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A Systematic Literature Review on BIM-based Facilities Management towards Sustainable Construction

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The adoption of Building Information Modelling (BIM) in the construction industry has revolutionized the way project teams collaborate and manage construction processes. Recently, the application of BIM has been extended to facilities management (FM), resulting in a new approach known as BIM-based facilities management (BIM-FM). This paper aims to explore the role of BIM-FM in achieving sustainable construction practices. The study employs a systematic literature review to examine existing research on BIM-FM and its impact on sustainability in the construction industry. The findings suggest that BIM-FM can significantly contribute to sustainable construction practices by improving the communication and collaboration among stakeholders, enhancing the efficiency of building operations, reducing maintenance costs, and optimizing energy consumption. BIM-FM enables the collection and management of building data throughout its lifecycle, which helps to identify potential improvements in the building's design, construction, and operation phases. BIM-FM facilitates the integration of sustainable strategies into the building management process, such as energy-efficient systems, and sustainable materials. The adoption of BIM-FM still faces several challenges, such as difficulties in data transfer, lack of interoperability, and the need for skilled professionals. In conclusion, this paper highlights the potential of BIM-FM in promoting sustainable construction practices and encourages its wider adoption in the industry. Policymakers, industry professionals, and researchers can benefit from the insights provided by this study to further explore the opportunities and challenges of BIM-FM for sustainable construction.

1. Introduction

Building Information Modelling (BIM) has revolutionized the construction industry by offering a collaborative and information-rich platform for design, construction, and project management processes. With the growing emphasis on sustainability in the built environment, BIM has emerged as a promising tool for facilitating sustainable construction practices. In particular, BIM-based facilities management (FM) has gained attention as a means to achieve sustainable outcomes throughout the lifecycle of a building. The integration of BIM and FM enables stakeholders to effectively manage and maintain facilities, optimize resource utilization, enhance energy efficiency, and improve overall building performance (Rahman, 2021). By incorporating sustainable principles and practices into FM processes, BIM can further contribute to the reduction of environmental impacts, enhance occupant comfort and well-being, and support long-term sustainability goals (Wills et al., 2018).

While there is a growing body of literature on BIM and sustainable construction individually, a comprehensive review that specifically investigates the role of BIM-based FM towards sustainable construction is necessary to identify the existing knowledge, key findings, and research gaps in this area. Such a review would provide valuable insights for researchers, practitioners, and policymakers to better understand the potential of BIM in supporting sustainable facilities management practices. This paper aims to present a systematic literature review on BIM-based FM towards sustainable construction. The review aims to address the research question on “What are the practices, benefits and challenges associated with the application of BIM in sustainable facilities management?”. By addressing this research question, this review will contribute to a comprehensive

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understanding of the practices, benefits and challenges associated with BIM-based FM for sustainable construction.

2. Methodology

A systematic literature review was conducted to investigate the role of BIM-based FM towards sustainable construction. The approach for the systematic literature review is based on the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). There are three main phases in implementing the systematic searching strategies: identification, screening, and eligibility. These three phases are shown in a flow chart as in Figure 1.

