

ENHANCING LEAN-ORIENTED SAFETY MANAGEMENT THROUGH BIM: A SOCIO-TECHNICAL PERSPECTIVE

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ABSTRACT

Building Information Modelling (BIM) is widely adopted to support construction safety management; however, its implementation remains predominantly technology-driven and inconsistently aligned with Lean Construction principles. This study examines how the conceptualisation of BIM shapes its alignment with Lean Construction principles, drawing on the Transformation–Flow–Value (TFV) theory of production as a theoretical lens. A qualitative study was conducted based on 22 semi-structured interviews with professionals from contractor, consultant, and client organisations within the Australian AEC industry. Using a deductive analytical framework, the study analyses how BIM-enabled safety practices align with Lean Construction principles. The findings reveal a pattern of selective alignment, where BIM strongly supports operational Lean Construction principles such as visualisation, coordination, and information integration, while providing limited support for system-level Lean Construction principles including standardisation, variability reduction, and production control. This imbalance stems from the predominant application of BIM as a technological tool rather than an integrated socio-technical methodology, limiting its potential to enable adaptive, learning-oriented safety practices. Consequently, the study highlights the importance of socio-technical implementation of BIM for operationalising Lean Construction principles and achieving more integrated and sustainable Lean-oriented safety management, when integrated with organisational processes, stakeholder roles, and governance structures.

KEYWORDS

Building Information Modelling, construction safety management, lean construction, theory of production, BIM-Lean integration.

INTRODUCTION

Globally, the construction sector continues to rank among the highest-risk industries in terms of occupational hazards, consistently reporting high levels of accidents, injuries, and fatalities (Almaskati et al., 2024). In Australia alone, 200 traumatic work-related deaths were recorded in 2023, exceeding the five-year average of 191 (Safe Work Australia, 2024). At a global

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scale, work-related incidents impose an estimated economic burden of USD 2.8–3.0 trillion annually, equivalent to approximately 4% of global GDP (Ludus Global, 2023). Beyond the human cost, safety failures disrupt project delivery through schedule delays, productivity losses, and cost overruns (Gray and Mendeloff, 2023). In response, construction safety management has progressively evolved, incorporating structured approaches such as Prevention through Design (PtD) and Job Hazard Analysis (JHA), collaborative delivery philosophies including Lean Construction and Agile, and emerging digital technologies such as Virtual Reality (VR), Artificial Intelligence (AI), and the Internet of Things (IoT) (Polat and Demirkesen, 2025).

In this context, Lean Construction, grounded in the theory of production, is widely recognised as a management philosophy that strengthens key construction performance dimensions, including time, cost, quality, and safety (Koskela, 2020). Through principles related to waste reduction, flow optimisation, and transparency, Lean Construction integrates safety into production systems rather than treating it as a separate objective (Moaveni et al., 2019). Empirical studies support this perspective. For example, Fauzan and Sunindijo (2021) reported that the implementation of Lean Construction tools within the Australian construction industry contributes to reducing safety incidents on construction sites. Similarly, Gao et al. (2023) further confirm that Lean-oriented safety practices significantly enhance safety performance across different project stages.

Within this Lean-oriented safety perspective, Building Information Modelling (BIM) has gained particular prominence due to its capacity to operationalise Lean Construction principles and support the integration of safety into production systems across the project lifecycle by enabling process integration, enhancing transparency, and improving cross-disciplinary collaboration (Ganah and John, 2015). Empirical studies provide evidence of BIM's potential: Dadashi Haji et al. (2023) reported a 38% reduction in site accidents following the implementation of a BIM-based safety framework, while Manzoor et al. (2025) observed an approximate 70% decrease in severe incidents over a two-year period, alongside improvements in schedule and cost performance.

Accordingly, effective BIM implementation as a socio-technical system requires organisational change beyond software adoption, involving the coordinated integration of technology, process, people, and policy to support the implementation of Lean Construction principles and sustained safety improvements (Sackey et al., 2015). Despite more than two decades of BIM use in safety-related applications, its implementation remains uneven and inconsistent, particularly within the Australian AEC context, largely due to divergent interpretations of what BIM represents and how it should be operationalised in practice (London et al., 2022). This inconsistency is further reinforced by the gap between theory and practice. Although BIM is increasingly conceptualised as a socio-technical system that reshapes collaboration, workflows, and organisational learning, the Australian AEC industry practice often tends to emphasise BIM as a technological tool (Siriwardhana et al., 2025).

