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Building Information Modelling in Hospital Facilities Management Services: A Significant Systematic Review

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ABSTRACT

Utilizing Building Information Modelling (BIM) in the context of hospital facilities has gained substantial attention due to its potential to revolutionize maintenance, operations, as well as decision-making processes. The systematic literature review investigates the effects, challenges and advantages associated with BIM application in hospital facilities management (FM), serving as a comprehensive resource for healthcare and construction industry professionals. However, a comprehensive comprehension with respect to the present state of study, the methodologies employed and the practical implications of BIM adoption in the context of hospital FM is lacking. The PRISMA framework serves as a guiding structure for systematic reviews and meta-analyses, ensuring the meticulous selection and analysis of pertinent studies while emphasizing transparency and methodological rigor throughout the process. Advanced searching techniques are employed to enhance the precision and inclusiveness of the literature search. The review specifically leverages the Scopus and Web of Science (WoS) databases, tapping into their extensive repositories of scholarly work. The synthesis of the literature yields a rich tapestry of insights, with expert validation emerging as a central theme. The results are organized into three key themes: (1) Advantages of BIM Implementation in Construction and Healthcare; (2) Effects of BIM on Construction Practices and Health Facilities; and (3) Issues and Challenges in BIM Adoption in Healthcare and Construction. The final finding data is (n=25), which review identified key themes. Results showcase the benefits of BIM implementation in optimizing maintenance practices and enhancing operational efficiency in healthcare settings. Finally, BIM can improve hospital facilities management by increasing maintenance, operational efficiency and decision-making. Despite issues with complexity and coordination, BIM's benefits make it important in healthcare. The literature review provides professionals with a clear path to efficiently implementing BIM in their work.

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1. Introduction

In the ever-evolving landscape of healthcare, the effective management of hospital facilities has emerged as a critical element in ensuring optimal patient care, safety and operational efficiency. To meet the growing demands of modern healthcare, an innovative tool has risen to prominence, promising to revolutionize the way hospital facilities are designed, constructed and maintained – Building Information Modelling (BIM). It refers to a transformative paradigm shift in the realm of hospital facilities management (FM). This cutting-edge approach integrates digital technologies and data-driven solutions to optimize the planning, design, construction and ongoing operation of healthcare facilities [1-4]. Hospitals, as complex and multifaceted structures, are particularly well-suited to benefit from the multifunctional capabilities of BIM. In the design phase, fundamental 3D models of actual buildings primarily function as visual representations for upcoming projects or as the groundwork for generating project documentation [5]. In this article, we explore the significant impact of BIM on hospital FM services and how this technology has the potential to reshape the future of healthcare infrastructure.

In the context of healthcare, where precision and efficiency are paramount, BIM offers a comprehensive and holistic view of a hospital's infrastructure, encompassing not only architectural aspects but also mechanical, plumbing, electrical, as well as Heating, Ventilation and Air Conditioning (HVAC) systems. It fosters interdisciplinary collaboration, allowing architects, engineers, contractors and facilities managers to collaborate seamlessly from project inception through to daily operation. BIM provides a digital platform for storing and managing vast amounts of information, offering a dynamic and real-time repository for the entire lifecycle of a hospital facility [6]. One of the primary benefits of implementing BIM in hospital FM services is the enhancement of design and construction processes. BIM enables 3D modelling and visualization, offering stakeholders a clear, immersive and interactive representation of the project before construction even begins [7]. This feature facilitates early detection of design errors, streamlining the construction phase and reducing costly rework. Furthermore, BIM's ability to simulate various design scenarios can lead to the creation of more patient-centric and efficient healthcare environments. Having all maintenance and inspection records is critical for properly planning future interventions [8].

However, the true transformative power of BIM comes to the fore during the operational phase of a hospital. It serves as an invaluable tool for facility managers by providing access to comprehensive data on the facility's systems, equipment and assets. With BIM, maintenance and repairs can be planned and executed with greater precision and less downtime [9]. This data-driven approach to FM not only ensures the longevity of infrastructure but also aids in cost optimization, contributing to overall operational efficiency and sustainability. This article delves into the multifaceted applications of BIM in hospital FM, discussing how it can bolster disaster preparedness, increase energy efficiency and enhance patient safety. Real-world case studies where BIM implementation has brought tangible benefits to healthcare institutions will be explored. Furthermore, we consider the challenges and hurdles that healthcare professionals may encounter when integrating BIM into their FM strategy, including the need for specialized training and the upfront investment required.

In conclusion, as healthcare continually seeks ways to provide the best possible patient care while managing operational costs, BIM offers an unparalleled opportunity to modernize and optimize hospital facilities. Over time, the role of hospital FM has expanded far beyond its traditional mandate of maintaining physical structures. Today, it plays a critical role in creating and maintaining an environment that optimally supports patient care, ensuring safety and managing operational costs [10]. This article intends to give an extensive understanding of the potential and challenges of implementing BIM in hospital FM services, shedding light on its role in moulding future healthcare

infrastructure. BIM improves operational efficiency, lowers costs and improves patient care by integrating data in real-time and doing predictive maintenance on hospital facilities. While it streamlines procedures and helps with lifecycle management, its implementation faces problems such as complexity, interdisciplinary coordination and data security. A thorough literature analysis emphasizes expert validation and collaboration as critical to realizing BIM's promise, providing professionals with useful insights into overcoming these challenges and optimizing hospital administration.