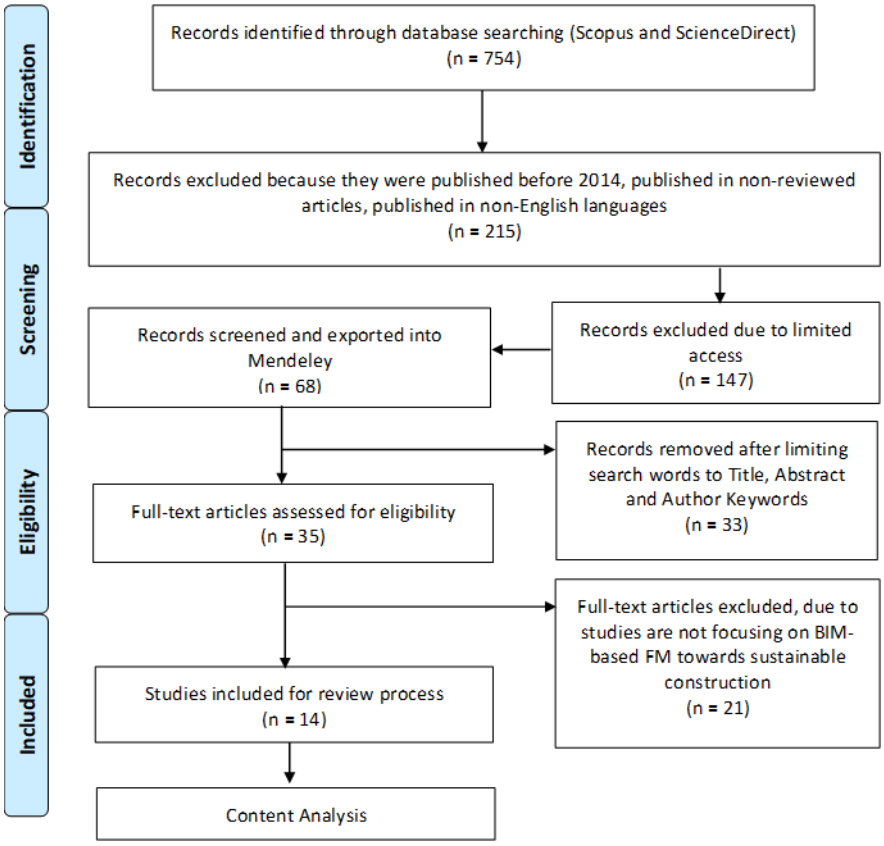

Figure 1: PRISMA Flow Diagram

The identification phase involves a comprehensive search strategy to identify relevant studies where two main databases (Scopus and ScienceDirect) were used to find related articles. The search strategy incorporated relevant keywords such as "Building Information Modelling", "facilities management", "sustainable construction" and related terms. Boolean operators (AND, OR) were used to combine keywords effectively (refer Table 1).

Table 1: The search string

Databases	Keywords used
Scopus and ScienceDirect	("Building Information Modelling" OR "BIM") AND ("facilities management" OR “FM practice” OR “building maintenance” OR “asset management”) AND ("sustainable construction" OR “sustainability” OR “green practice”)

For the screening phase, clear inclusion and exclusion criteria were established to determine the relevance of the studies. The criteria considered the research focus, publication type, publication year, accessibility, and language. The inclusion criteria encompassed studies that focused on the application of BIM in FM practices towards sustainable construction, published in peer-reviewed journals, conference proceedings, and other relevant sources. Studies published from the year 2014 onwards were considered to ensure the inclusion of

recent developments. Only studies published in the English language and allowed open access were included to facilitate the review process. The inclusion and exclusion criteria are defined in Table 2 as follows:

Table 2: Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Literature type	Reviewed articles	Non-reviewed articles
Language	English	Non-English
Timeline	2014 to 2023	<2014
Subject area	Studies focused on BIM-based FM in the context of sustainable construction	Studies not related to BIM-based FM for sustainable construction
Accessibility	Studies that are accessible (open access)	Studies that are not accessible (limited access)

The eligibility phase evaluates the article's relevancy to the needs of the study by examining the title, abstract, findings and discussions. After the remaining articles were screened based on titles and abstracts against the inclusion and exclusion criteria, finally, the full texts of the selected articles were reviewed to determine their eligibility for the systematic review. The full texts of the potentially relevant articles were retrieved and further evaluated for final inclusion in the review.

3. Results and Discussion

The systematic literature review on BIM-based FM towards sustainable construction yielded several key findings, which are portrayed below (Table 3). The results provide insights into the practices, benefits and challenges associated with BIM-based FM.

