Dulanto Cam, G. R., Chamochumbi Chvedine, R. A., Del Savio, A. A. (2025). Lean Construction for BIM Asset Management in Healthcare Facilities: A Systematic Literature Review. In O. Seppänen, L. Koskela, & K. Murata (Eds.), *Proceedings of the 33rd Annual Conference of the International Group for Lean Construction* (IGLC33) (pp. 929-940). https://doi.org/10.24928/2025/0253

LEAN CONSTRUCTION FOR BIM ASSET MANAGEMENT IN HEALTHCARE FACILITIES: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Building Information Modeling (BIM) has become a transformative tool for managing facility assets across their lifecycle. In Healthcare Facilities (HF), its integration into Asset Management (AM) offers potential benefits, including operational efficiency, cost reduction, and enhanced patient safety. However, implementing BIM AM in HF remains challenging due to issues related to interoperability and data, organizational and procedural barriers, limited expertise, and resource demands. This study conducts a systematic literature review (SLR) to examine how Lean Construction principles can be integrated into BIM AM practices to address these barriers. A total of 23 peer-reviewed studies were analyzed from the Scopus and IGLC.net databases. The findings reveal that Lean principles enhance BIM AM by improving interoperability, enabling incremental data exchange, and supporting real-time decision-making. Collaborative planning frameworks, post-occupancy evaluations, and early FM involvement further align organizational workflows with lifecycle needs. Additionally, simplified modeling strategies and training initiatives address expertise gaps and resource constraints. The study contributes to the integration of Lean into BIM AM, offering practical insights for optimizing cost efficiency, operational adaptability, and long-term performance of AM in HF.

KEYWORDS

Lean Construction, BIM, Asset Management, Facility Management, Healthcare Facilities.

INTRODUCTION

Healthcare Facilities (HF) are complex environments that require efficient Asset Management (AM) to ensure optimal service delivery, operational efficiency, and cost-effectiveness (Rousek et al., 2014). These facilities face increasing demands due to rising patient numbers, evolving regulations, and the need for advanced technological integration (Man et al., 2015). Managing HF involves handling large volumes of data, coordinating multiple stakeholders, and maintaining critical infrastructure, making AM a key factor in ensuring long-term sustainability and efficiency.

Building Information Modeling (BIM) has emerged as a powerful tool for managing facility assets. However, BIM AM adoption remains underutilized (Wijeratne et al., 2024) and faces barriers to adoption in HF (Chamochumbi Chvedine et al., 2023). This prevents BIM from realizing its full potential in optimizing AM practices in HF.

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Lean Construction (LC) principles offer a promising approach to overcoming these BIM AM challenges. While LC has been successfully integrated into project delivery and construction processes, its application in BIM AM remains underexplored. Given that Lean principles prioritize efficiency, data flow, and continuous improvement, their integration into BIM AM could address many of the barriers limiting its adoption and effectiveness.

RESEARCH GAP AND SIGNIFICANCE

Current research highlights significant gaps in understanding the synergies between Lean principles and BIM AM in HF. While BIM offers tools for managing lifecycle information, its implementation is often hindered by budget limitations, regulatory frameworks, organizational culture, and limited expertise (Chamochumbi Chvedine et al., 2023). Lean principles, focusing on efficiency and value, could provide a framework to address these barriers.

The significance of this research lies in bridging this gap by exploring how Lean principles can be systematically applied to BIM workflows to enhance AM practices in HF. Improving the efficiency and effectiveness of AM can lead to better cost management and service delivery in HF. This research aims to fill that gap, offering practical insights into optimizing BIM AM for operational efficiency, cost-effectiveness, and streamlined facility management.

SCOPE AND OBJECTIVES

This research focuses on understanding the integration of Lean principles into BIM AM for HF. The key objectives are:

1. Identifying Lean principles that can be applied with BIM AM in HF.
2. Analyze how Lean principles can address BIM AM challenges in HF.

LITERATURE REVIEW

The literature review explores the current context of BIM AM and Lean principles.

BIM AM IN HEALTHCARE FACILITIES

AM encompasses the activities required to extract value from various organizational assets by ensuring their sustainable and effective management. Facility Management (FM), a component of AM, focuses on the integration of processes, people, and technology to enhance life quality and organizational productivity. While AM provides a strategic framework for value extraction, FM operationalizes these strategies.

