ISBN: 978-628-96613-1-6. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2025.1.1.1453

Modern BIM Implementations on Hospitals Life Cycle Management: Systematic review

Andrea Ponce* ; Dany Nieto† ; Manuel Adalid Gamero-V.‡ ;
*,†,‡ Facultad de Ingeniería, Universidad Tecnológica Centroamericana (UNITEC), San Pedro Sula, Honduras
acpcandrea@unitec.edu, danynietouni20@unitec.edu, manuelgamero@unitec.edu

***Abstract*—Building Information Modeling (BIM) has emerged as a pivotal methodology in the design, construction, and management of healthcare facilities. This bibliographic review explores the application of BIM in enhancing hospital infrastructure by focusing on optimization, sustainability, and resilience. The systematic analysis highlights the transformative role of BIM in streamlining project design, improving resource efficiency, and ensuring adaptive facility management. Additionally, it examines the integration of emergent technologies such as artificial intelligence, virtual reality, and blockchain, which further extend BIM's capabilities. This study underscores BIM's potential in revolutionizing hospital design and operational paradigms to meet contemporary challenges and future demands.**

***Keywords*—BIM, hospital infrastructure, emerging technologies, sustainability, integrated management, resilience.**

I. Introduction

In recent decades, the development of new technologies in the construction industry has led to significant innovations in project management and planning. One of the key digital tools that has revolutionized design and management processes is the Building Information Modeling (BIM) methodology. Effective building and facility design relies on the integration of a multidisciplinary team of professionals, including architects and engineers [1]. Due to this, the BIM methodology has become an essential tool for collaborative work in the design, construction, and maintenance of large-scale projects [2].

In the early stages of a project, the implementation of the BIM methodology enables the production of three-dimensional models that integrate the geometric representation and technical information of the building. It provides a precise visualization of fundamental infrastructure features, such as architectural design, materials, and structural components to be used. This approach facilitates the early identification of potential inconsistencies or conflicts in the design, helping mitigate risks associated with planning errors, cost overruns, and delays during the execution phase. Additionally, this methodology offers the ability to analyze the project in a virtual environment, enabling the optimization of technical decisions and ensuring greater efficiency in construction [3].

The transition to BIM represents a significant shift by overcoming the integration and sustainability limitations of tools such as Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE). Although these tools allow creation and analysis of digital models, they often lack a comprehensive collaborative approach and effective management of the construction lifecycle. In contrast, BIM facilitates the optimization of design, construction, and infrastructure operation by integrating metrics such as energy consumption, natural lighting, and airflow, promoting performance-based decision-making [4]. Additionally, BIM's interoperability with certifications like LEED, which promote sustainability goals such as energy efficiency and waste reduction, solidifies it as a key tool for comprehensive project management [5].

Hospital infrastructure, like any building, follows a life-cycle that spans from its initial design to its operation and maintenance. Due to its complexity and the importance of ensuring continuous functionality, it is logical to integrate advanced tools that enable effective management of each stage of this process. In this context, the BIM methodology has become a fundamental element. Beyond transforming digital designs into dynamic models, BIM facilitates the centralization and management of information throughout the entire lifespan of buildings [6]. To systematically evaluate the capabilities and applications of BIM across different stages, the BIM-CAREM model emerges. This tool proposes a comprehensive framework for exploring new possibilities in the management of critical infrastructure, such as hospitals, from planning to sustainable operation [7].

II. Methodology

In this bibliographic review article, the systematic literature review methodology was adopted to analyze the use of BIM in the hospital sector. This structured approach involved an exhaustive search in scientific databases to identify relevant research on the implementation of BIM in various areas of the healthcare sector. This search was divided into two parts to achieve better filtering and selection of pertinent literature. The methodology followed is presented in Figure 1, where the main steps of the analysis are detailed.

First, an initial search was conducted in the Science Direct, Pubmed, and IEEE databases in November 2024. The key terms used in the search were "BIM," "hospitals," and "healthcare facilities." The two search formulas employed were "BIM" AND "Hospitals" & "BIM" AND "Healthcare Facilities." During this initial search, a relevant filter was applied to obtain literature published between 2019 and 2024. The title and abstract of all articles found were examined. Studies that did not specifically address the use of BIM in healthcare facilities, articles with limited access to the full text, and publications in languages other than English or Spanish were excluded (See Table I).