3.1 BIM-based FM Practices for Sustainable Construction

The literature review identified several BIM-based FM practices that contribute to sustainable construction. These practices include energy management (GhaffarianHoseini et al., 2017), indoor environmental quality (IEQ) optimization (Villa et al., 2022), lifecycle assessment (LCA) (Pan et al., 2023), laser scanning (Skrzypczak et al., 2022), collaboration and communication (Shi et al., 2016), data transfer and integration workflow (Loeh et al., 2021), maintenance and facility operations (Cruz et al., 2018), occupant comfort (Hosamo et al., 2023) and performance monitoring and analysis (Edirisinghe et al., 2021).

3.2 Benefits of BIM-based FM

The application of BIM-based FM in sustainable construction offers numerous benefits. Energy management using BIM enables the identification of energy-saving opportunities and reduction of operational costs (Araszkiewicz, 2017). BIM supports IEQ optimization by assisting facility managers in evaluating the monitored building conditions within the 3D model (Villa et al., 2022). Lifecycle assessment using BIM enables the evaluation of environmental impacts (Pan et al., 2023) and carbon footprint analysis through 6D modelling incorporating 3D model information (Kaewunruen et al., 2020). Collaboration and communication efficiency are enhanced via shared immersive virtual environment in the FM phase to achieve sustainable goals (Yangming Shi et al., 2016). In terms of attaining sustainable data, accurate measurement and visual data for facilities buildings are obtained through laser scanning (Skrzypczak et al., 2022) and BIM integrated visual data aid operation and maintenance of facilities through tablet/mobile device during site visits (Loeh et al., 2021). BIM also improves maintenance and facility operations by providing accurate and up-to-date information and streamlining workflows (Cruz et al., 2018). Occupant comfort is enhanced through BIM-enabled visualization aiding facility managers in decision making process (Hosamo et al., 2023).

3.3 Challenges and Barriers

Several challenges and barriers have been analysed through reviewed literature with regards to the implementation of BIM-based FM for sustainable construction. Technical challenges include interoperability (Hosamo et al., 2023) and incompatibility issues (Kaewunruen et al., 2020), difficulties in data transfer (McArthur, 2015), and incomplete information and documentation (McArthur, 2015). The integration of diverse data sources and software platforms remains a challenge (GhaffarianHoseini et al., 2017), hindering seamless information exchange. Organizational challenges relate to the adoption for new roles descriptions and workflows (Edirisinghe et al., 2021), incompetencies among stakeholders (Hosamo et al., 2023) and other human factors (Skrzypczak et al., 2022). Lack of incentives within organizations can also impede the successful adoption of BIM for sustainable FM (Hosamo et al., 2023).

Table 3: Key findings on practice, benefits and challenges related to BIM-based facilities management (FM) towards sustainable construction