HF face unique challenges in implementing AM due to the diverse range of assets, including medical equipment, IT systems, and medications (Man et al., 2015). Poor data integration and visibility across systems create inefficiencies, hindering real-time decision-making and increasing administrative burdens. Manual inventory tracking leads to supply shortages or surpluses that jeopardize patient care. Inadequate tracking of maintenance schedules increases operational risks and financial strain, particularly as HF must continually adapt to technological advancements and demands (Rousek et al., 2014). Addressing such challenges requires the adoption of advanced technological solutions.

BIM is a critical tool for AM by integrating project data throughout the lifecycle, from design and construction to operation and maintenance (O&M). Wijeratne et al. (2024) highlighted the main benefit of BIM AM as the seamless integration of 3D model data with asset databases. This integration streamlines information access, minimizes errors, saves time and costs, and enhances risk management by promoting safety and mitigating risks across the building lifecycle. Furthermore, BIM AM facilitates regulatory compliance, improves disaster preparedness and response, and ensures adherence to safety standards, offering real-time data for effective safety and emergency management.

LEAN-BIM SYNERGY

LC can be classified as a methodology to enhance project management, while BIM is an approach to information management . Therefore, BIM can be associated with Lean approaches to more efficient project management. BIM and LC have no dependable or interconnected principles; however, some standards are related beyond their common approach. The synergic potential of the mentioned methodologies throughout the entire lifecycle of a construction project. Combining these two approaches can significantly transform construction practices, aligning the strengths of both systems to drive better project outcomes.

BIM supports Lean by providing accurate, real-time data that informs decision-making and enhances coordination among stakeholders (Sacks, Koskela, et al., 2010). This interconnection is exemplified in the matrix developed by Sacks, Koskela, et al. (2010), which illustrates how Lean principles and BIM functionalities interact and mutually reinforce each other.

APPLICATION OF LEAN-BIM FOR AM

Integrating Lean principles with BIM can transform AM by optimizing processes across the asset lifecycle. Lean-BIM synergy enables more efficient asset planning and operation by leveraging BIM's digital models and Lean's process-oriented tools. This approach aligns closely with AM's holistic goals, such as minimizing lifecycle costs, extending asset longevity, and optimizing performance.

This study is based on the matrix developed by Sacks, Koskela, et al. (2010) on the interactions between Lean principles and BIM functionalities, from which the identified Lean principles were taken into consideration, to evaluate which of them are or could be applied to face the challenges of implementing BIM AM in HF.

CHALLENGES OF BIM AM IN HEALTHCARE FACILITIES

The challenges of implementing BIM AM in HF are multifaceted. These were categorized (Table 1) into four types. This categorization has been adapted from Dulanto Cam (2024).

Table 1: BIM AM challenges in HF (Adapted from Dulanto Cam 2024)

Type	Index	BIM AM Challenge
Interoperability and Data	I	BIM-FM system interoperability issues
	II	Data Management and Integration issues
	III	Data Collection and Accessibility issues
Organizational and Procedural	IV	Resistance to change
	V	BIM developed sans AM needs.
	VI	Healthcare facilities requirements change
Lack of Expertise	VII	Limited BIM expertise
	VIII	Limited studies of BIM-FM integration.
Resource demands	IX	BIM AM implementation cost
	X	Time-intensive BIM AM implementation

METHODOLOGY

This study employed a Systematic Literature Review (SLR) to explore how Lean principles can be applied with or within BIM AM. Due to the limited number of studies explicitly addressing BIM AM challenges within Lean Construction research, this review focused on identifying

Lean principles relevant to AM and evaluating their potential applicability to BIM AM contexts. The Scopus and IGLC.net databases were chosen as the primary source of literature. Scopus is recognized for its comprehensive and quality scholarly content, offering broader coverage than other databases. The IGLC.net database focuses on papers specifically related to LC practices.

The review adhered to the PRISMA-2020 guidelines, ensuring transparency, replicability, and methodological rigor. Figure 1 illustrates the Flow Diagram for the identification, screening, eligibility, and inclusion of studies. The search string was TITLE-ABS-KEY ("Lean" OR "Lean Construction") AND ("Asset Management" OR "Facility Management") to identify all relevant studies. For IGLC.net, since all proceedings are inherently related to LC, the search was limited to the keywords "Asset Management" and "Facility Management". The inclusion criteria required studies to be journal articles, conference papers, or book chapters published in English to ensure accessibility and consistency in interpretation.