Consistent with this trend, existing research globally and within the Australian AEC context has largely positioned BIM as a technological enabler supporting Lean Construction practices, particularly in areas such as visualisation, clash detection, and design-based risk identification by implementing its functionalities (Chan et al., 2016). While these implementations remain largely confined to operational-level Lean Construction practices for safety, they do not fully support the broader production system perspective emphasised in Lean Construction theory for achieving stable and reliable safety performance (Koskela, 2020). This highlights a gap in the literature, where BIM is frequently conceptualised and implemented as a set of technological tools rather than as a socio-technical methodology capable of supporting integrated and sustained safety management.

Given these shortcomings, there is a need for empirical investigation into how BIM is currently implemented for safety management in construction organisations and how its conceptualisation, as either a technological tool or a socio-technical system, influences its ability to enhance Lean Construction principles grounded in the theory of production. In particular, there is a need to identify patterns of selective alignment where certain principles are effectively supported while others remain underrepresented, and to critically assess the implications of this uneven alignment for improving construction safety management.

Accordingly, this study addresses the following research question: How does the conceptualisation of BIM influence the alignment of Lean Construction principles in construction safety management?

To address this question, the study adopts an exploratory qualitative approach based on semi-structured interviews with professionals from the Australian Architecture, Engineering, and Construction (AEC) industry. Using a deductive analytical framework grounded in Lean Construction principles, the study examines how current BIM-enabled safety practices align with key Lean Construction principles and identifies patterns of both alignment and fragmentation. As a result, this study contributes to the literature by providing empirical evidence that BIM-enabled safety practices exhibit a selective alignment with Lean Construction principles, revealing underlying organisational and process-related constraints that limit its full potential for improving safety outcomes. Building on this, the study advances the reconceptualization of BIM from a technology-centric tool to a socio-technical methodology aligned with Lean thinking.

This paper outlines the theoretical foundations of BIM and Lean in construction safety management, presents the research methodology, reports the empirical findings and discussion, and concludes with key implications for theory and practice, while noting that these are early results from an ongoing study, with more comprehensive analyses planned for future journal publications.

THEORETICAL BACKGROUND

The delivery of complex construction projects depends on effective collaboration and the systematic management of project knowledge across organisational and disciplinary boundaries. Lean Construction is grounded in Transformation–Flow–Value (TFV) theory of production, which reconceptualises construction not as a sequence of discrete tasks but as an integrated production system operating across three interdependent dimensions (Koskela, 1992). The Transformation dimension focuses on the efficient execution of tasks, while Flow emphasises process continuity through the reduction of waste, variability, and interruptions. The Value dimension ensures that outcomes align with client and stakeholder requirements (Koskela, 2000). These dimensions are operationalised in Lean Construction through a set of principles and practices such as visual management, variability reduction, continuous improvement, and cycle time reduction (Sacks et al., 2009).

Lean Construction principles can be broadly understood as operating at both operational and system levels, where operational-level principles enhance task-level efficiency and day-to-day decision-making, while system-level principles focus on standardisation, variability reduction, and production control to ensure stable, reliable, and scalable project performance (Garcés and Peña, 2023). This distinction is critical in the context of construction safety management, as improvements at the operational level may enhance visibility and coordination, such as through visual management tools, toolbox meetings, or short-term planning used to identify and communicate hazards (Gambatese and Pestana, 2014). However, without system-level integration, including standardised procedures, consistent production control, and organisation-wide safety governance, these efforts remain fragmented and difficult to sustain over time (Moaveni et al., 2019).

In this context, Koskela (2000) highlights that many existing technologies have been developed based on traditional transformation-oriented views, focusing on discrete tasks rather than flow and value generation. However, BIM has emerged as a key enabler of integrated information management, with demonstrated benefits for project flow and value, including improved safety outcomes (Phung and Tong, 2021). Accordingly, BIM is best conceptualised through a dual ontological lens, recognising both its technological capabilities and the socio-technical structures that shape their implementation in practice (Sackey et al., 2015). BIM has been widely applied to construction safety through automated rule checking, risk visualisation, and design-phase hazard identification (Chan et al., 2016). While these studies demonstrate the technical potential of BIM for discrete safety applications, they tend to overlook the socio-technical aspects required for consistent and sustainable safety improvement such as safety training, continuous safety feedback mechanisms. This trend highlights the need for a structured socio-technical implementation approach that aligns technological capabilities with organisational processes, skilled personnel, and supportive policies (Sackey et al., 2015).

