación. Estos datos se utilizaron para desarrollar una versión inicial del marco de BIM basado en KM, que fue sometido a un riguroso proceso de evaluación de expertos en dos fases mediante entrevistas con expertos de la industria para mejorar la aplicabilidad y relevancia del marco.
Resultados: Se identificaron los factores significativos que influyen en la gestión del conocimiento en el contexto de BIM. Además, a través del proceso de evaluación de expertos, se determinó que el marco de BIM basado en KM propuesto proporcionaba una valiosa ayuda para abordar estos factores y gestionar el conocimiento organizativo de BIM.
Implicaciones de la Investigación: La investigación tiene implicaciones para el campo del diseño y construcción de edificios. Al promover la adopción de un marco de BIM basado en KM, busca abordar los desafíos asociados con la gestión de datos heterogéneos y silos de información. El marco tiene el potencial de mejorar el proceso de toma de decisiones en el contexto de BIM.
Originalidad/valor: Esta es la primera investigación que proporciona un enfoque metódico para gestionar el conocimiento relacionado con BIM a través de KM, y que ofrece un marco validado por expertos para mejorar la toma de decisiones.

Palabras clave: Gestión del Conocimiento, Modelado de Información de Construcción (BIM), Pérdida de Conocimiento, Marco Integrado, BIM Basado en KM.

INTRODUCTION

Building information modelling (BIM) has drastically transformed how construction and design projects are managed and performed. In fact, the use of BIM has made it possible for stakeholders to collaborate more effectively, efficiently, and accurately, hence reducing errors and rework, and enhancing project outcomes (Chen et al., 2022). Despite this, it has become increasingly evident that a more systematic approach to managing the massive knowledge produced by BIM procedures is required. Currently, the use of BIM generates a significant amount of data and information, which can be challenging to handle without a methodical approach. Furthermore, the software tools used in BIM produce data and information in various forms and at various phases of the project lifecycle. As a result, stakeholders may only have access to a small portion of the data and information produced by the BIM processes, which will in turn result in creating data and information silos.

From a different angle, the systematic development, sharing, and use of information within an organization is the focus of Knowledge Management (KM). BIM-related knowledge may be captured and shared following KM practices, enabling stakeholders to make more informed strategic decisions. Because it aids in the collection, organization, and distribution of knowledge across all phases of the project, from design to construction and maintenance (Koshelieva et al., 2023), KM is considered to be a crucial component and contributing factor for the success of BIM projects. In this paper, an integrated KM-based BIM framework is proposed, addressing an existing knowledge gap. It also looks at the difficulties in managing the knowledge produced by BIM processes and how a KM-based strategy might assist in resolving these difficulties. This paper is structured as follows: section II presents a review of the most pertinent works. The methodology followed, including the knowledge loss model and KM activities-BIM features mapping is discussed in Section III. Finally, section VI presents the results and discussion, in which the proposed framework is thoroughly explain and the evaluation process described.

LITERATURE REVIEW

KM and BIM are essential elements and contributing factors to the success of construction projects. The aim of this literature review is to examine state-of-the-art published studies on how KM and BIM interact.

According to Bakker et al. (2016), BIM has been acknowledged as a useful method for collecting and managing knowledge in the construction sector. In order to manage and

distribute information among project stakeholders, BIM allows the production of a digital model of the building (Sacks et al., 2018). BIM also enables project teams to cooperate more successfully, increasing productivity and minimizing mistakes (Zhang et al., 2016).

Likewise, and according to research by Yin et al. (2018), KM has also been demonstrated to be crucial to the success of building projects. Project teams may use KM to collect and share best practices, lessons learned, and other useful information (Zhang et al., 2020). In the construction business, KM can also boost innovation and decision-making quality (Chen et al., 2019).

Numerous research has investigated the connection between KM and BIM. For instance, Zhang et al. (2016) discovered that by offering a platform for collaboration and information exchange, BIM may be utilized to promote KM. In addition, and according to Bakker et al. (2016), tacit knowledge might be difficult to convey using standard KM approaches and can be captured and managed using BIM. Other studies have concentrated on some particular KM and BIM elements. For instance, Chen et al. (2019) investigated the effect of KM in boosting the adoption of BIM, while Sacks et al. (2018) analyzed the use of BIM for managing safety knowledge in building projects.