2. Literature Review

The knowledge of the BIM in a hospital or healthcare institution is important for an understanding of the needs in the development, especially during the maintenance process. The researcher explores the economic benefits of BIM in hospital buildings post-construction. In comparison to the two case studies, it found that BIM-based projects had lower aggregated value and saved 343 INR per square meter in operation as well as maintenance compared to non-BIM practices. The study is unique in measuring BIM advantages in the hospitals' post-construction stage, highlighting the need for more research on BIM implementation [11]. Hospital construction faces challenges due to increased stakeholders and building trades, leading to more intricate construction processes. The study identifies interfaces in hospital construction through guided interviews and qualitative content analysis. The optimization of interfaces in complex buildings heavily relies on BIM. A task and trade control matrix is required to enhance coordinate interfaces, alleviate disputes and improve time and financial predictability, especially during inflationary periods [12].

Previous studies have reported the importance of a framework. The study presents a framework for designing fire safety measures in buildings, focusing on reducing casualties and improving evacuation rates. The framework includes four phases: initial preparation, optimization with a meta-heuristic algorithm, decision-making and application into BIM. The framework's performance is evaluated in residential and hospital buildings, demonstrating its effectiveness in modifying design for safe evacuation and potentially reducing fire fatalities [13]. China has built infectious disease hospitals to control the COVID-19 epidemic. China issued guidelines for constructing various types of hospitals, including temporary emergency facilities, makeshift setups and the conversion of general wards into infectious units. Among these guidelines was the utilization of innovative construction techniques and technologies, exemplified by the Thunder God Mountain Hospital, which employed prefabricated modular design, BIM, as well as Computational Fluid Dynamics technology. This efficient construction system helped control the epidemic [14]. The COVID-19 pandemic has posed challenges for conventional hospital operations, necessitating a mixed-use system for the epidemic as well as normal conditions. The development of a BIM-based simulation approach aimed at addressing lifecycle quality control within hospitals post-pandemic. The method improved design efficiency and quality, meeting all functional requirements as well as technical specifications. An optimal pipeline synthesis scheme was achieved, minimizing rework and conserving construction time. This approach serves as a valuable reference for upcoming healthcare facility construction [15].

A different study presents a new framework for optimizing healthcare repair and maintenance (R&M) schedules in hospitals. Utilizing BIM, Genetic Algorithm (GA), as well as Discrete Event Simulation (DES), the system determines optimal R&M tasks. The system reduces time and costs, allowing healthcare managers to use personnel more efficiently. Implemented in a case study, it provides visualized work packages [16]. The global increase in BIM adoption within the construction industry has revolutionized conventional phases such as planning, design, construction and FM by integrating them into BIM-based projects. Despite this transformation, a notable deficiency exists in

having a unified model to evaluate BIM capabilities across these individual stages. Addressing this gap, a study has introduced the Building Information Modelling Capability Assessment Reference Model (BIM-CAREM), demonstrating its usability through case studies with international companies and general contractors in Turkey [17]. The paper delves into the influence of the digital transition on healthcare FM and the enduring effects of digitalization in hospital constructions post-COVID-19. It assesses research spanning from 2011 to 2021, concentrating on digital challenges such as artificial intelligence, BIM, as well as the Internet of Things (IoT). It underscores that prevailing control and management systems are insufficient for handling the complete operational phase of hospital buildings, advocating that digitalization offers a means for facility managers to tackle challenges as well as alleviate the consequences of the pandemic. Furthermore, it categorizes as well as consolidates the inclinations of facility managers concerning high-level information management issues, emphasizing strategies that hold promise for significantly impacting FM within the hospital building context [18].

Previous research also proposes a model in terms of safety rescue. The study introduces a BIM-based ontology model aimed at assisting firefighters in identifying more efficient rescue routes within long-term care facilities. This model takes into account various factors such as building components, path length, materials, as well as the utilization of forcible entry tools. By evaluating existing routes against this model, real-life LTC fire investigation reports are analysed. Experts concur that this method could significantly enhance fire rescue route planning. Furthermore, the applicability of this model could be extended to optimize rescue operations in hospital fire scenarios, thereby improving the effectiveness as well as efficiency of firefighting efforts within these critical facilities [19]. Moreover, the digital evolution of operational and maintenance (O&M) activities has been steering the FM sector towards a more strategic role, emphasizing the performance of businesses and the sustainable utilization of natural resources throughout the lifecycles of assets [20].