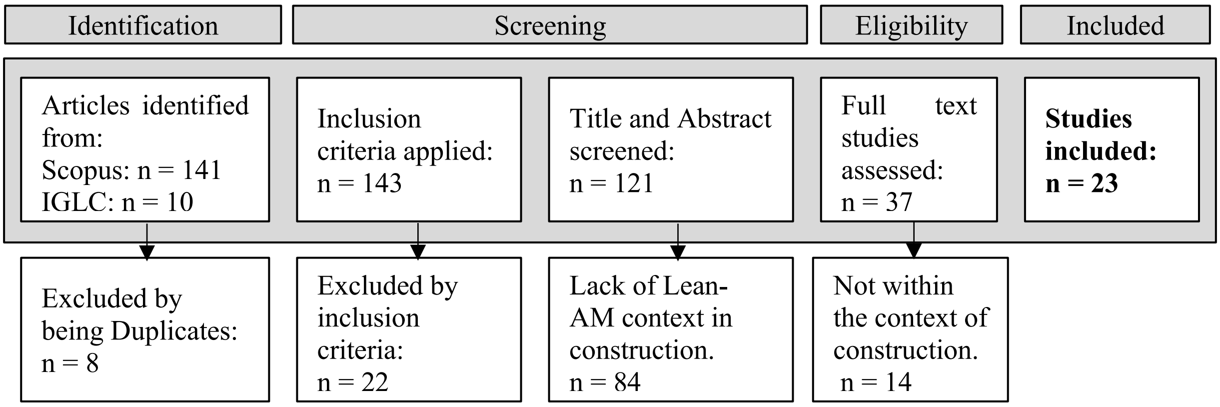

Figure 1: Flow diagram (Own elaboration)

RESULTS

This section presents the findings from the SLR, identifying how Lean principles have been applied to mitigate BIM AM challenges. The review analyzed 23 studies, categorizing their contributions based on the four main types of BIM AM challenges previously identified. Each challenge is examined in relation to the Lean principles leveraged to address them, highlighting their relevance and impact on BIM AM integration. Table 2 provides an overview of the 23 reviewed studies. Table 3 maps the identified Lean principles against the specific BIM AM challenges, cross-referencing them with relevant studies.

Table 2: Summary of reviewed articles on Lean in AM

N°	Author's	N°	Author's	N°	Author's
1	Bascoul et al. (2018)	9	Mbabu et al. (2023a)	17	Nazareth (2019)
2	Bazán Montalto et al. (2024)	10	Mbabu et al. (2023b)	18	Re Cecconi (2017)
3	Beck et al. (2016)	11	McArthur & Bortoluzzi (2018)	19	Schultz & Klungseth (2022)
4	Dave et al. (2011)	12	Mills et al. (2011)	20	Sharma et al. (2007)
5	Demirdöğen et al. (2020)	13	Mohammadi et al. (2018)	21	Teizer et al. 2017)
6	Guzman & Ulloa (2020)	14	Murguia et al. (2020)	22	Thompson & Nassereddine (2021)
7	Haapasalo et al. (2015)	15	Musharavati (2023)		
8	Kunz & Fischer (2020)	16	Nascimento et al. (2018)	23	Umstot et al. (2014)