From TFM theory of production perspective, BIM aligns with the Theory of Production, which promotes a shift from fragmented, task-specific practices toward collaborative and integrated project delivery models that are essential for sustainable safety management (Akram et al., 2019). However, BIM is applied primarily as a technological tool in the literature, and it influences predominantly operational Lean Construction principles, with supporting functionalities such as clash detection, data flow, and visualisation, while providing limited support for system-level principles governing flow stability, variability reduction, and production control (Alnajjar et al., 2025). In this regard, the literature has widely positioned BIM as a technological enabler that facilitates the implementation of Lean Construction practices for safety management (Mahalingam et al., 2015). Therefore, this perspective remains largely limited to examining how BIM as a socio-technical system including technology, process, people, and policy pillars contributes to the enhancement of Lean Construction principles, particularly within the construction safety management.

This study addresses this gap by empirically investigating the extent to which current BIM-enabled safety practices align with Lean Construction principles grounded in TFM theory, and by examining how these patterns of alignment reflect the underlying conceptualisation of BIM as either a technological tool or a socio-technical system. Using Lean Construction principles as a deductive analytical framework, the study provides an empirical basis for understanding how these practices are distributed across operational and system levels within the TFM theory, and explains how these patterns are shaped by the underlying conceptualisation of BIM.

RESEARCH METHODOLOGY

This study adopts an exploratory qualitative research approach to investigate how BIM is currently implemented in construction safety management and how such practices may enhance Lean Construction principles grounded in the Theory of Production. A cross-sectional design is employed to capture participants' perspectives at a specific point in time, aligning with the study's aim to examine current BIM-based safety management practices within the Australian AEC industry rather than their longitudinal development (Yin, 2009).

To address these aims, data were collected through semi-structured interviews with industry professionals directly involved in BIM-enabled safety management. This approach enables the examination of real-world practices, organisational routines, and professional interpretations in their natural contexts, providing the depth and flexibility required to capture practice-based insights that cannot be adequately explored through hypothesis-driven methods (Adeoye-Olatunde and Olenik, 2021).

PARTICIPANT SELECTION AND SAMPLING STRATEGY

The target population comprises professionals actively involved in BIM implementation and/or construction safety management within the Australian AEC industry. This includes BIM users, digital engineering professionals, project managers, designers, contractors, and safety practitioners with direct experience of BIM-enabled processes.

Given the exploratory and field-oriented nature of the study, a non-probability sampling strategy was adopted. Purposive sampling was used to identify information-rich participants with relevant expertise in BIM and safety management, ensuring alignment with the research objectives (Palinkas et al., 2015). This was complemented by snowball sampling, which facilitated access to additional knowledgeable practitioners through professional networks.

To enhance diversity and credibility, the sample was intentionally heterogeneous, including participants from contractor, consultancy, and client organisations, as well as professionals working across building and infrastructure projects. Participants also represented varying levels of BIM maturity and experience, enabling the study to capture a broad range of perspectives on methodological BIM implementation for safety management.

SAMPLE SIZE AND DATA SATURATION

In qualitative research, sample adequacy is determined through data saturation rather than statistical representativeness. Accordingly, this study conducted 22 semi-structured interviews across contractor, consultancy, and client organisations within the Australian AEC industry. The sample deliberately included both BIM users and safety professionals to capture diverse perspectives on technological and safety-related practices. Data collection and analysis were undertaken iteratively, with preliminary coding conducted after successive rounds of interviews to assess the adequacy and coverage of the predefined analytical framework. Saturation was considered achieved after approximately 18–20 interviews, when no substantially new insights relevant to the established coding categories were identified, and additional data confirmed the consistency of observed patterns. This approach is consistent with established guidance for achieving saturation in heterogeneous samples in exploratory qualitative research (Hennink et al., 2017).

DATA COLLECTION PROCEDURE

The interview protocol guided discussions around key themes, including BIM usage in safety management, organisational processes, role distributions, barriers, enablers, and improvement opportunities. Interviews were conducted online via Microsoft Teams and lasted 45–75 minutes. While the protocol ensured consistency, participants were encouraged to elaborate on issues they deemed significant, allowing unanticipated insights to emerge.