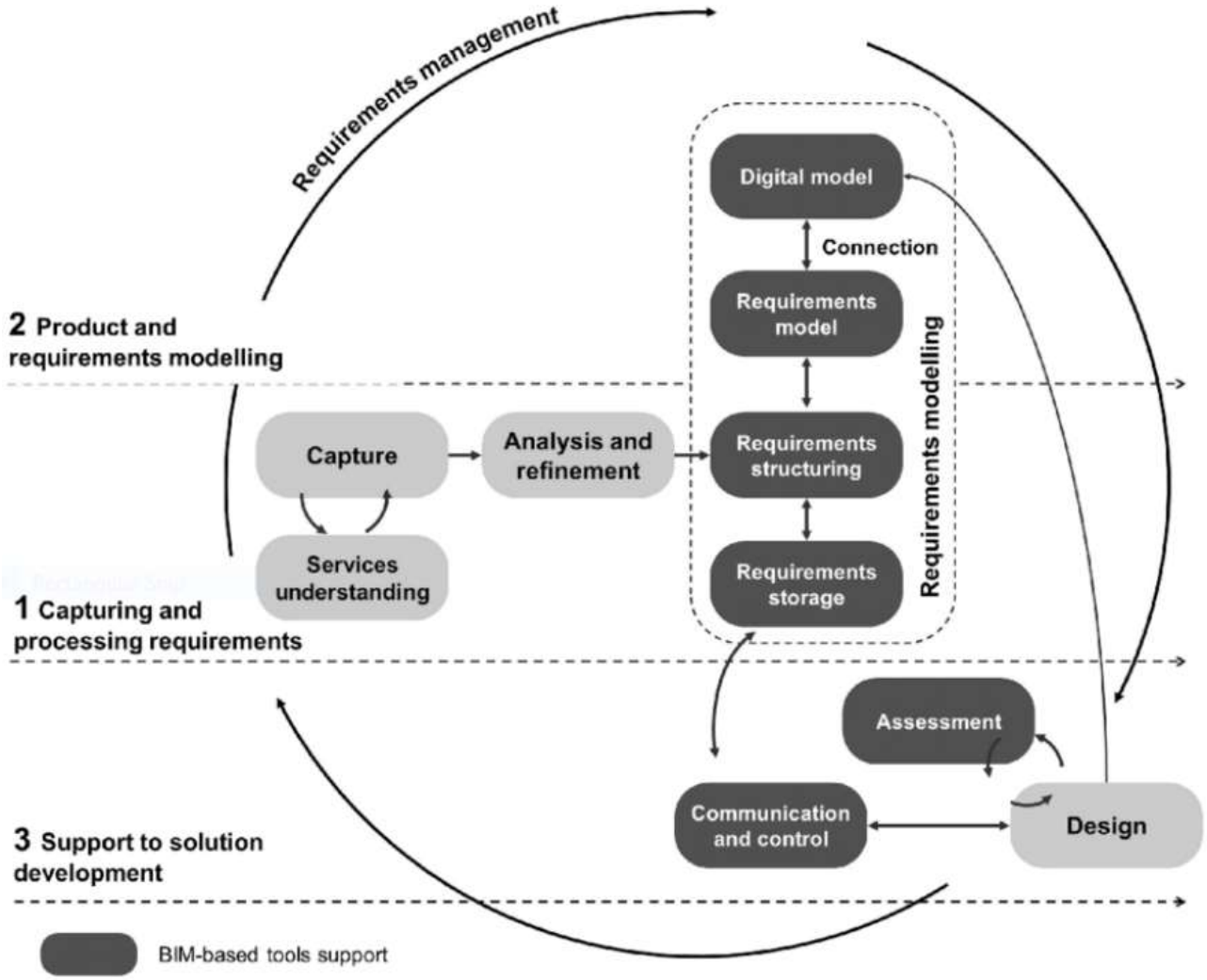

Fig. 1. Requirements in Healthcare projects [1]

3. Material and Methods

3.1 Identification

The systematic review process involves three fundamental phases that guide the selection of numerous relevant papers for this study. Initially, keywords were identified and associated terms were searched using dictionaries, thesauri, encyclopaedias, as well as previous research. Once all pertinent terms were chosen, search strings were formulated for the Scopus as well as WoS databases (Table 1). During the first stage of the systematic review process, the current research successfully retrieved a total of 831 papers from both databases.

Table 1
The search string

Scopus	TITLE-ABS-KEY ((“Building Information Modeling" OR bim) AND (hospital OR ward OR healthservice OR institution)) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (PUBSTAGE, “final”))
WoS	(“Building Information Modeling” OR bim) AND (hospital OR ward OR healthservice OR institution) (Topic) and 2023 or 2022 (Publication Years) and Article (Document Types) and English (Languages)

3.2 Screening

In this phase, any duplicate papers discovered will be excluded from the compiled list of searched documents. The initial screening phase excluded 718 publications, while the subsequent phase involved the examination of 113 papers using distinct inclusion as well as exclusion criteria illustrated in Table 2. Additionally, the primary criterion employed was the literature itself, encompassing research papers as the primary source of practical suggestions. The category encompassed a wide range of content, including meta-syntheses, reviews, meta-analyses, book series, chapters, books, as well as conference proceedings not included in the latest study. The review was specifically limited to publications in the English language and exclusively concentrated on the period from 2022 to 2023. A total of 30 publications were excluded due to duplication criteria.