Given the potential advantages of enhancing teaching, learning, research, and facilities management, Higher Education Institutions (HEIs) have begun to acknowledge the implementation of BIM and KM. By giving students practical experience in digital design and construction, BIM has been acknowledged as a viable tool for improving the learning process in HE (Chen et al., 2020). According to Froese et al. (2018), BIM can aid students in acquiring technical knowledge of the built environment as well as problem-solving and teamwork skills. By offering a digital representation of the buildings, BIM may also assist universities in improving their facility management (Gustavsson et al., 2019). This enables improved maintenance and cost-saving decisions. Moreover, KM has also been considered as a crucial element in enhancing the efficacy of institutions of higher learning (Liu et al., 2018). To boost creativity, decision-making, and competitiveness, universities may use KM to collect and disseminate tacit and explicit knowledge among professors, staff, and students (Chen et al., 2019). By promoting the exchange of best practices and lessons gained, KM may also enhance the calibre of research and instruction (Martins et al., 2019).

The link between BIM and KM at HEIs has been examined in several research. For instance, Froese et al. (2018) discovered that BIM may be utilized to support KM by giving students and professors a platform for collaboration and knowledge exchange. Similar to this,

Chen et al. (2020) showed how BIM may be utilized to include KM into the curriculum by giving students a platform to share their knowledge and abilities in design. The challenges associated with adopting BIM and KM in HEIs have been the subject of other research such as that of Liu et al. (2018) in which the scholars noted the significance of leadership and culture in fostering BIM and KM projects at HEIs, and that of Gustavsson et al. (2019) who underlined the necessity for proper organizational structures and support for BIM and KM initiatives in HEIs.

METHODOLOGY

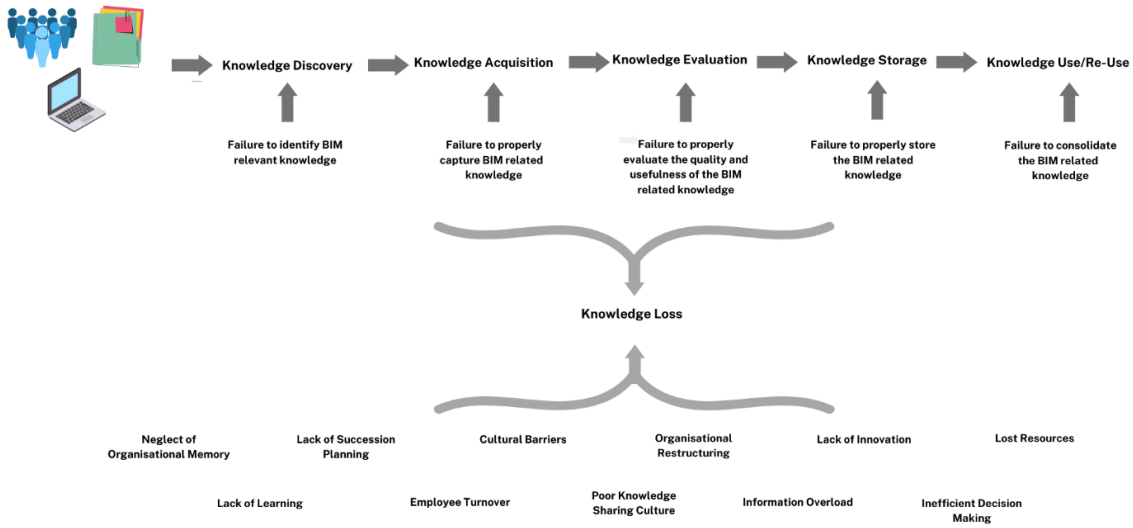
The methodology employed in this research follows a systemattic approach. An extensive review of the most pertinent works was conducted to identify the gap in knowledge. Then, a second review of the literature was conducted to validate the initially-identified gap. Second, a knowledge loss model was developed to address some aspects of the gaps, providing a theoretical foundation for further investigation. Moreover, to demonstrate the practical applicability of KM-based BIM, KM activities were precisely mapped and correlated with BIM features and processes. Building upon the aforementioned, an integrated framework was developped. The latter was validated through in-depth interviews with experts and stakeholders.