Table 3: Lean Principles addressing BIM AM Challenges in HF

		BIM AM CHALLENGE									
		Interoperability and Data			**Organizational and Procedural**			**Expertise and Knowledge Gaps**		**Resource Demands and Costs**	
Index	LEAN PRINCIPLES	I	II	III	IV	V	VI	VII	VIII	IX	X
A	Reduce variability		18, 20	5	6			6, 15	9	8	
B	Reduce cycle times		10, 17			2			10	11, 16, 19, 20	11
C	Reduce batch sizes	3	3			6			6	18	
D	Increase flexibility		6, 11	21		2			11	13, 15	11
E	Select an appropriate production control approach								13	5, 11, 16, 19	
F	Standardize	3	6, 18		19			9	4, 5	15	
G	Institute continuous improvement		12, 18	14	6, 9, 16, 19, 23	22	1	6, 15	4, 5, 11	8	
H	Use visual management		16	21				4, 19		11	
I	Design the production system for flow and value		7		13			10	4, 9, 10, 13	7	
J	Ensure comprehensive requirement capture		17, 23	1, 2, 9, 21	12, 19	1, 6, 13, 22, 23	1, 12	3, 19	6	5, 7, 8, 18	
K	Focus on concept selection		14, 23	14	12, 14	6	12		6	7, 18	11
L	Ensure requirement flow down		10, 18		19	3, 6, 10		9	6	17	11
M	Verify and validate			9, 21				4		8	
N	Decide by consensus, consider all options			9	17	6, 13		6		17	

DISCUSSION

This section examines how Lean principles mitigate BIM AM challenges in HF. While the results section categorized findings, this discussion expands on their application by linking specific Lean principles to the identified challenges. To enhance clarity and alignment with Table 3, this discussion refers to Lean principles using the index notation instead of their full names. Each challenge is analyzed through the corresponding Lean principle index, ensuring a structured and concise approach to linking principles with BIM AM challenges.

BIM-FM System Interoperability Issues

Separate O&M models are generated in AM practices because many Computer-Aided Facilities Management (CAFM) solutions cannot process entire models from planning and construction phases [C] (Beck et al., 2016). Additionally, several IT solutions exist to integrate AM with digital tools, but a lack of standardization hinders effective implementation [F] (Beck et al., 2016).

These principles can be applied to address BIM-FM system interoperability by reducing batch sizes, enabling incremental data exchanges between BIM and FM systems, preventing data overload and ensuring real-time facility updates. Similarly, standardization through structured data formats and shared IT frameworks ensures that BIM AM systems communicate effectively, reducing fragmentation and inefficiencies.

Data Management and Integration Issues

Simulation models help optimize resource allocation and enhance information flow in FM operations [A] ((Sharma et al., 2007). BIM integrated with digital twins enables real-time modeling and predictive maintenance [B] (Mbabu et al., 2023b), and circular economy frameworks reduce inefficiencies in material and data flows [B] (Nazareth, 2019). These approaches improve responsiveness and proactive asset control, addressing a key limitation of traditional FM systems: the reactive, fragmented use of data. In BIM AM, leveraging these tools could reduce data silos and support early interventions through continuous data feedback loops.

To enhance flexibility, integrating BIM data with work order (W.O.) systems improve task coordination and maintenance planning [D] (Guzman & Ulloa, 2020), while Big Data tools and sensor networks automate analytics and enable real-time insights [D] (McArthur & Bortoluzzi, 2018). CAFM systems' inability to handle full BIM models often results in fragmented O&M models, underscoring the need for incremental data exchange strategies [C] (Beck et al., 2016). These Lean principles, when applied to BIM AM, can shift FM from static data repositories to adaptive platforms that react to operational needs in real time.

Standardization is critical to overcoming system fragmentation. COBie enables structured data exchange between BIM and FM platforms, ensuring consistent and accessible information [F] (Re Cecconi, 2017). Visual management techniques further enhance interdisciplinary collaboration through multidimensional data environments [H] (Nascimento et al., 2018). In the BIM AM context, such standardization efforts support interoperability and enable the seamless transfer of reliable data throughout the facility lifecycle.

Structured FM data also underpins continuous improvement [G] (Re Cecconi, 2017), while active stakeholder involvement ensures that asset requirements are captured during early project stages [J] (Umstot et al., 2014). However, the absence of systematic post-occupancy evaluations causes valuable FM insights to be lost [K] (Murguia et al., 2020), weakening long-term learning cycles. Ensuring data flow across design, construction, and operations phases reinforces lifecycle alignment [L] (Nazareth, 2019). These practices are essential in healthcare facilities, where operational requirements evolve rapidly and demand robust, adaptable AM systems.

DATA COLLECTION AND ACCESSIBILITY ISSUES

Filtering unnecessary data reduces inefficiencies by minimizing variability in FM processes (Demirdöğen et al., 2020). Integrating IoT with BIM on cloud-based platforms facilitates seamless data exchange and enhances system flexibility [D] (Teizer et al., 2017). Furthermore, within a VDC framework, the use of the COBie standard as a controllable factor helps with the objective of including all the information required for BIM maintenance (Bazán Montalto et al., 2024) [J].