3.3 Eligibility

In the third step, which involves eligibility assessment, 83 articles were compiled. Each article's title and key content underwent meticulous scrutiny to ensure alignment with the study's inclusion criteria and research objectives. Consequently, 58 reports were excluded due to being out of scope, having titles lacking relevance or abstracts not aligning with the study's objectives. As a result, 25 articles have been selected for further review (Table 2).

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2022 until 2023	< 2022
literature type	Journal (Article)	Review, Book, Conference
Publication Stage	Final	In Press

3.4 Data Abstraction and Analysis

The study employed an integrative analysis as a key assessment method to scrutinize and amalgamate diverse research designs encompassing qualitative, quantitative, as well as mixed methods. The primary objective of this proficient investigation was to pinpoint pertinent topics and subtopics. The initial phase of this thematic development centred on data collection. Figure 2 visually demonstrates the authors' meticulous analysis of 25 publications to extract assertions and materials pertinent to the study's topics. This involved a comprehensive examination of methodologies and research findings across all the studies under scrutiny. Subsequently, the author engaged in collaboration with fellow co-authors to derive themes from the context of the study. Throughout the data analysis, a log meticulously documented all analyses, perspectives, puzzles, as well as pertinent thoughts guiding the data interpretation. Upon completion, the authors cross-referenced the results to identify any disparities in the thematic development process. It is important to highlight that in cases of conflicting concepts, the authors deliberate among themselves to reach a consensus. The examinations underwent a rigorous validation process conducted by two experts to ensure the accuracy of the problems. This review phase focused on establishing domain validity and assessing the clarity, significance, as well as sufficiency of each sub-theme. The author incorporated adjustments based on expert feedback and comments to enhance the content.