Author (Year)	Practice	Benefits	Challenges
McArthur (2015)	Space allocation and tracking, energy management, asbestos hazard mapping		Identification of critical information, information transfer, controlling effort for BIM models, incomplete building documentation
Shi et al. (2016)	Multiuser shared immersive virtual environment in FM communication	Shared immersive virtual environment & walkthrough experience improves the efficiency of communication in FM and encourage the project participants to achieve sustainable goals	Data transfer protocol, level of realism in the virtual environment, difficulty of transferring data, juddering issue for visualization of large and complex projects
GhaffarianHoseini et al. (2017)	Building energy efficiency field	Reduced energy consumption during post-construction phase, integrated & structured rich information, further developed technologies (passive RFID tags, 3D scanning, cloud computing)	Current BIM not discipline-oriented enough (lack of experiential multi-discipline experts and not integrated for the immature interfaces)
Araszkiewicz (2017)	Energy savings lighting system (LED using PoE (Power over Ethernet of modern computer networks)	Great savings in building maintenance costs, data analytics capabilities, improve sustainability, lower operations cost, provide maximum comfort	
Davies et al. (2018)	Impact of BIM implementation to sustainability aspects in construction and building	Improvement in life cycle asset management (improves sustainability), longer-term benefits to asset within the operation and maintenance stage	
Cruz et al. (2018)	A strategic roadmap for BIM-FM implementation	BIM databases integration & cross-linking information on infrastructure	Difficulties in integrating digital databases
Kaewunruen et al. (2020)	6D modelling, incorporating 3D model information with time schedule, cost estimation, and carbon footprint analysis across the lifecycle of the bridge project	Saves time by transforming 2D information to 3D information, reduces errors during pre-construction & construction stages, promotes efficient asset and project management, promotes cooperation & improve visualisation of the stakeholders	BIM is limited as more compatible with a standard building environment, BIM software needs further development to improve its compatibility with complex bridge modelling
Edirisinghe et al. (2021)	Routine facility management to support environmental performance (energy analysis, envelope variations and interactions, evaluation of environmentally sustainable proposals, etc.)		Challenges of adopting data, hardware, software, role descriptions and work practices to BIM requirements
Vite et al. (2021)	Building a shared vocabulary for sustainable construction across communities of practice	Technical and process innovation, improved energy efficiency and environmental sustainability of buildings and the building process	Data valences across communities of practice concerned with sustainability

Table 3: Key findings on practice, benefits and challenges related to BIM-based facilities management (FM) towards sustainable construction (continue)

Author (Year)	Practice	Benefits	Challenges
Loeh et al. (2021)	SFM-enhanced BIM model used to support sustainable facility management data transfer and integration workflow	Aids operation and maintenance of facilities, model visual capabilities, possibility of viewing BIM model & associated information on a tablet/mobile device during site visits	
Villa et al. (2022)	Framework's competence to predict anomalies in the heating ventilation air conditioning (HVAC) system	Enhances building's maintenance plan, solves sustainable maintenance issues in terms of plan and schedule maintenance work	Investigations are required to conduct sizable research by connecting more building facilities
Skrzypczak et al. (2022)	Measurement and modelling of facilities buildings using terrestrial laser scanning	More accurate measurements & visual data, reduces time & costs of data collection, high-quality 3D documentation & remote access to photos and images, safer towards surveying difficulties & inaccessible areas, useful for managing the construction process, updated & enhanced documentation for planned assessments & periodical inspections	External factors & human factor (measurement assumptions, data processing, control, and interpretation of results)
Hosamo et al. (2023)	Digital Twin approach for incorporating building information modelling (BIM) with real-time sensor data, occupants' feedback, a probabilistic model of occupants' comfort, and HVAC faults detection and prediction that may affect occupants' comfort	Improves occupants' comfort conditions in buildings, BIM visualization predicts the condition of the building components, aids facility managers in making more informed decisions at the appropriate time	Depends on Internet of Things (IoT) technologies to receive data from smart devices, BIM models in companies used during the design phase are not appropriate for usage during maintenance, requires competent staff, FM software utilized during maintenance phase cannot read information directly from BIM models, building owners need more incentives to invest in preventative maintenance
Pan et al. (2023)	BIM supports towards Life Cycle Assessment (LCA) studies for sustainability to evaluate environmental impact through an integrated methodology	Allows evaluation at every stage of the architectural design process, enables designers to make more informed decision	

4. Conclusions

The systematic literature review on BIM-based facilities management (FM) towards sustainable construction has provided a comprehensive analysis of the existing research in this field. The review highlighted the key practices, benefits and challenges related to the integration of BIM in FM processes to achieve sustainability goals throughout the building lifecycle. In conclusion, the findings provide valuable insights for both researchers

and practitioners, guiding them in harnessing the capabilities of BIM integrated into FM practices to achieve sustainable outcomes in the built environment. By adopting BIM-based FM practices, organizations could potentially contribute to a more sustainable future in the construction industry. In future research, efforts to overcome the limitation of open-access subscription could involve more solutions in enabling a more comprehensive analysis.

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