# A guideline for BIM and lean integrated construction practice

Smart and Sustainable Built Environment

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## Abstract

**Purpose** – This study proposes a guideline for integrating Building Information Modelling (BIM) technology and lean construction practices to address the construction industry's challenges in transitioning to environmentally friendly developments.

**Design/methodology/approach** – This study employs a qualitative research method, integrating and validating lean principles with BIM tools by extensively analysing previous studies. Subject matter expert interviews were conducted to validate the findings and create conceptual maps. Thematic and content analyses were performed to develop the proposed guidelines and recommendations.

**Findings** – The study highlights the potential of integrating BIM and lean construction practices to enhance productivity and reduce waste. The proposed guidelines provide practical recommendations for improving the implementation of BIM and lean practices, offering a structured approach for stakeholders to address critical challenges.

**Research limitations/implications** – While this study provides valuable insights, it primarily focuses on the New Zealand (NZ) context. Future research could explore the applicability of the proposed guidelines in different regions and consider quantitative validation methods to strengthen the findings.

**Originality/value** – This research contributes to the field by providing a novel guideline for integrating BIM and lean construction practices, addressing critical implementation challenges. The study offers valuable insights for global construction practices aiming to adopt advanced management approaches.

**Keywords** BIM, Lean, Construction, Guideline, Integration

**Paper type** Research paper

## 1. Introduction

Traditional delivery methods used in the construction industry can result in project issues like cost overruns, time overruns, disagreements and delays. As a result, it can be challenging to maintain coordination and cooperation throughout the process, which is crucial (Shoar *et al.*, 2023). The development of Information and Communication Technology (ICT.) and its advantages have been employed in response to the complex nature of the construction industry and its implications on productivity and performance (Omrany *et al.*, 2023). BIM and lean construction, including Last Planner, a lean-based approach for collaborative project scheduling and production planning, are examples of how ICT. for the construction sector is growing (Succar, 2009).

BIM models present design and construction information, enhancing project participants' ability to communicate and work together (Koo and Fischer, 2000). For instance, 4D modelling aids in improving understanding and communication of the construction plan among project participants (Kuo *et al.*, 2011; McKinney and Fischer, 1998). Lean construction eliminates waste throughout the building process, whereas BIM aims to enhance cooperation among project teams during a project's design and construction phases. The project delivery



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method is another effective process encompassing the cycle of design and construction aspects, such as activity sequence, roles and responsibilities, material cost and labour (Demirkesen and Ozorhon, 2017). The integration of BIM functionalities and lean principles is crucial for developing the new BIM–lean and Integrated Project Delivery (IPD) concepts, a collaborative project approach bringing all stakeholders together to optimise project outcomes (Evans and Farrell, 2023).

## 2. Literature review

BIM and lean are gaining popularity in practice and research (Evans *et al.*, 2021); however, with a few exceptions, the scientific community treats both lean and BIM approaches independently (Schimanski *et al.*, 2020). Although BIM and lean construction principles have shown substantial benefits individually, their combined application is still underutilised. The primary barriers to this integration include cultural resistance, a lack of knowledge and insufficient support from senior management. These issues prevent the construction industry from fully harnessing the potential of BIM and lean principles to drive sustainable and efficient project outcomes (Likita *et al.*, 2024; El-Diraby *et al.*, 2017).

The case studies on integrating BIM and lean principles show improved global construction project efficiency, collaboration and outcomes. For instance, the Istanbul Grand Airport (IGA) project highlighted how BIM's visualisation capabilities facilitated collaborative planning and progress tracking, resulting in significant time and cost savings. Integrating lean principles ensured efficient resource utilisation and minimised waste, contributing to the project's timely and on-budget completion (Koseoglu *et al.*, 2018). In Malaysia, a qualitative study identified vital factors driving lean–BIM implementation, showing potential to address local industry needs and enhance overall construction efficiency (Aziz and Zainon, 2023).

Additional case studies underscore the practical benefits of these integrated approaches. For example, a case study in Egypt demonstrated the use of BIM as a lean management tool, reducing waste and improving efficiency in construction processes, thus avoiding an 11% increase in the total contract price and a 25% increase from the original contract time (Eldeep *et al.*, 2022). This study showcases BIM's role as a lean management tool, effectively reducing waste and avoiding high cost and schedule overruns, demonstrating the potential of BIM–lean integration to address barriers like waste management challenges. However, limited studies are exploring the practical integration of these tools, especially with clear adoption strategies and possible challenges such as resistance to change processes. The study clearly outlines the need for coordination for adoption amongst stakeholders, especially main contractors and subcontractors, and highlights the need for a framework to address the realistic challenges that firms face when adopting lean and BIM (Eldeep *et al.*, 2022). The University of Alicante, Spain case study conducted by Andújar-Montoya *et al.* (2020), also reflects the challenges noted in interviews, such as resistance to change and fragmented supply chains, reinforcing the need for better lean training and understanding. The study provides evidence for addressing resistance through leadership and incentivised training programmes.