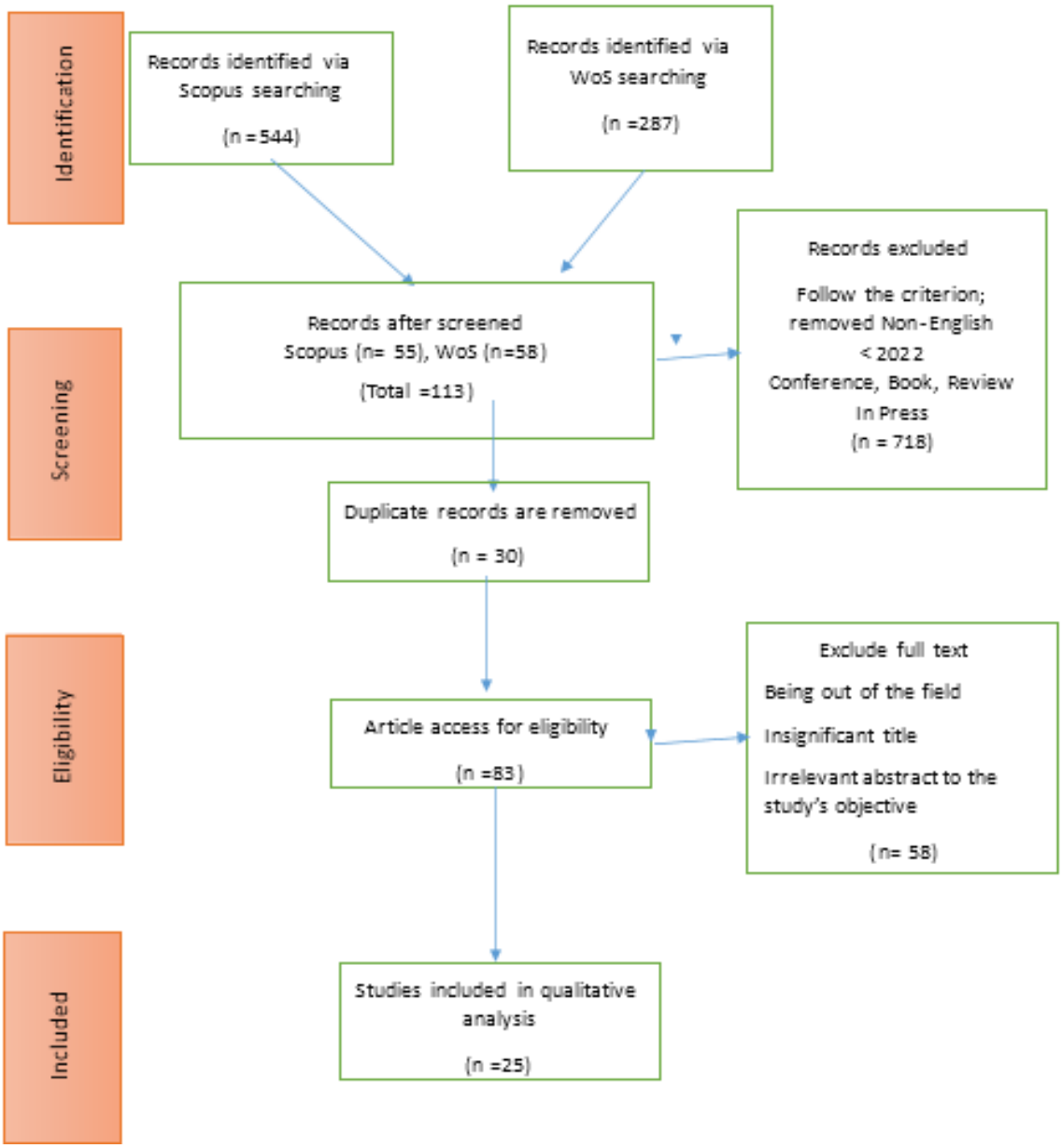

Fig. 2. Flow diagram of the suggested searching study [21]

4. Result

These themes are designed to capture the advantages, effects and challenges associated with implementing BIM in both construction and healthcare contexts, providing a well-rounded view for your paper in the engineering technology domain. Based on the searching technique, 25 articles were extracted and analysed. All articles were categorized based on three main themes, which are the Advantages of BIM Implementation in Construction and Healthcare (9 articles), the Effects of BIM on Construction Practices and Health Facilities (6 articles) and Issues and Challenges in BIM Adoption in Healthcare and Construction (10 articles) (Table 3). BIM is crucial for hospital facilities management, improving operational efficiency, patient safety and compliance with safety laws. Integrated with IoT devices, BIM enhances predictive maintenance, reduces equipment failures, improves space management and promotes sustainability through energy tracking. It also facilitates cross-departmental collaboration, leading to better communication and decision-making in healthcare settings.

Table 3
The research article's findings are based on the proposed searching criterion

Theme 1: Advantages of BIM Implementation in Construction and Healthcare					
Authors	Title	Year	Journal	Methodology	Advantages and finding
Herzanita *et al.,* [22]	The Application of BIM-Based OHSMS Information Systems to Improve Safety Performance	2022	International Journal of Safety and Security Engineering	The study aimed to enhance safety performance in OHSMS information systems by creating a safety plan using a case study method.	The WBS integrates with BIM to visualize projects, enabling easier identification of hazards and risks. Data security information is built in BIM, resulting in a BIM-based OHSMS system.
Sabbaghzadeh *et al.,* [13]	A BIM-Based Solution for the Optimisation of Fire Safety Measures in the Building Design	2022	Sustainability (Switzerland)	This study develops a framework for determining fire safety measures in residential as well as hospital buildings. The framework includes four phases: initial preparation, optimization, involves a meta-heuristic algorithm, decision-making and application into BIM. The performance is evaluated using a case study approach.	The framework effectively and economically modifies building designs for safe evacuation, reducing fire fatalities and improving fire safety measures.
Petersen *et al.,* [23]	Adding value through enterprise building information models in healthcare services	2023	Journal of Facilities Management	Three prototypes, utilizing various technologies and EBIM, demonstrate the various applications of EBIM in hospitals and Healthcare operations, using a case study approach.	EBIM data enhances healthcare-related processes, benefiting stakeholders beyond hospital design and construction life cycle Phases, providing value across various healthcare-related processes in combination with other data sources.
Condotta *et al.,* [24]	BIM-based method to inform operation and maintenance phases through a simplified procedure	2023	Journal of Building Engineering	The paper outlines a study focusing on the integration of BIM and CMMS software through the utilization of the IFC open standard. This integration aims to facilitate building management processes. The research is conducted in collaboration with Prometeo Srl and GEMMO SpA.	The ad hoc BIM model was technically validated may be employed by other practitioners to develop the method in other investigations.
Gao *et al.,* [15]	A BIM-Based Simulation Approach for Lifecycle Quality Control in Post-Pandemic Hospitals	2023	Buildings	Implementing a case study-based methodology using grey literature to create a BIM-centred simulation strategy for ensuring lifecycle quality control in post-pandemic hospital infrastructure.	The design scheme effectively adhered to functional and technical specifications, incorporating an optimal pipeline synthesis scheme, reducing rework and saving construction time, providing valuable insights for future healthcare facility construction.