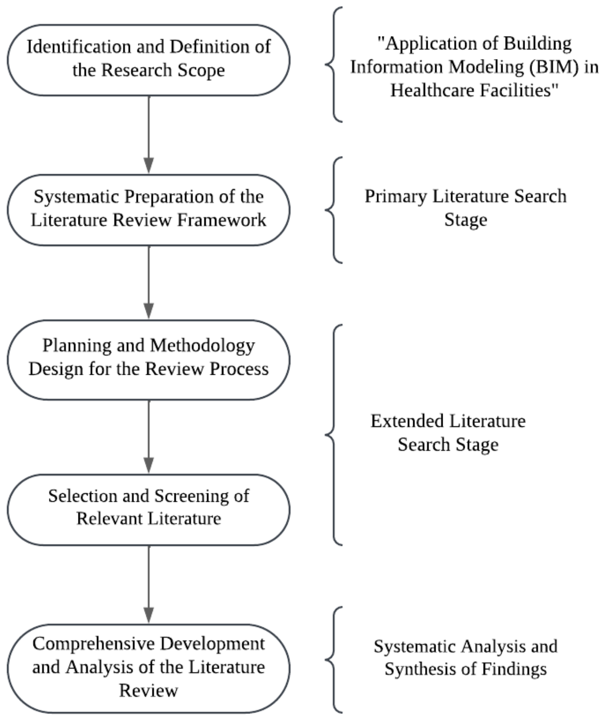

Fig. 1. Diagram of the methodology used in the bibliographic review.

TABLE I
SEARCH PARAMETERS (FIRST LEVEL)

Databases	3
Time Restriction	2019 - 2024
Search Fields	Title, Abstract, Keywords
Search Equation 1	”BIM” AND ”Hospitals”
Search Equation 2	”BIM” AND ”Healthcare Facilities”

In the second level of the search (See Table II), the scope was expanded to include articles related to the use of BIM in the hospital sector. In addition to the previously mentioned databases, MDPI, Researchgate, the Digital Library of the Association for Computing Machinery (ACM), the American Society of Civil Engineers (ASCE), and Taylor & Francis were used. The additional search formulas employed were ”BIM” AND ”Construction” and ”BIM” AND ”Design.” This approach aimed to explore broader research that could contribute to the analysis from complementary perspectives. During this process, exclusion criteria similar to those of the first level were applied: studies that did not specifically address the use of BIM in the construction or design of healthcare facilities, redundant publications, or those with low methodological rigor, and articles in languages other than English or Spanish were discarded. This strategy allowed for the refinement and diversification of the selected literature, maximizing its relevance for the analysis.

TABLE II
SEARCH PARAMETERS (SECOND LEVEL)

Databases	9
Time Restriction	2019 - 2024
Search Fields	Titulo, Abstract, Keywords
Search Equation 1	”BIM” AND ”Hospitals”
Search Equation 2	”BIM” AND ”Healthcare Facilities”
Search Equation 3	”BIM” AND ”Resilience”
Search Equation 3	”BIM” AND ”Big Data”
Search Equation 4	”BIM” AND ”IoT”
Search Equation 5	”BIM” AND ”Artificial intelligence”

A. Locations Where the Studies Were Conducted.

Among the analyzed articles, the distribution of countries shows that China had the highest participation with 31.6% of the studies (n = 12). This was followed by the United Kingdom with 10.5% (n = 4), and Malaysia and Germany, each with 7.9% (n = 3). Turkey, Sweden, Italy, and Iran contributed 5.3% each (n = 2), while the Netherlands, Kuwait, the United States, Chile, Brazil, Australia, and Saudi Arabia each contributed 2.6% (n = 1).

In regional terms, Asia is the most represented region, accounting for 50% of the studies, due to the combined contributions of China, Malaysia, Iran, Kuwait, and Saudi Arabia. China, in particular, leads in production with 31.6% of the total studies. Europe contributed a significant proportion, with the United Kingdom and Germany standing out, while representation from the Americas and the Middle East was lower. No studies from the African continent were recorded in the analyzed set.