First off, the knowledge loss model. Understanding how to effectively manage organizational knowledge means knowing that there is the possibility to lose that knowledge. Therefore, controlling knowledge loss is crucial for several reasons:

1. Protecting and preserving knowledge: When organizations and/or people are aware of the consequences and the impact of knowledge loss, they are better prepared to take action to maintain the vital knowledge they already possess.
2. Risk management: Knowledge loss may pose a serious threat to businesses, particularly those that largely rely on the tacit knowledge that experienced employees possess. Being aware of this risk enables businesses to think ahead and create backup plans and risk-reduction tactics to lessen the impact of any possible information loss.
3. Innovation: information loss can also hinder innovation since a lack of sharing or retention of information inhibits the emergence of fresh and innovative concepts and methods.
4. Efficiency: When knowledge is lost, it can result in inefficiencies because staff members may spend a lot of time trying to recreate lost information or addressing problems that might have been avoided if the knowledge had been maintained.

Figure 1 presents the knowledge loss model.

Figure 1: Knowledge Loss Model



Source: Prepared by the authors, 2023

Failure to recognize pertinent information can prove to be a serious issue for both individuals and organizations as it may result in ineffective decision-making, the loss of resources, and the missed opportunities. The loss of important data (explicit knowledge) and expertise (tacit knowledge) might result from improper knowledge collection. Similarly, inaccurate decision-making, resource waste, and missed opportunities can result from improperly evaluating the quality and the use of knowledge, and improperly storing it will result in the loss of important knowledge and expertise. Lastly, if knowledge is not consolidated, KM initiatives may be incoherent and result in duplicate or contradicting information.

Furthermore, the mapping of BIM elements with KM activities is fundamental for maximizing the value of BIM. The important BIM components are identified during this phase and are then matched with their corresponding KM activities. Stakeholders may systematically gather, organize, and share knowledge produced by BIM processes in this way, increasing its usability and accessibility for decision-making. Moreover, some of the problems with BIM implementation, such data and information silos, poor communication, and a lack of cooperation, can be solved by mapping BIM characteristics with KM activities. Ensuring that stakeholders have access to the appropriate information at the right time through the establishment of a systematic KM method may improve decision-making, reduce errors, and optimise project results.

Depending on its unique features and practical use, each BIM component can be connected to one or more KM activities. Organizations may better manage the information produced by BIM processes and support efficient KM practices throughout the project lifecycle by utilizing these BIM capabilities and connecting them to KM activities.

Table 1: KM activities - BIM features Mapping

KM Activities	BIM Features
Knowledge Discovery	Clash Detection
	Data Management
	Simulation and Analysis
Knowledge Capturing	Parametric Modelling
	Lifecycle Management
	Object-Oriented Modelling
	Metadata Management
	Revision Tracking
	Asset Management
	Cost Estimation
	Construction Sequencing
	4D Scheduling
	Energy Analysis
	Code Compliance Checking
	Model Simulation and Checking
	Construction Documentation
	Procurement Management
	Risk Management
	Issue Tracking
	Quality Control
Knowledge Sharing	Cost Estimation
	3D Visualization
	Collaborative Design
	Lifecycle Management
	Model-based Analysis
	Information Exchange Standards
	Clash Resolution
	Cloud-Based Collaboration
	Model Coordination
Knowledge Retention	Lifecycle Management
	Object-Oriented Modelling
	Revision Tracking
	Metadata Management
	Asset Management
	Historical Data Analysis
	Facility Management
	Version Control
	Facility Maintenance
	Facility Operation
	Digital Twin
Knowledge Storage	3D Modelling
	Integrated Platform
	Data Integration
	Object-Oriented Modelling
	Centralized Data Storage
	Classification Systems