Kamal *et al.,* [16]	BIM-based repair and maintenance for hospital work order management	2022	Automation in Construction	The suggested framework employs BIM, GA and DES to optimize R&M tasks, reducing time and costs as well as improving personnel efficiency. Implemented in a case study, it provides visualized work packages	The paper proposes a novel framework for optimizing R&M schedules in hospitals by minimizing indirect and direct costs, considering managers' preferences and constraints.
Zheng *et al.,* [25]	Dynamic prompt-based virtual assistant framework for BIM information search	2023	Automation in Construction	The "BIMSGPT" framework presented in this paper is a dynamic prompt-based virtual assistant. It integrates advanced generative pre-trained transformer technologies to facilitate efficient information retrieval from building information models.	This paper advances virtual assistants for BIM in the construction industry, improving accessibility and reducing data requirements for processing Nationally Significant Queries (NL queries).
Musarat *et al.,* [26]	Applications of Building Information Modelling in the Operation and Maintenance Phase of Construction Projects: A Framework for the Malaysian Construction Industry	2023	Sustainability (Switzerland)	This study explores the factors influencing BIM technology adoption during the O&M phase, assessing over 50 research papers from the prior decade to identify potential barriers and drivers.	The study developed a conceptual framework to improve the adoption of BIM software during the O&M phase of a construction project, providing valuable insights for future researchers.
Demirdöğen *et al.,* [27]	BIM-based big data analytic system for healthcare facility management	2023	Journal of Building Engineering	This paper proposes a healthcare FM system employing BIM, Big Data Analytics, as well as NoSQL databases for the visualization of Key Performance Indicators and FM information queries.	The study illustrates the system's efficacy and practicality in enabling healthcare FM practitioners to efficiently retrieve and analyse FM data.
Theme 2: Effects of BIM on Construction Practices and Health Facilities					
Hartmann *et al.,* [12]	Optimizing Interfaces of Construction Processes by Digitalization Using the Example of Hospital Construction in Germany	2023	Buildings	The study analysed hospital construction interfaces through guided interviews with health sector experts, utilizing qualitative content analysis to identify and evaluate suitable solutions.	The paper discusses the usage of BIM in hospital construction in Germany, focusing on optimizing interfaces, task coordination and trade control matrix to reduce disputes, improve predictability and alleviate misunderstandings.

Tanko *et al.,* [28]	BIM in the Malaysian construction industry: a scientometric review and case study	2022	Engineering, Construction and Architectural Management	The paper uses Scopus database data and scientometric analysis to assess BIM literature in Malaysia, identifying research gaps. One hundred questionnaires were distributed to practitioners and descriptive analysis was performed using SPSS software.	Research gaps in construction projects, energy efficiency, buildings, lifecycle, as well as housing are identified. BIM applications used in Johor and Selangor include quantity take-off, site utilization planning, clash detection, digital fabrication, as well as 4D stimulation.
Al-Musawi *et al.,* [29]	Evaluation of Construction Project's Cost Using BIM Technology	2023	Mathematical Modelling of Engineering Problems	This research examines a construction project using manual quantity surveying and numerical project take-off using the RevIT software package for budget calculation and analysis.	The study found that BIM technology is a reliable solution for determining construction project costs, especially in complex projects. It also found that REVIT software significantly reduced human errors and saved time and effort for engineers in estimating the budget for a hospital building with various structural components.
Iadanza *et al.,* [30]	Automatic Classification of Hospital Settings through Artificial Intelligence	2022	Electronics (Switzerland)	This study proposes an automatic recognition system for hospital settings, incorporating cloud-based models, a customized model from Clarifai Custom Model service and object recognition software from Facebook AI Research integrated with a random forest classifier.	The customized model consistently classified photos with 96% confidence, while the third tool achieved 99% accuracy in limited hospital settings. However, increasing room typologies affected performance negatively.
Wang *et al.,* [19]	Route Planning for Fire Rescue Operations in Long Term Care Facilities Using Ontology and Building Information Models	2022	Buildings	The research introduces an ontology model based on BIM aimed at aiding firefighters in optimizing rescue routes. It takes into account various factors such as path length, building components, materials and the selection of forcible entry tools.	Experts suggest extending the BIM-based ontology model for hospital fire scenes to improve fire rescue route planning and enhance firefighters' efficiency in crucial facilities.
Zhou *et al.,* [31]	Intelligent Fangcang Shelter Hospital Systems for Major Public Health Emergencies: The Case of the Optics Valley Fangcang Shelter Hospital	2022	Journal of Management in Engineering	The investigation conducted in this paper delves into the creation and operational use of an intelligent system within a Fangcang shelter hospital. This exploration involves interviews, document analysis, as well as the study of sensors, models and platforms.	This paper offers insights into implementing an intelligent Fangcang shelter hospital system, highlighting challenges and lessons learned. It serves as a reference for COVID-19 field hospitals as well as provides theoretical guidance for future public health emergencies.