Systematic post-occupancy evaluations are critical for long-term FM adaptability, as their absence prevents teams from capturing lessons learned [G, K] ((Murguia et al., 2020). Real-time data visualization supports decision-making by enabling FM teams to monitor key metrics and integrate smart technologies for improved data representation [H, M] (Teizer et al., 2017).

Early FM involvement ensures stakeholders make informed decisions (Bascoul et al., 2018). Relationship modeling bridges information gaps, aligning FM outputs with business objectives to facilitate accurate data use [J, N] (Mbabu et al., 2023a).

By systematically filtering data, integrating IoT, leveraging real-time visualization, and enhancing FM-business alignment, Lean principles can address data accessibility issues, ensuring that relevant information is effectively captured and utilized.

RESISTANCE TO CHANGE

Structured activity planning reduces operational variability by clearly scheduling FM tasks and issuing alerts to responsible staff [A] (Guzman & Ulloa, 2020). This minimizes uncertainty and helps staff anticipate upcoming responsibilities, which lowers psychological resistance to procedural changes. Predictable workflows create a stable baseline, making it easier for teams to absorb new routines without disrupting daily operations. Additionally, integrating Kaizen workshops helps standardize change communication and reinforce new work directives through structured routines [F] (Schultz & Klungseth, 2022), supporting transparent transitions during organizational shifts.

Digital technologies also support long-term adoption by facilitating continuous improvement. BIM-based digital twins allow real-time data modeling and automation, enhancing visibility over asset performance and enabling FM teams to respond proactively [G] (Mbabu et al., 2023b). Frameworks like the Digital Obeya Room embed iterative PDCA cycles to guide change efforts [G] (Nascimento et al., 2018), while Lean-driven workshops contribute to cultural shifts by reinforcing learning and collective engagement [G] (Umstot et al., 2014). These tools make change visible, data-driven, and gradually essential conditions for overcoming resistance rooted in ambiguity or workload disruptions.

Sustaining change depends not only on training but also on involving stakeholders early in the design phase, where long-term FM needs can be embedded into project decisions [J] (Mills et al., 2011). When decisions align with lifecycle value, resistance driven by uncertainty or lack of relevance is reduced [I] (Mohammadi et al., 2018). However, without systematic post-occupancy evaluation, valuable experiential data is lost [K] (Murguia et al., 2020), cutting off feedback loops that would otherwise support continuous adaptation in evolving healthcare environments.

Stakeholder alignment and long-term buy-in are strengthened when operational and environmental benefits are made clear. Embedding circular economy principles alongside Lean demonstrates value beyond immediate efficiency gains, helping staff and decision-makers see the broader benefits of process transformation [N] (Nazareth, 2019). In healthcare facilities where change is frequent and sensitive, such framing can make the difference between passive compliance and active support.

BIM Developed Sans AM Needs

Early FM involvement ensures that operational needs are embedded into project decisions before design lock-in. Engaging FM teams during early stages improves understanding of building complexity and usage patterns (Bascoul et al., 2018) [J], while collaborative workflows promote alignment of asset requirements across project phasess (Umstot et al., 2014) [J]. When FM is treated as a long-term coordination partner, it contributes to reducing waste and promoting predictability in asset operation (Thompson & Nassereddine, 2021) [G]. A VDC framework helps to address maintenance needs in advance, pursuing preventive maintenance instead of corrective maintenance (Bazán Montalto et al., 2024) [B, D]. Establishing a unified digital twin consolidates asset information throughout the lifecycle, allowing for real-time decision-making and continuity between design, construction, and operation (Mbabu et al., 2023b) [I].

Integrating FM needs also require structured data frameworks that enable continuity across stages. COBie facilitates the exchange of relevant FM information between design and operation, ensuring that AM is not sidelined during BIM delivery (Guzman & Ulloa, 2020) [C]. FM-relevant parameters should be embedded from the outset to prevent rework and data misalignment (Beck et al., 2016) [L]. Structuring this information through COBie improves clarity and consistency during handovers, reducing the risk of FM disconnects (Guzman & Ulloa, 2020) [L].