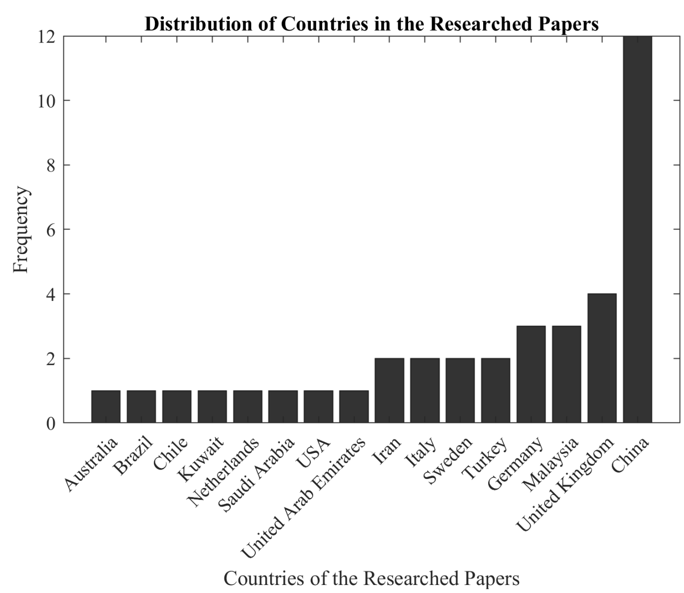

Fig. 2. Distribution of Countries in Researched Papers

B. Analysis of Keyword Interrelation.

The analysis shows how different key areas interrelate in the construction and management of hospitals, especially in emergency situations. First, the incorporation of advanced technologies such as Building Information Modeling (BIM), Blockchain-as-a-Service (BaaS), and the Internet of Things (IoT) has transformed the way hospital projects are managed, facilitating the integration and optimization of processes. This goes hand in hand with efficient resource management, highlighting terms such as cost management, quality management, and risk management, which are essential for maintaining control in large-scale projects, ensuring both their feasibility and the quality of services.

In emergency situations, concepts such as modular hospitals, emergency projects, and the context of the COVID-19 pandemic reflect the need for quick and flexible solutions. In this regard, sustainability becomes a fundamental factor, with a focus on green hospital designs and climate resilience, which not only aim to reduce the carbon footprint but also to prepare infrastructures for future challenges. Finally, the optimization of hospital design and hospital service systems underscores the importance of improving the operability and efficiency of hospitals, ensuring that they are better prepared to provide care in critical moments.

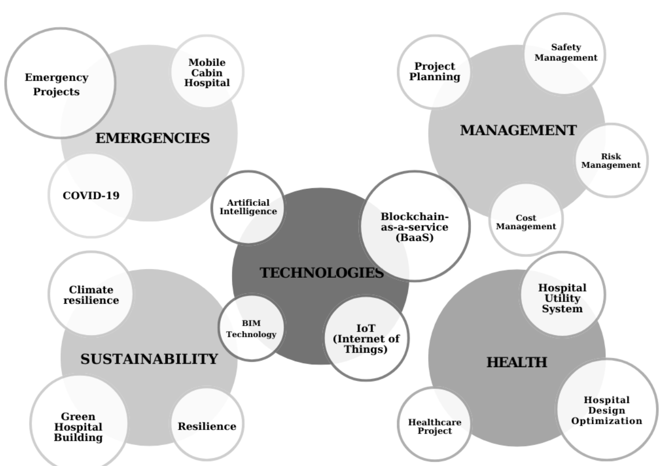

Fig. 3. High Frequency Keywords

C. Analysis of the Interrelationship in Keywords

The graph shows the distribution of articles published between the years 2019 and 2024, highlighting trends in the volume of publications per year.

Figure 4 illustrates the trend in article publication in this field during the analyzed period. From 2019 to 2021, there was a gradual increase in the number of published articles, reaching a peak in 2022 with 8 publications. This year marked a particularly active period for the topic. However, in 2023, the number of articles slightly decreased, stabilizing at 6 publications, suggesting a possible consolidation of academic interest in the subject after a growth peak in 2022. This trend could indicate a mature phase of exploration and implementation compared to the initial years of analysis.