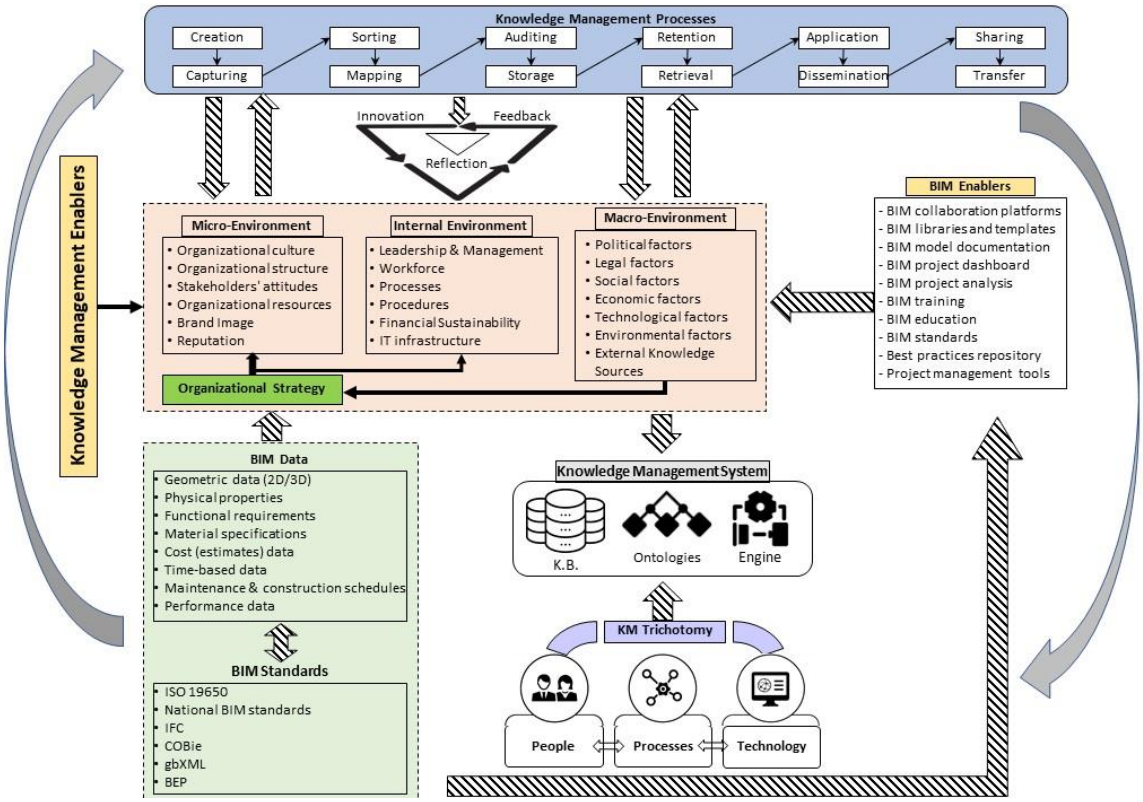
	Revision Tracking
Knowledge (Re)-Use	Analysis and Evaluation
	Object-Oriented Modelling
	Centralised Data Storage
	Parametric Design
	Model-Based Analysis

Source: Prepared by the authors, 2023

RESULTS AND DISCUSSION

KM processes in BIM lack a holistic, integrated framework that encompasses all aspects related to KM. Currently, there is a knowledge gap as there are no published, existing, frameworks. The proposed framework is crucial in facilitating efficient and effective knowledge sharing and collaboration among project teams, enhancing productivity, and improving the overall quality of building projects.

Figure 2: The Proposed Framework



Source: Prepared by the authors, 2023

The proposed framework integrates several elements. First off, the KM activities considered are as follows:

- Knowledge mapping: the process of identifying, visualizing, and organizing the organisational knowledge resources. It entails making a graphical representation of the

knowledge assets like databases, documents, subject matter experts, and people, to pinpoint where organisational knowledge is stored, who is in possession of it, and how it can be accessed.