Theme 3: Issues and Challenges in BIM Adoption in Healthcare and Construction					
Hassan *et al.,* [32]	Exploring the Challenges and Opportunities of BIM Implementation in Major Architectural Projects in Iraq	2023	International Journal of Sustainable Development and Planning	The research delves into the utilization of BIM within significant architectural projects in Iraq. It explores the factors contributing to its constrained adoption, utilizing interviews with specialists and surveys to gain insights.	The study reveals limited BIM application in Iraq's major projects due to a lack of government as well as private institution requirements. It aims to guide managers in determining the adequate level of detail relying on project characteristics as well as integration limits.
Ebekozien *et al.,* [33]	Maintenance of public hospital buildings in Nigeria – an assessment of current practices and policy options	2022	Journal of Facilities Management	The research utilized a mixed research design, combining quantitative as well as qualitative data analysis through a structured questionnaire among hospital maintenance experts.	The paper identifies six main causes of insufficient maintenance practices in public hospital buildings: design, statutory requirements, budget, construction stages, managing activities, as well as user perception.
Ensafi *et al.,* [34]	Developing systems-centric as-built BIMs to support facility emergency management: A case study approach	2022	Automation in Construction	The present as-built BIM does not meet facility management needs. For enhanced safety and efficiency, it is essential to reconfigure as-built models. These models should offer crucial operational and maintenance data, effectively address operational issues and prioritize a system-oriented approach. This enables facility owners to access model graphics promptly during maintenance emergencies, aiding visualization and swift decision-making.	This paper defines requirements and procedures for configuring systems-centric as-built BIM models, defining fourteen properties and implementing them in a case study analysing mechanical and plumbing systems in a science and classroom building.
Pedral Sampaio *et al.,* [18]	A discussion of digital transition impact on facility management of hospital buildings	2023	Facilities	This paper reviews research on digital challenges for FM from 2011-2021, using qualitative and quantitative methods and addresses the digital transition effect on hospital buildings.	This paper discusses the digital transition in the FM industry, especially in hospital buildings. It highlights the need for intelligent building systems to be reactive, interactive and immersive. Digitalization can help facility managers meet elevating health demands as well as reduce the impacts of future pandemics, enhancing the overall digital transformation.

Oladimeji *et al.,* [35]	The Influence of Building Information Modelling Adoption in the Viability of Medium, Small and Micro Scale Construction Firms (MSMSCFs)	2023	Buildings	The study assesses how BIM affects the sustainability of construction companies in Nigeria, with a specific focus on 65 employees within 31 MSMSCFs.	Stakeholders must promptly consider BIM-influenced factors to enhance the sustainability of MSMSCFs, which will accelerate their adoption and usage, especially in developing nations.
Oke *et al.,* [36]	Appraisal of awareness and usage of digital technologies for sustainable well-being among construction workers in a developing economy	2023	International Journal Of Construction Management	Utilizing a quantitative research approach, the article delves into the exploration of awareness and utilization of DT within the construction industry. Questionnaires were administered to Lagos State, Nigerian professionals.	This article offers an extensive roadmap for Nigerian developing economies, outlining the collaborative efforts of various stakeholders, including professional bodies, lawmakers, policymakers, government, financial institutions, as well as HEIs.
Schönbeck *et al.,* [37]	A Decision Support System for Hospital Configurations in Construction Projects	2022	Buildings	The primary goal of this study was to develop a comprehensive decision support system leveraging building data. The system aimed to assist construction projects in making informed hospital configuration decisions, offering an end-to-end perspective.	The research shows the feasibility of utilizing building model data for configuration decision support in construction projects, highlighting operational gaps and the need for changes in data collection and management.
Memari *et al.,* [38]	The interdisciplinary conceptualization of future-proofing in the context of hospital buildings	2022	Building Research And Information	This research employs a scoping review methodology to discover the concept of future-proofing in hospital building contexts, examining design, built environment, as well as hospital buildings.	Various research employs a crisis-driven approach to future-proofing, focusing on adaptability and resilience, indicating a need for further research and dialogue in hospital building design.
Yilmaz *et al.,* [17]	BIM-CAREM: Assessing the BIM capabilities of design, construction and facilities management processes in the construction industry	2023	Computers in Industry	BIM adoption in construction is accelerating globally, transforming traditional stages into BIM-integrated projects. Evaluating BIM capabilities helps identify gaps and improve their use.	The study revealed that the BIM capability levels in design, construction, as well as FM processes vary both across and within companies.
Li *et al.,* [39]	BIM-based determination of indoor navigation sign layout using hybrid simulation and optimization	2022	Automation in Construction	The research suggests a new framework for designing navigation sign layouts using BIM, aiming to enhance spatial matching between occupants' and signs' navigation cues.	The study uses crowd simulation and mathematical modelling to determine navigation cue demand and supply. A programming model optimizes sign location orientation and navigation text. A case study of a large hospital entrance lobby evaluates sign layouts, proving effective in reducing navigation difficulty and time.