Where AM is excluded from early decision-making, resistance or inefficiency can emerge later. Involving FM in consensus-based planning ensures that priorities reflect long-term facility use and stakeholder goals (Mohammadi et al., 2018) [N]. Clear communication channels across disciplines further strengthens collaboration, allowing AM-related decisions to be integrated into the broader BIM process (Guzman & Ulloa, 2020) [N].

Changing Healthcare Facility Requirements

Early FM engagement, as seen on UCSF projects, facilitates continuous experimentation and learning, optimizing when and how FM contributes to project delivery [G] (Bascoul et al., 2018). Similarly, ongoing stakeholder involvement during design fosters a learning culture, ensuring facility requirements remain aligned with evolving needs [J] (Mills et al., 2011).

For BIM AM integration, these principles highlight the importance of early FM involvement to capture evolving healthcare facility requirements. Establishing structured feedback loops ensures designs remain adaptable to operational changes, while stakeholder-driven decision-making prevents outdated facility strategies [K].

By embedding continuous learning and adaptive design processes, BIM AM can accommodate shifting healthcare facility needs, improving long-term facility management efficiency and adaptability.

Limited BIM Expertise

Technical competence remains a key barrier to BIM AM adoption. Iterative training efforts and structured upskilling are essential for building internal capacity and narrowing BIM knowledge gaps [A, G] (Musharavati, 2023). This reflects a broader need for lean-aligned workforce development strategies tailored to FM teams who often lack advanced digital modeling skills.

Standardizing asset data into structured formats like Asset Information Model (AIM) improves consistency in information delivery and facilitates interoperability across systems [F] (Mbabu et al., 2023a). Yet standardization alone may not suffice if information is not visualized effectively. BIM platforms enhance interpretation by making asset data more intuitive and navigable than conventional tools [H] (Dave et al., 2011). Visual management frameworks and targeted training workshops can further embed these practices and support user learning through direct engagement with live models [H, J] (Schultz & Klungseth, 2022).

Ensuring that FM-relevant parameters are captured from the outset reinforces knowledge transfer and reduces dependency on external expertise [J] (Beck et al., 2016). Establishing a structured requirement flow through AIM reinforces continuity from design to operations [L] (Mbabu et al., 2023a). These processes act as scaffolding for FM teams to build BIM proficiency gradually through engagement with project data.

BIM's visualization capabilities also facilitate validation and feedback loops, enhancing communication during planning and review phases [M] (Dave et al., 2011). Aligning collaborative decision-making with Lean logic encourages cross-functional integration without overwhelming users [N] (Guzman & Ulloa, 2020)In contexts of limited expertise, these strategies collectively enable BIM AM adoption without requiring deep technical fluency from all stakeholders. Instead, they build familiarity through structured learning, visual feedback, and simplified workflows.

LIMITED STUDIES ON BIM-FM INTEGRATION

Digital twins supported by IoT, AI, and data science enhance BIM's capacity for real-time asset insights and operational reasoning [A] (Mbabu et al., 2023a) These approaches illustrate how technology-enabled Lean principles can compensate for the absence of extensive case studies by offering replicable digital strategies.

Integrating Lean production tools like VisiLean into BIM environments improves workflow synchronization and resource planning, demonstrating how Lean practices can strengthen BIM-FM coordination even in under-researched contexts [F, I] (Dave et al., 2011).

Real-time analytics and decision-making frameworks further enable effective FM execution. Automated data processing through Big Data systems provides timely feedback and predictive maintenance capabilities, helping to bridge the gap left by limited empirical models [D] (McArthur & Bortoluzzi, 2018). Structured lifecycle planning improves long-term asset performance and stakeholder alignment [E] (Mohammadi et al., 2018).

Long-term value creation relies on frameworks that prioritize end-user needs and knowledge continuity. End-user-centered FM platforms promote ongoing improvement cycles and foster Lean integration in healthcare settings [G] (Demirdöğen et al., 2020).

BIM AM IMPLEMENTATION COSTS

Reducing BIM AM costs starts with minimizing inefficiencies in implementation. Virtual Design and Construction (VDC) methods improve coordination, reduce rework, and enhance real-time alignment with project goals, contributing to cost-efficient delivery [A] (Kunz & Fischer, 2020). Similarly, streamlining maintenance through the elimination of non-value-adding activities delivers tangible savings in FM operations [E] (Nascimento et al., 2018).