- Knowledge auditing: the procedure of assessing a company's current knowledge assets and discovering weaknesses in KM procedures. This involves evaluating the value, applicability, and usefulness of knowledge resources to ascertain how they may be enhanced to fulfil organizational objectives.
- Knowledge retention is the process of keeping important information alive inside an organization to stop its loss due to staff turnover, retirement, or other circumstances. This requires locating the essential knowledge areas, capturing them in writing, and creating plans for imparting that information to new hires or other divisions of the company.
- Knowledge dissemination: the process of disseminating information inside a company to make it more accessible and available. To transmit information from specialists to other employees, employing a variety of communication channels, including meetings, reports, presentations, and training programs is needed.
- Knowledge retrieval: the process of accessing and locating pertinent knowledge resources inside an organization. It involves utilizing databases, search engines, and other technologies to swiftly find precise information.
- Knowledge application: the process of utilizing knowledge resources to address issues, make choices, or create new goods or services by putting knowledge to use in real-world settings to add value for the company.
- Knowledge capturing: this is the procedure used to gather and record knowledge resources inside an organization. Both explicit and tacit information, such as that found in written materials, reports, and databases, must be captured in this process.
- Knowledge storage: the act of keeping informational assets on hand within a company. This includes storing and organizing knowledge resources for simple retrieval and access utilizing a variety of information technologies, including databases, content management systems, and knowledge bases.

Effective KM techniques may indeed help BIM projects in a big way. To aid with job planning and execution, knowledge mapping, for instance, might be used to identify knowledge resources like models, requirements, and regulations. Critical knowledge, such as building techniques, supplies, and design purpose, may be kept and, in fact, passed to new staff or

(re)used in subsequent projects by ensuring knowledge retention. To guarantee that all parties have access to the most recent information, knowledge distribution can enhance communication and cooperation among stakeholders, including architects, engineers, contractors, and subcontractors. It should be noted that BIM projects involve a number of internal and external stakeholders who need to cooperate and communicate effectively to ensure the project runs smoothly. Moreover, to enhance decision-making and problem-solving, knowledge retrieval can help stakeholders quickly access pertinent information, such as design choices. Also, knowledge capture can be used to record tacit information, including skills and experiences, and to enhance decision-making in upcoming projects or when training new staff. By ensuring that information resources are structured and available to stakeholders, knowledge storage may improve project management while reducing errors and rework.

The influence of KM activities on the micro, macro, and internal environments is further explained by the presented framework. The organizational culture, structure, and stakeholder attitudes are all found at the micro level. The organizational strategy is essential in determining the resources, structure, and culture of the business. The strategy explains the organization's aims and objectives and offers a plan for accomplishing them. The strategy shapes the common values, attitudes, and behaviours of the employees, which are in turn reflected in the company culture. To exemplify, the culture may be more likely to support experimentation and creativity if the organisational strategy prioritizes innovation and taking risks. On the other hand, if stability and effectiveness are prioritized by the strategy, consistency, and adherence to established procedures would be necessary.

Furthermore, the organizational structure reflects how the company is set up to accomplish its aims and objectives. Depending on the set approach, the structure may be hierarchical, flat, or matrix based. A strategy centered on specialization and efficiency, for instance, may call for a hierarchical structure with distinct lines of authority and responsibility, whereas a strategy centered on speed and agility may call for a flat, decentralized structure to enable decision-making. The strategy also has an impact on the organizational resources, such as the financial, human, and technical resources. The latter establishes the investments necessary to fulfil the goals and objectives as well as the priorities for resource allocation. For example, a strategy focused on innovation and technology may require significant investments in research and development, while a strategy focused on cost leadership may require investments in cost-cutting measures and operational efficiencies.

The perceptions of the organisational stakeholders may also be greatly influenced by organizational strategy. The community, suppliers, shareholders, and workers are examples of stakeholders. Positive views about the organisation may be fostered if the organisational strategy is in line with the expectations and needs of the stakeholders. Customers may have a favourable opinion of the company and be more inclined to make purchases from it, for instance, if the strategy emphasizes offering high-quality goods or services. Employees may feel appreciated and inspired to contribute to the success of the business if the strategy focuses their growth and well-being.