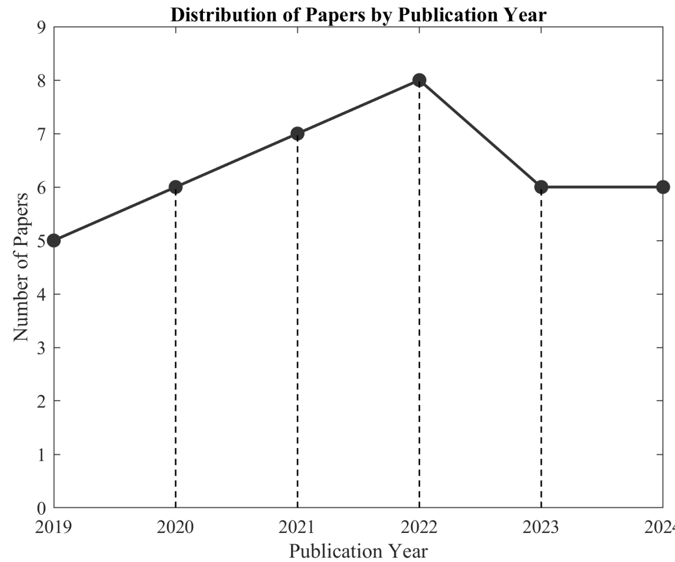

Fig. 4. Distribution of Papers by Year of Publication

III. Results

A. Use of BIM in Design, Planning, and Project Management.

Design, planning, and project management are fundamental stages in any industry, particularly in construction [8]. These phases are interrelated and aim to ensure that a project meets its objectives efficiently within the established timelines. The BIM methodology enables interdisciplinary collaboration, a more precise visualization of the design, and a reduction in project delivery time [9]. This methodology has emerged as a forward-looking technology used to advance construction project management [4]. The successful management of the design, execution, and completion stages of a construction project falls within the scope of project management [10]. According to a survey conducted by Dodge Data & Analytics in 2020, approximately 68% of respondents reported using BIM technology in more than half of their projects and technical construction aspects [11], [12]. Likewise, a BIM-based strategy for infrastructure resource management has been defined, highlighting the effectiveness of this technology in optimizing resource management within construction projects [13].

Meanwhile, the use of BIM has become a predominant trend in the healthcare sector. BIM has transformed the process by which buildings are designed and delivered in various ways, particularly in the construction of highly complex infrastructures such as healthcare facilities [14]. The design of hospitals generally requires the application of systematic design methodologies and advanced computational tools to meet complex functional requirements [15], which underscores the importance of adopting advanced methodologies like BIM to optimize the planning, construction, and operation processes of such facilities [16]. A notable example of this application is the use of BIM technology in the design and construction management stage of the Jinzhou New District Medical Center, which is part of the First Affiliated Hospital of Dalian Medical University [17].

Furthermore, Wang et al. [18] developed a model to examine the influence of the COVID-19 pandemic on the adoption of BIM in hospitals associated with Architecture, Engineering, and Construction (AEC) projects, demonstrating its application as a project management tool. On the other hand, in the article "Predicting implications of design changes in BIM-based construction projects through machine learning" by Abdulfattah et al. [19], the integration of machine learning algorithms in BIM-based projects to predict the implications of design changes is discussed. The results suggest that this integration can reduce uncertainty in project planning and management, improving adherence to budgets and schedules. Finally, it is important to highlight that BIM-based planning development allows for the optimization of costs and economic benefits for a project [19].

B. Use of BIM in Hospital Optimization, Sustainability, and Resilience

Sustainability and hospital resilience are fundamental pillars in the design and management of healthcare facilities, especially considering the growing global environmental awareness and the challenges derived from the scarcity of natural resources [20]. Lu et al. [21] conducted a study in a hospital in Anhui province, China, where they proposed the integration of methodologies such as BIM and Life Cycle Assessment (LCA) to obtain a simulation of the Building Life Cycle Carbon Emissions (BLCCE). Similarly, Zhang et al. [22] address the implementation of BIM through a process aimed at expediting the design and construction of more sustainable buildings.

On the other hand, the article by TohidiFar, Mousavi, and Alvanchi [23] proposes a hybrid model based on BIM and Bayesian Networks (BN) to enhance the resilience of hospital public service systems during disasters. The study addresses how critical infrastructures, such as energy, water, and HVAC systems, can be optimized to minimize disruptions. The approach integrates BIM simulations to visualize potential failures and uses BN to analyze risk probabilities and mitigation strategies. Equally important, a study focused on municipal hospitals in Shanghai develops a conceptual reference framework for the optimization of healthcare facilities. This framework addresses five key dimensions: cost-effectiveness, customer satisfaction, energy and resource efficiency, management effectiveness, and operational and maintenance efficiency [24].