5. Discussion

BIM refers to a transformative tool in healthcare construction, integrating design and operations, ensuring safety compliance, efficient space utilization and streamlined maintenance practices. It optimizes hospital facilities' lifecycle, improves patient care quality and reduces operational costs. The advantages of BIM implementation in construction and healthcare are vast and multifaceted which are:

i. Risk Identification and Visualization: Integration of the Work Breakdown Structure (WBS) with BIM permits for the projects' visualization, enabling easier identification of hazards and risks. This enhances safety measures, crucial in both construction and healthcare environments, where safety is paramount.
ii. Data Security and OHSMS in BIM: Building data security information within BIM results in an Occupational Health and Safety Management System (OHSMS). This ensures a secure framework for managing potential risks and safety concerns, particularly vital in healthcare settings to safeguard sensitive patient data.
iii. Improved Design Modification for Safety Measures: BIM facilitates effective and economical modification of building designs for safe evacuation, reducing fire fatalities and enhancing fire safety measures. This is crucial in healthcare facilities, ensuring patient and staff safety during emergencies.
iv. Optimization of R&M Schedules: A novel framework proposed for optimizing R&M schedules in hospitals reduces costs and considers managerial preferences and constraints. BIM facilitates predictive maintenance and cost-effective scheduling, which is crucial for healthcare FM.
v. Advancements in Virtual Assistants and Accessibility: Advancing virtual assistants for BIM in the construction industry improves accessibility and reduces data requirements for processing queries. This contributes to smoother workflows and faster decision-making, particularly for nationally significant queries.
vi. Enhanced Implementation during the O&M Phase: The development of a conceptual framework to enhance BIM software implementation during the Operations and Maintenance (O&M) phase provides insights for future researchers. This ensures that BIM's benefits extend to the entire lifecycle of a building, ensuring long-term efficiency.
vii. Effective Facility Management (FM) and Data Retrieval: Demonstrating BIM's effectiveness in efficient FM data retrieval and analysis supports the practicality of using BIM for managing healthcare facilities. It streamlines data retrieval and aids in informed decision-making for better FM.

The research investigates the utilization of BIM in hospital construction in Germany, with a particular interest in enhancing interfaces, task coordination and trade control matrix to mitigate disputes, enhance predictability and mitigate misunderstandings. It identifies critical research gaps in energy efficiency, construction projects, as well as housing, showcasing varied BIM applications, for instance, clash detection, quantity take-off, digital fabrication, site planning, including 4D simulation in regions like Johor and Selangor. Notably, the study confirms BIM's reliability in determining construction costs, particularly in complex projects, highlighting the efficiency of REVIT software in reducing errors and time in budget estimations for hospitals. While exhibiting high accuracy in classifying photos, the study reveals limitations in performance with increased room typologies. Furthermore, experts propose expanding BIM-based ontology models for hospital fire scenes to

enhance firefighting efficiency in vital facilities. This paper not only provides insights into implementing an intelligent Fangcang shelter hospital system but also serves as a valuable reference for COVID-19 field hospitals, offering theoretical guidance for future public health emergencies, thereby underlining the pivotal role of BIM in advancing hospital construction and emergency healthcare response strategies.

6. Conclusion

The research underscores several challenges and limitations hindering BIM adoption in healthcare and construction, especially in the context with regard to major Iraqi projects. It highlights the absence of sufficient government and private institutional requirements as a primary reason for the limited application of BIM in Iraq's projects. The study aims to guide project managers in determining appropriate levels of detail in BIM based on project characteristics and integration constraints, providing crucial insights into system-centric as-built BIM models' implementation. Moreover, it identifies six key causes contributing to insufficient maintenance practices in public hospital buildings, encompassing statutory, construction, design, budgetary, managerial and user perception-related factors. The paper stresses the urgent need for digital transformation in the FM industry, especially within hospital buildings, emphasizing the necessity for intelligent, reactive, interactive and immersive building systems to meet healthcare demands and manage potential future crises. The Building Industry Development Board Malaysia (CIDB), which governs the Construction Industry Standard (CIS), requires employers to guarantee that their staff have the requisite certification and CIDB Green Card before allowing them access to construction sites in Malaysia.

The goal of this strategy is to ensure that all personnel are compatible and aware of potential risks in their surroundings that could cause a risk [40]. It suggests collaborative efforts among stakeholders, including governmental bodies, policymakers, financial institutions and professional organizations, to create a comprehensive roadmap for adopting BIM in developing economies like Nigeria. Furthermore, the study accentuates the variability in BIM capability levels within and across companies, indicating the necessity for standardization and increased dialogue in the industry for future-proofing designs and enhancing adaptability and resilience in hospital construction. In conclusion, these findings collectively highlight the complex landscape of challenges and the diverse spectrum of factors affecting BIM adoption, underscoring the necessity for collaborative efforts, standardization and further research to resolve the barriers as well as fully harness the BIM potential in healthcare and construction. Finally, BIM can improve hospital facilities management by increasing maintenance, operational efficiency and decision-making. Despite obstacles in complexity and coordination, as well as the necessity for a considerable initial investment, BIM's benefits make it important in healthcare. However, its adoption may be limited by technological readiness and organisational alignment. The literature review provides professionals with a clear guide to effectively adopting BIM, emphasising the importance of proper training, interdisciplinary collaboration and strategic planning in order to fully realise its potential.

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