The internal environment is made up of several elements, including IT infrastructure, leadership, management, and personnel as well as processes and procedures. Setting a corporate culture and ensuring that the workforce is in line with the organization's goals are crucial roles that leadership and management play. The firm must have effective processes and procedures in place to guarantee that activities are completed swiftly and effectively, and a competent and motivated personnel is a must for success. To secure the organization's long-term existence, appropriate financial management procedures must be in place as it is also essential to its success. Finally, firms need to invest in strong and secure IT systems to support their operations and safeguard data in the digital age. All these factors are interconnected, and the success of the organization will depend on their effective integration and alignment towards achieving the organization's objectives. The internal environment is also affected by innovation, feedback, and reflection.

The political, legal, social, economic, and technical aspects that have an influence on an organization's activities are all included in the macro environment. These aspects can significantly affect the adoption and application of BIM technologies. First, political variables including governmental laws, rules, and initiatives can have an impact on how BIM is used in the building sector. Governments may, for instance, mandate the use of BIM for infrastructure projects involving the public, which might result in a rise in the use and standardization of BIM techniques. Second, legal aspects including licensing contracts, intellectual property rights, and liability issues may also have an influence on the adoption of BIM. For example, the ownership and sharing of BIM data can be complex and require clear agreements and contracts to ensure proper attribution and protection of intellectual property. Thirdly, sociological influences on the usage of BIM include shifting demographics, consumer preferences, and sustainability issues. The use of BIM technologies that might aid in the design and construction of ecologically friendly buildings, for instance, may be prompted by rising demands for

sustainable and energy-efficient structures. Fourth, economic variables like market demand, rivalry, and price might also have an influence on the adoption of BIM. For example, smaller businesses may find it difficult to enter the market due to the expense of deploying BIM technology, but bigger businesses may have the means and scale to engage in BIM and gain a competitive edge. Finally, technological developments in BIM hardware, software, and interoperability standards can have an impact on how BIM is adopted and used. For example, emerging technologies such as artificial intelligence and machine learning may enhance the capabilities of BIM software and enable new applications in areas such as predictive maintenance and asset management.

In addition, enablers in organizations are the elements and/or the resources that aid in the achievement of organizational goals. Both material and intangible resources can serve as enablers. Organizations may take use of a few enablers in the context of KM-based BIM to enhance performance and results. These enablers include project management software, project dashboards, project analytics, BIM standards, and BIM libraries. The table below provides an explanation of the BIM enablers.

Table 2: BIM Enablers

BIM Enablers	Explanation
BIM collaborative platforms	software solutions that allow different stakeholders to collaborate and work together on a project in a coordinated way. These systems let teams work together more effectively and efficiently by facilitating communication, data exchange, and collaboration.
BIM libraries	digital archives that include standardized BIM elements including systems, materials, and objects. These libraries offer a consolidated repository of knowledge that may be utilized to help building design, construction, and upkeep, lowering mistakes and enhancing uniformity across projects.
Project dashboards	They give a perspective of the status, development, and performance metrics of a project in real time. Project managers and stakeholders may use these dashboards to track project performance, spot problems, and make defensible decisions based on the most recent data.
Project analytics	It entails using tools and techniques for data analysis to glean insights and spot trends in project data. These revelations may be applied to enhance project performance, decision-making, and planning.
BIM standards	Developed standards and procedures that encourage the consistent and effective usage of BIM throughout

	projects. Organizations can increase interoperability, decrease mistakes, and raise project quality by complying to these standards.
Project management tools	These refer to a number of tools that can assist project managers in properly planning, monitoring, and controlling project operations, such as scheduling software and risk management tools. Project managers may use these tools to detect and reduce risks, keep track of development, and make sure projects are completed on schedule and within budget.

Source: Prepared by the authors, 2023

From another perspective, BIM Data and BIM standards also influence the organisational environment. BIM Standards are explained in the table below.