C. Integration of Emerging Technologies in Construction and Design.

The advantages of using BIM in hospital construction outweigh the disadvantages when considering the entire building life cycle. This includes not only planning and construction but also the operation and management of the hospital. BIM provides favorable compatibility for integrating digital applications in the management of hospital services [25]. The incorporation of artificial intelligence (AI) and virtual reality (VR) within BIM has led to significant advances in design and planning [26], [27]. One study employed optimization algorithms, such as PSO, along with digital twins and the visual programming language Dynamo, to generate precise three-dimensional models that can adapt to the changing needs of healthcare facilities [2]. Another analysis implemented VR simulations to enhance safety in construction projects by identifying overlooked connections between spaces and optimizing coordination among teams [28]. These technologies show great potential to optimize precision and efficiency, although practical challenges persist, especially in the application of VR.

In addition, BIM plays a key role in the simulation and evaluation of sustainable buildings, optimizing factors such as natural lighting, ventilation, thermal comfort, and energy efficiency, using tools such as Ecotect and MATLAB. The integration of Big Data and AI allows for real-time adjustments, ensuring that hospital buildings not only meet current standards but also adapt to future needs and emerging technologies [29]. Various studies have investigated the integration of BIM and Big Data in the construction and management of hospital facilities. For example, a group of researchers highlights integrated modular construction for emergency hospitals, emphasizing the rapid and efficient response capacity in critical situations [30], [31]. Additionally, an analysis combines BIM with design experiments and the Analytic Hierarchy Process (AHP) to optimize the energy-efficient design of hospitals [32]. These studies demonstrate how the integration of BIM and Big Data can significantly improve the planning, construction, and operation of hospital facilities, providing rapid and sustainable solutions in emergency contexts.

A BIM-based prototype for the robotic assembly of hospital units, essential in emergencies such as the COVID-19 pandemic, integrates two algorithms: ACASD, which defines coordinates and assembly sequences using BIM, and RRT*, which optimizes robotic trajectories by avoiding collisions. This integration improves efficiency and safety in hospital construction, extending to situations where human safety is at risk [33].

Blockchain has been explored in construction projects for its ability to improve transparency, traceability, and data security. In the case of mobile hospitals (MCH) during the COVID-19 pandemic, the Lightweight Blockchain-as-a-Service (LBaaS) system was implemented, which automates permissions, ensures data integrity, and facilitates real-time collaboration, thus optimizing the execution of critical projects in situations of high demand [34].

D. Risk Management, Maintenance, and Safety in Hospitals.

Various studies highlight how the integration of BIM in risk management, maintenance, and safety in hospitals improves efficiency and resilience in critical situations. One analysis emphasizes that BIM enables proactive risk management, enhancing the safety of patients and staff, especially in the face of extreme weather events and failures in information technology (IT) systems [35]. Moreover, the use of systems such as HERO-MIS, which incorporates BIM and augmented reality, optimizes the maintenance of hospital equipment, reducing downtime and increasing safety [36]. Finally, another study indicates that adaptive design supported by BIM improves the flexibility of facilities and their capacity to adapt in emergencies. Overall, BIM contributes to more efficient and safer management in hospitals, both in everyday operations and during crises [37].

Conclusions

This analysis highlights the BIM methodology as a comprehensive solution in the management and design of hospital infrastructures, positioning it as an indispensable tool to address the challenges associated with the planning, construction, and operation of such facilities. BIM optimizes data interoperability, enables advanced simulations, and facilitates decision-making based on performance metrics, ensuring a systematic and sustainable approach throughout the entire building life cycle. The incorporation of emerging technologies, such as artificial intelligence, virtual reality, and blockchain, extends the capabilities of BIM, promoting adaptive designs, resilience in emergencies, and greater operational efficiency.

This study emphasizes the importance of continuing to explore innovative approaches in the use of BIM to strengthen its applicability in critical hospital projects, consolidating its role as a catalyst in the modernization of healthcare infrastructure on a global scale.

References

[1] R. C. F. M. M. F. Marcio Presente de Souza, Beatriz Campos Fialho and R. Codinhoto, "Modelling and coordination of building design: an experience of bim learning/upskilling," *Architectural Engineering and Design Management*, vol. 19, no. 1, pp. 74–91, 2023.

[2] H. Alavi, P. Gordo-Gregorio, N. Forcada, A. Bayramova, and D. J. Edwards, "Ai-driven bim integration for optimizing healthcare facility design," *Buildings*, vol. 14, no. 8, 2024.

[3] A. Massafra, C. Costantino, G. Predari, and R. Gulli, "Building information modeling and building performance simulation-based decision support systems for improved built heritage operation," *Sustainability*, vol. 15, no. 14, 2023.