Ethical approval was obtained from the relevant Human Research Ethics Committee. Participants received detailed information about the study, their rights, confidentiality, and voluntary participation. All interviews were audio-recorded with consent and transcribed verbatim, with identifying information removed to ensure anonymity.

DATA ANALYSIS

This study adopted a deductive analytical approach to examine the extent to which current industry practices reflect established Lean Construction principles, using a theory-driven coding framework developed prior to analysis (Braun et al., 2019). Interview transcripts were transcribed verbatim, de-identified, and analysed in NVivo 15 to support systematic data organisation and transparency (Proudfoot et al., 2023). A predefined coding structure, derived from Lean Construction literature (Koskela, 1992; Sacks et al., 2009), was used to categorise BIM-enabled safety practices, with relevant data segments assigned to corresponding

principles. This facilitated the identification of patterns and enabled the systematic alignment of empirical evidence with theoretical constructs (Naeem et al., 2023).

To enhance analytical rigour, the frequency and distribution of coded instances were examined to identify dominant principles underpinning current practices (Proudfoot et al., 2023), allowing the analysis to move beyond descriptive insights and indicate which Lean principles are most strongly associated with BIM-enabled safety management (Brandão, 2015). Overall, the deductive approach ensured a direct linkage between empirical findings and established theory, providing a robust basis for interpreting BIM-enabled safety practices within a Lean framework (Patton, 2014).

RESEARCH TRUSTWORTHINESS

To enhance trustworthiness, the interview protocol was developed based on the study's theoretical framework and refined iteratively. Triangulation was achieved through a heterogeneous sample across organisations and project contexts. Analytical reliability was ensured through a systematic, theory-driven coding process with transparent documentation of coding decisions. Researcher bias was minimised through the use of an audit trail, including coding memos and reflective notes. These strategies strengthen the credibility and transferability of the findings (Guba and Lincoln, 1994).

RESULTS

Data from 22 semi-structured interviews were analysed using a deductive thematic approach based on Lean Construction principles grounded in the Theory of Production. As presented in Table 1, the distribution of coded instances reveals a clear pattern of selective alignment, where certain Lean Construction principles are consistently supported by BIM-enabled safety practices while others remain weakly represented or absent.

Table 1: Patterns of alignment between BIM-enabled safety practices and Lean Construction principles

Lean Construction Principle	Frequency
Reduce cycle times	21
Use visual management	21
Design the production system for flow and value	20
Verify and validate	18
Cultivate an extended network of partners	18
Decide by consensus, consider all options	12
Ensure comprehensive requirements capture	12
Go and see for yourself	12
Ensure requirement flow down	10
Institute continuous improvement	9
Increase flexibility	8
Reduce variability	8
Standardize	7
Reducing batch sizes	6
Focus on concept selection	2
Select an appropriate production control approach	0

The results in Table 1 reveal a pattern of selective alignment between BIM-enabled safety practices and Lean Construction principles, indicating that BIM is more effectively applied to

specific aspects of Lean thinking. The most strongly represented principles are examined in detail below, drawing on empirical evidence from participant accounts.

1. Reduce Cycle Times – It emerged as a strongly aligned Lean principle, reflecting BIM's capacity to accelerate safety processes through earlier hazard identification, faster coordination, and proactive risk resolution. Within the TFV perspective, BIM enables this principle through integrated, model-based information, which shortens the interval between identification and resolution, improves workflow continuity and coordination, and enables more timely and reliable safety decision-making. One participant explained: *"We were able to identify safety problems early with BIM. We would coordinate with the utility provider to see if lines could be relocated or decommissioned."*

2. Design the Production System for Flow and Value – This principle was consistently reflected in the data, indicating BIM's role in linking design and construction processes and bringing safety considerations into earlier project stages. BIM in existing safety practices enables risks mitigation, reduces rework, and minimises disruptions. From the TFV theory, it improves workflow efficiency while generating value through safer and more reliable project delivery. One participant mentioned: *"BIM models eliminate the majority of the issues in the beginning by giving us a clear understanding."*