Table 3: BIM Standards

Term	Description	In-text citation
ISO 19650	ISO 19650 is a global standard for managing information over the whole life cycle of a built asset using BIM. It provides a common framework for BIM processes and information management.	(ISO, 2018)
National BIM Standards	National BIM Standards (NBIMS) are a set of guidelines for BIM in the United States that provide a common language, procedures, and information exchange requirements for BIM projects.	(National Institute of Building Sciences, 2021)
IFC	Industry Foundation Classes (IFC) is an open and neutral file format standard for exchanging data between different software applications used in the construction industry.	(BuildingSMART International, 2021)
CoBie	Construction Operations Building Information Exchange (CoBie) is an international standard for the exchange of facility management data between different software applications.	(National Institute of Building Sciences, 2021)
gbXML	Green Building XML (gbXML) is an open file format standard for exchanging data between different building design and analysis software applications.	(Green Building XML, 2021)
BEP	The BIM Execution Plan (BEP) is a document that outlines the processes and procedures to be used during a BIM project. It defines the roles and responsibilities of all project stakeholders.	(Eastman, Teicholz, Sacks, & Liston, 2018)

Source: Prepared by the authors, 2023

A strong KM system must be in place to efficiently manage and use the significant quantity of data produced by BIM procedures and other organizational operations. An

organisational KM system acts as a single hub for gathering, managing, and disseminating knowledge and information from many sources, such as BIM models, project documentation, and other data sources. Ontologies, machine learning techniques, and a recommender engine are examples of KM system components. Ontologies would offer a formal framework for classifying and organizing data, enabling effective data retrieval and analysis. Organisations may make better decisions by using machine learning algorithms to find patterns and insights in the data. Based on the unique requirements of a user or project, a recommender engine can be used to make recommendations for pertinent material or best practices. Utilising these resources can help firms manage and use their data more effectively, which will enhance project outcomes and boost organizational effectiveness.

As a framework for organizing the complete KM system, the KM trichotomy—which comprises of people, processes, and technology—is also used. While "processes" refer to the techniques and routines used to gather, store, and transfer knowledge, "people" refers to the persons within the company who create, utilize, and manage knowledge. The systems and tools used to support KM operations are referred to as "technology". One of these three categories will apply to each element of the KM framework. Technology solutions that enable KM procedures include, for instance, BIM collaboration platforms, BIM libraries, project dashboards, and project analytics. Examples of technologies encompass ontologies, machine learning algorithms, and recommender engines can be categorized as technology that supports the KM process.

The initial version of the framework has been evaluated and validated by 4 domain experts. The validation process was carried out through semi-structured interviews and lasted 2 weeks overall. Experts provided valuable comments and feedback that were considered when updating the framework. Similarly, the second version of the framework was also evaluated and validated.

CONCLUSION

This research paper proposed a KM-based BIM framework that can enhance collaboration, communication, and decision-making processes. The study highlighted the importance of KM in improving project performance and reducing the risk of errors and conflicts. By incorporating KM activities, such as data and information sharing, knowledge creation, and knowledge transfer, into the BIM framework, stakeholders can ensure that knowledge is captured, stored, and utilized effectively throughout the project lifecycle.

The suggested framework can help stakeholders collaborate and share knowledge, which will result in more informed decisions and more effective project execution. A promising field of study that has the potential to completely transform how businesses capture and use the knowledge of their people is the creation of a system for the management of tacit knowledge based on ontologies and machine learning. Future research in this area will concentrate on enhancing the system's accuracy and dependability by using cutting-edge machine learning algorithms and natural language processing strategies. With these approaches, the system will be able to automatically recognize and extract pertinent information from unstructured data sources including emails, documents, and social media postings. Moreover, in order to facilitate user navigation and information access, efforts will also be undertaken to develop and deploy ontologies that reflect the intricate links between various knowledge domains. The potential for improved visualisation approaches to support knowledge exchange and cooperation among staff will also be investigated through study. In conclusion, the creation of a tacit KM system based on ontologies and machine learning has the potential to dramatically improve organizational learning and innovation, allowing businesses to remain competitive in today's quickly evolving business environment.

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