[4] B. Hashim, H. Sallehudin, H. Safie, A. H. Hussain, N. A. Abu Bakar, F. Yahya, A. Ihsan, and S. Abdelghany, "Building information modeling and internet of things integration in the construction industry: A scoping study," *Advances in Civil Engineering*, vol. 2022, pp. 1–20, 06 2022.

[5] A. Mohammed Alshehri, F. A. Hajj, A. Waqar, A. S. Bageis, M. Houda, and O. Benjeddou, "Building information modeling (bim) driven performance-based construction for the optimization of sustainable and smart structures development," *Environmental Challenges*, vol. 16, p. 100980, 2024.

[6] E. Forcael, C. Puentes, R. García-Alvarado, A. Opazo-Vega, J. Soto-Muñoz, and G. Moroni, "Profile characterization of building information modeling users," *Buildings*, vol. 13, no. 1, 2023.

[7] G. Yilmaz, A. Akcamete, and O. Demirors, "Bim-carem: Assessing the bim capabilities of design, construction and facilities management processes in the construction industry," *Computers in Industry*, vol. 147, p. 103861, 2023.

[8] S. Hedborg and S. Addyman, "Space in project organising: Insights from planning within and between construction projects," *Project Leadership and Society*, vol. 5, p. 100159, 2024.

[9] B. Saad Alotaibi, A. Waqar, D. Radu, A. M.Khan, Y. Dodo, F. Althoey, and H. Almujibah, "Building information modeling (bim) adoption for enhanced legal and contractual management in construction projects," *Ain Shams Engineering Journal*, vol. 15, no. 7, p. 102822, 2024.

[10] J. Taraben and G. Morgenthal, "Methods for the automated assignment and comparison of building damage geometries," *Advanced Engineering Informatics*, vol. 47, p. 101186, 2021.

[11] A. H. A. Jamil and M. S. Fathi, "Enhancing bim-based information interoperability: Dispute resolution from legal and contractual perspectives," *Journal of Construction Engineering and Management*, vol. 146, no. 7, p. 05020007, 2020.

[12] M. M. K. O. H. A. H. S. A. A. N. A. Yunis Ali Ahmed, Hafiz Muhammad Faisal Shehzad, "Examining the effect of interoperability factors on building information modelling (bim) adoption in malaysia," *Construction Innovation*, vol. 24, pp. 1–37, 10 2022.

[13] P. Hagedorn, L. Liu, M. König, R. Hajdin, T. Blumenfeld, M. Stöckner, M. Billmaier, K. Grossauer, and K. Gavin, "Bim-enabled infrastructure asset management using information containers and semantic web," *Journal of Computing in Civil Engineering*, vol. 37, 01 2023.

[14] J. Choi, F. Leite, and D. P. de Oliveira, "Bim-based benchmarking for healthcare construction projects," *Automation in Construction*, vol. 119, p. 103347, 2020.

[15] C. Cubukcuoglu, P. Nourian, I. S. Sariyildiz, and M. F. Tasgetiren, "Optimal design of new hospitals: A computational workflow for stacking, zoning, and routing," *Automation in Construction*, vol. 134, p. 104102, 2022.

[16] C.-W. Zhao, J. Yang, and J. Li, "Generation of hospital emergency department layouts based on generative adversarial networks," *Journal of Building Engineering*, vol. 43, p. 102539, 2021.

[17] L. Zhen, "Application and innovation of bim technology in construction management stage of large medical construction projects," *E3S Web of Conferences*, vol. 253, p. 01028, 01 2021.

[18] W. Wang, S. Gao, L. Mi, J. Xing, K. Shang, Y. Qiao, Y. Fu, G. Ni, and N. Xu, "Exploring the adoption of bim amidst the covid-19 crisis in china," *Building Research Information*, vol. 49, pp. 1–18, 05 2021.

[19] B. S. Abdulfattah, H. A. Abdelsalam, M. Abdelsalam, M. Bolpagni, N. Thurairajah, L. F. Perez, and T. E. Butt, "Predicting implications of design changes in bim-based construction projects through machine learning," *Automation in Construction*, vol. 155, p. 105057, 2023.

[20] H. Camgoz Akdag, A. Konyalıoğlu, and T. Beldek, "The comparison and similarity study between green buildings and green hospitals: A general view," *Proceedings of the International Symposium for Production Research*, pp. 181–190, 01 2019.