3. Use Visual Management – It was evident that BIM enhances safety management through 3D and 4D visualisation, enabling stakeholders to better understand construction processes and associated safety risks. From the TFV perspective, visualisation was found to enhance communication and support more effective safety decision-making, as one interviewee stated: *"Using BIM models allows us to walk through the project and clearly identify potential risks, which is much more effective than relying on traditional drawings."*

4. Verify and Validate – It was consistently identified that BIM supports verification and validation through practices such as clash detection, issue tracking, and coordinated model reviews. These practices enable early identification and resolution of design conflicts, contributing to safer construction processes. One participant highlighted: *"We use BIM to identify and resolve issues during the design stage, which helps prevent problems and safety risks before construction begins."*

5. Cultivate an Extended Network of Partners – Participants were consistently described that BIM facilitates collaboration across designers, contractors, safety professionals, and clients through shared platforms and integrated information environments. Interpreted through TFV, BIM models were considered as a tool to enable coordinated workflows and improve communication between disciplines. In this regard, one participant emphasised: *"BIM enables different teams to collaborate effectively by sharing information in a common environment, which improves coordination and supports better safety outcomes."*

In contrast to the strongly represented principles, several Lean Construction principles were only weakly reflected or entirely absent in BIM-enabled safety practices. These include principles related to standardisation, variability reduction, production control, and concept selection. This pattern suggests that BIM is currently underutilised in supporting comprehensive Lean Construction principles for sustainable safety management practices. These Lean Construction principles require structured processes, formal control mechanisms, and organisational alignment, which are not sufficiently supported through current BIM implementations for effective and improved safety performance. Instead, BIM remains predominantly applied as a technology to design coordination, visualisation, and issue identification, resulting in stronger alignment with operational Lean Construction principles and limited support for system-level Lean Construction practices.

Overall, the findings indicate that BIM-enabled safety practices remain fragmented and primarily technology-driven, leading to partial Lean Construction implementation and limited safety improvement. In contrast, when BIM is implemented as a socio-technical system

aligned with Lean principles, safety can be more effectively integrated into the production system, enabling more consistent and sustainable improvements.

DISCUSSION

This study examined how BIM-enabled safety practices align with Lean Construction principles and the findings reveal a pattern of selective alignment, where BIM predominantly reinforces operational Lean Construction principles through its technological capabilities. While these capabilities improve transparency, communication, and early risk identification, the findings indicate that they provide limited support for system-level Lean Construction principles such as standardisation, variability reduction, and continuous control.

To interpret these findings, adopting socio-technical perspective highlights that BIM's effectiveness in construction safety management depends on the integration of technology, process, people, and policy (Sackey et al., 2015; Succar, 2009). While BIM provides technological capabilities such as visualisation, simulation, and data integration to support hazard identification (Chan et al., 2016), these remain limited unless embedded within structured processes that enable consistent application and continuous learning through feedback loops and lessons learned (Cudney et al., 2015). At the same time, effective implementation relies on cross-disciplinary collaboration and shared understanding between BIM users and safety professionals (Semaan et al., 2021), as well as governance mechanisms such as organisational standards, regulatory frameworks, and client requirements that shape its application in practice (Succar, 2009). Therefore, BIM can only function as an effective safety management methodology when these pillars are aligned, reinforcing that its value lies not solely in its technological capabilities but in its integration as a socio-technical system supporting holistic and sustainable safety outcomes (Sackey et al., 2015).

Despite this potential, the findings of this study suggest that the predominance of technology-driven BIM implementation and its alignment with operational-level Lean principles can be partly explained by several organisational and industry-level barriers. These include organisational silos, uneven digital maturity across project stakeholders, resistance to change, and the lack of standardised practices, which have been widely reported in the literature (Mahalingam et al., 2015; Sepasgozar et al., 2020). These conditions reinforce a technology-centric application of BIM, restricting its use to isolated functions rather than coordinated workflows (Guo et al., 2022). Furthermore, the findings show that BIM-enabled safety practices are largely concentrated in the design phase, particularly in activities such as visualisation and design-based risk identification, with limited integration into construction and operational stages. This disrupts the continuity of information flow and learning across project phases, limiting sustained safety improvement from a Lean perspective (Sacks et al., 2010).