A low-geometry BIM strategy enables incremental implementation by using simplified, non-3D models, which reduces upfront modeling efforts and lowers costs until the organization is ready to scale up [B, H] (McArthur & Bortoluzzi, 2018). COBie complements this by allowing early-stage data structuring without needing full geometry, easing initial BIM adoption [C, J] (Re Cecconi, 2017). These practices offer cost control mechanisms that lower the entry barrier for organizations with limited resources.

Optimizing resource use over the facility lifecycle also plays a key role in managing costs. BIM integrated with Building Energy Performance Simulation (BEPS) and Big Data analytics enables organizations to optimize energy use, space, and maintenance planning [D, I] (Demirdöğen et al., 2020). Cost-conscious procurement methods that prioritize user needs and lifecycle value further ensure efficient resource investment [J, K] (Haapasalo et al., 2015).

Incorporating circular economy principles into BIM AM extends cost-saving beyond operational efficiency. Designing for reuse, reducing material waste, and fostering long-term adaptability creates value that is both financial and environmental [L, M] (Nazareth, 2019).

These strategies transform BIM AM from a cost burden into a long-term investment platform, particularly relevant in healthcare, where operational continuity and sustainable asset management are critical.

TIME-INTENSIVE BIM AM IMPLEMENTATION

Minimizing excessive modeling at early stages can significantly reduce time demands during BIM AM implementation. Using non-geometric information in place of complex 3D modeling enables faster development of BIM content and CAFM data interfaces [K] (McArthur & Bortoluzzi, 2018). This approach prioritizes functionality over detail, streamlining adoption while still meeting FM needs.

To improve implementation flow, incremental development strategies have been proposed, where both BIM content and FM data interfaces evolve iteratively. This phased progression prevents bottlenecks and allows systems to mature with project demands [B, D] (McArthur & Bortoluzzi, 2018). Combined with automation, these workflows ensure continuous FM critical data integration, reducing manual effort and oversight [L] (McArthur & Bortoluzzi, 2018).

By replacing upfront modeling intensity with leaner, staged delivery and automation, healthcare facilities can accelerate BIM AM deployment while preserving long-term system integrity and operational alignment.

CONCLUSIONS

This study explored how Lean principles can be systematically integrated into BIM AM to address critical implementation challenges in HF. Through a structured SLR of 22 studies, the research mapped key synergies between Lean methods and BIM AM processes, offering a novel lens to enhance HF performance.

The findings demonstrate that Lean principles offer a way to address the complex challenges of BIM AM implementation in healthcare settings. Standardization through COBie and reduction of batch sizes facilitate interoperability by enabling consistent, incremental data exchanges. Integration of digital twins, IoT platforms, and real-time analytics enhances data accessibility, supporting predictive maintenance and adaptive asset control. Visual management tools and structured feedback mechanisms, such as post-occupancy evaluations, further promote continuous learning and long-term alignment of operational and design requirements.

Moreover, Lean principles mitigate organizational resistance by embedding FM needs early in project phases, fostering transparency through collaborative planning, and stabilizing workflows via structured routines. Training strategies combined with simplified, visualized data delivery reduce expertise barriers, while incremental development, low-geometry BIM strategies, and elimination of non-value-adding activities address resource constraints and implementation costs. Across all challenges, early FM involvement, flexible workflows, and lifecycle-focused planning emerge as essential enablers, ensuring BIM AM practices are adaptable, interoperable, and cost-efficient within HF.

This research contributes by structuring the integration of Lean into BIM AM and addressing a gap in both theory and practice. The mapping developed can support FM teams, designers, and healthcare managers in structuring implementation approaches that are cost-effective and lifecycle-oriented.

However, the study is limited by its reliance on secondary data. While the SLR provides a broad evidence base, the absence of primary case validation means that contextual variations, such as organizational maturity, procurement constraints, or cultural resistance, could affect applicability. Further empirical studies are needed to test how these principles perform in live BIM AM projects within healthcare settings.

Despite these limitations, the findings offer actionable insight into how Lean can guide more adaptive, interoperable, and sustainable BIM AM practices.

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