[21] K. Lu, X. Jiang, V. Tam, M. Li, H. Wang, B. Xia, and Q. Chen, "Development of a carbon emissions analysis framework using building information modeling and life cycle assessment for the construction of hospital projects," *Sustainability*, vol. 11, p. 6274, 11 2019.

[22] D. Zhang, J. Zhang, J. Guo, and H. Xiong, "A semantic and social approach for real-time green building rating in bim-based design," *Sustainability*, vol. 11, no. 14, 2019.

[23] A. TohidiFar, M. Mousavi, and A. Alvanchi, "A hybrid bim and bn-based model to improve the resiliency of hospitals' utility systems in disasters," *International Journal of Disaster Risk Reduction*, vol. 57, p. 102176, 2021.

[24] Y. Li, L. Cao, Y. Han, and J. Wei, "Development of a conceptual benchmarking framework for healthcare facilities management: Case study of shanghai municipal hospitals," *Journal of Construction Engineering and Management*, vol. 146, no. 1, p. 05019016, 2020.

[25] S. Hartmann, C. Patberg, and K. Klemt-Albert, "Opportunities and challenges of building information modeling in hospital construction," in *Proceedings of the 2023 7th International Conference on Medical and Health Informatics*, ICMHI '23, (New York, NY, USA), p. 310–315, Association for Computing Machinery, 2023.

[26] K. G. Ahmed, "Integrating vr-enabled bim in building design studios, architectural engineering program, uaeu: A pilot study," in *2020 Advances in Science and Engineering Technology International Conferences (ASET)*, pp. 1–6, 2020.

[27] Z. Wu, L. Wang, Z. Fu, L. Zhu, F. Dou, and P. Xu, "Vr+bim: Perception and design optimization of highway," in *2018 International Conference on Virtual Reality and Visualization (ICVRV)*, pp. 164–165, 2018.

[28] V. Getuli, P. Capone, A. Bruttini, and S. Isaac, "Bim-based immersive virtual reality for construction workspace planning: A safety-oriented approach," *Automation in Construction*, vol. 114, p. 103160, 2020.

[29] Z. Zhan, W. Xu, L. Xu, X. Qi, W. Song, C. Wang, and Z. Huang, "Bim-based green hospital building performance pre-evaluation: A case study," *Sustainability*, vol. 14, no. 4, 2022.

[30] L.-K. Chen, R.-P. Yuan, X.-J. Ji, X.-Y. Lu, J. Xiao, J.-B. Tao, X. Kang, X. Li, Z.-H. He, S. Quan, and L.-Z. Jiang, "Modular composite building in urgent emergency engineering projects: A case study of accelerated design and construction of wuhan thunder god mountain/leishenshan hospital to covid-19 pandemic," *Automation in Construction*, vol. 124, p. 103555, 2021.

[31] L. Chen, C. Zhai, L. Wang, X. Hu, and X. Huang, "Modular structure construction progress scenario: A case study of an emergency hospital to address the covid-19 pandemic," *Sustainability*, vol. 14, no. 18, 2022.

[32] E. Jalilzadehazhari, A. Vadiee, and P. Johansson, "Achieving a trade-off construction solution using bim, an optimization algorithm, and a multi-criteria decision-making method," *Buildings*, vol. 9, no. 4, 2019.

[33] Y. Gao, J. Meng, J. Shu, and Y. Liu, "Bim-based task and motion planning prototype for robotic assembly of covid-19 hospitalisation light weight structures," *Automation in Construction*, vol. 140, p. 104370, 2022.

[34] X. Tao, M. Das, C. Zheng, Y. Liu, P. K.-Y. Wong, Y. Xu, H. Liu, X. Gong, and J. C. Cheng, "Enhancing bim security in emergency construction projects using lightweight blockchain-as-a-service," *Automation in Construction*, vol. 150, p. 104846, 2023.

[35] M. Marinelli, "Emergency healthcare facilities: Managing design in a post covid-19 world," *IEEE Engineering Management Review*, vol. 48, no. 4, pp. 65–71, 2020.

[36] Z. Kamal, H. Taghaddos, and S. Metvaei, "Bim-based repair and maintenance for hospital work order management," *Automation in Construction*, vol. 143, p. 104546, 2022.

[37] F. Pascale and N. Achour, "Envisioning the sustainable and climate resilient hospital of the future," *Public Health*, vol. 237, pp. 435–442, 2024.