In response to these findings, Lean Construction can provide a structured framework to address these limitations through techniques such as early identification of client requirements, process mapping, and mistake-proofing, which establish the organisational and process-oriented foundation necessary for BIM to move beyond a technology-centric application towards a more integrated socio-technical methodology (Sepasgozar et al., 2020; Pedo et al., 2021). Previous studies show that Lean Construction principles enhance BIM-supported processes by improving information flow and value creation (McDermott et al., 2023), and their shared flow- and value-based production logic suggests strong potential for mutual reinforcement in safety management (Sacks et al., 2009). The integration of BIM and Lean Construction has therefore gained increasing attention, as both methodologies share common theoretical foundations and complementary strengths (Sacks et al., 2010). Therefore, combined BIM–Lean applications outperform standalone BIM use by enhancing collaboration, coordination, and process reliability (Mahalingam et al., 2015).

Overall, the findings indicate that BIM-enabled safety practices remain predominantly operational and technology-driven, limiting their alignment with the broader production system perspective of Lean Construction. This suggests that BIM's contribution to safety management depends not only on its digital capabilities, but on its implementation as a socio-technical system aligned with comprehensive Lean Construction principles.

IMPLICATIONS FOR THEORY AND PRACTICE

From a theoretical perspective, this study contributes to the existing body of knowledge by advancing the conceptualisation of BIM from a technology-centric toolset to a socio-technical methodology within the context of construction safety management. In doing so, it extends existing theoretical discussions by emphasising that the effective integration of BIM and Lean Construction requires not only technological capabilities but also organisational processes including training, process integration, cross-disciplinary collaboration, skilled actors, and supportive governance structures established by clients and regulatory bodies. This reinforces the importance of adopting a socio-technical perspective to better understand how BIM can contribute to holistic and sustainable safety management. From a practical perspective, the findings indicate that BIM can be more effectively utilised when it is embedded within routine safety management processes as a socio-technical system, rather than applied as an isolated digital tool. Aligning BIM with Lean Construction principles of flow, variability reduction, and process reliability may be reflected through clearer role integration between BIM and safety professionals, more consistent workflows, and the incorporation of feedback mechanisms to support continuous improvement. In this sense, BIM can function as a socio-technical mechanism that enables addressing comprehensive Lean Construction principles, which contributes to more coordinated, proactive, and sustainable safety management.

CONCLUSION

This study examined the alignment between BIM-enabled safety practices and Lean Construction principles by analysing how BIM is conceptualised and implemented in practice. Drawing on deductive thematic analysis of 22 semi-structured interviews with professionals from the Australian AEC industry, the findings reveal that BIM-enabled safety practices strongly support operational Lean Construction principles such as visualisation, coordination, and information integration, while remaining limited in addressing system-level principles including standardisation, variability reduction, and production control. This imbalance is not incidental. Rather, it reflects the prevailing conceptualisation of BIM as a technological tool, which does not inherently support the socio-technical conditions required for improved and sustained construction safety management. As a result, BIM-enabled safety practices remain fragmented and insufficiently embedded within the production system. When applied as a technology-driven tool, BIM primarily reinforces operational practices such as clash detection and early hazard identification through model-based simulations, resulting in uneven support for Lean-oriented safety management. In contrast, when implemented as a socio-technical system, BIM integrates technology with organisational processes, stakeholder roles, and governance structures, thereby more effectively supporting Lean-oriented safety management. For example, BIM outputs can be embedded into standardised safety workflows, used collaboratively by BIM and safety professionals, and aligned with organisational policies and regulatory requirements. This socio-technical implementation approach strengthens the alignment between BIM practices and Lean principles, supporting more coordinated and sustainable safety outcomes. In this sense, the central finding of this study is that the limitation of current BIM–Lean–safety integration is not a technical deficiency, but a socio-technical one. It is rooted in an implementation logic that positions BIM primarily as a hazard identification and visualisation tool, rather than as a production system-oriented safety

methodology. Despite these contributions, the study is limited by its qualitative design and its focus on the Australian AEC context, which may constrain the generalizability of the findings to other geographical regions, project types, and organisational settings. In addition, the reliance on interview-based data reflects participants' perceptions and experiences rather than direct measurement of safety performance outcomes. Future research could address these limitations by examining BIM–Lean integration across a wider range of contexts, including different countries and project environments, and by employing quantitative or mixed-method approaches to assess how socio-technical BIM implementation influences measurable safety performance indicators. Furthermore, longitudinal studies could provide deeper insights into how BIM-enabled safety practices evolve over time and contribute to sustained improvements in construction safety management.

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