A study from China on BIM and lean construction for enhanced disassembly and reuse highlighted sustainability benefits, such as resource optimisation and reduced environmental impact (Hei *et al.*, 2024). It emphasises expanding BIM–lean integration beyond traditional construction phases to support circular economy principles, particularly during construction. A community hospital project case study from the USA validated that BIM can be used to achieve lean principles, successfully integrated the two to develop construction safety, reduce inventory, rework and avoid construction clashes (Zhang *et al.*, 2018). The case underscores the importance of addressing operational challenges, such as on-site clashes and inventory control, which are critical to project success and efficiency. However, such practices lack proper record-keeping and practical guidelines. Another study found that combining BIM functions with lean principles improves construction execution, with 4D visualisation boosting labour productivity (Karatas and Budak, 2023). It highlights the need to address knowledge gaps in BIM functionalities and provide actionable training, necessitating further development of strategies and guidelines. Integrating BIM and lean paradigms in a public construction project at the University of Alicante reduced architectural conflicts and improved coordination. However, while it also lessened facility systems issues, notable conflicts and budget deviations persisted. Despite improvements, challenges remained in managing costs and facilities (Andújar-Montoya *et al.*, 2020). The processes involved can be refined using BIM–lean integration, and higher efficiency and profitability can be achieved in residential projects (Pérez *et al.*, 2024). Quantitative analysis shows significant positive interactions between lean construction and BIM, enhancing project outcomes and providing empirical support for their integration (Arayici *et al.*, 2023). The reviewed case studies validate the feasibility and advantages of BIM–lean integration while exposing gaps that must be addressed in the NZ context. Collectively, these studies provide empirical evidence supporting the positive impacts of combining BIM and lean principles on project management, efficiency, sustainability and stakeholder collaboration, offering valuable insights for researchers and practitioners in the construction industry.

### *2.1 Existing combined BIM and lean philosophy in construction*

Many countries have implemented reforms to conduct projects using lean and BIM, and others have made renderings necessary for public procurement, such as the Architecture Engineering Construction Owners Operators (AECOO) continue their efforts for their value added to countries' economies, employability, failures and poor reputation (Bradley *et al.*, 2016). Frameworks in construction provide a standardised approach to implementing modern methods, ensuring consistent quality and efficient knowledge transfer and facilitating the adoption of innovative technologies and best practices, enhancing project outcomes (Rashidi *et al.*, 2024; Siriwardhana and Moehler, 2024). A BIM–lean model was developed through an analytic network process (ANP) and provides a framework for enhancing lean/BIM integration in the construction industry (Bayhan *et al.*, 2023). It focused on three main clusters: communication, production and visualisation, with 17 nodes representing factor groups from the LC and BIM literature. Barkokebas *et al.* (2021) examine how BIM and lean principles can enhance premanufacturing processes in off-site construction. The study highlights the underutilisation of digital tools and the lack of focus on early phases, providing detailed steps for evaluation and improvement through quantitative and qualitative assessments. Sbiti *et al.* (2021) created a BIM–lean framework and identified the reliance on manual processes as a critical obstacle to effective BIM–LPS integration.

Similarly, an integrative literature review devised a conceptual model for BIM–LPS integration to provide an overview and develop a conceptual integration model (Schimanski *et al.*, 2020, 2021). In the original BIM–lean interaction matrix developed by Maraqa *et al.* (2021), some identified interactions were declared "not mature technology" at the time. For example, visualising process status via reliable technology further motivates the development of a new BIM–lean integrating information system.

### *2.2 Research problem*

In previous studies, cultural resistance, lack of knowledge, lack of understanding, resistance to change and lack of support from senior staff in NZ organisations have been identified as barriers slowing the integrated uptake of BIM–lean technologies (Likita *et al.*, 2022). Hence, there is a specific need for a unique guideline for NZ which ensures the practical relevance and applicability of BIM and lean integration. As these have matured independently, combining the two parallel streams is necessary to reap more excellent benefits for the industry (El Mounla *et al.*, 2023). While there have been attempts to demonstrate the overlap between BIM and lean concepts (Dave *et al.*, 2016; Forbes and Ahmed, 2010; Likita *et al.*, 2020), a BIM lean integration guideline for the NZ construction sector has not been developed or reported. The fragmented nature of current construction practices exacerbates these challenges, highlighting the need for a cohesive guide for implementing BIM and lean construction effectively.

Based on the literature identifying the knowledge gap, this study aims to develop a comprehensive guideline for integrating BIM and lean construction practices, addressing the critical barriers to their adoption and utilisation. The specific objectives are to analyse the current state of BIM and lean construction integration in the NZ construction industry, identify key challenges and opportunities, create a guideline illustrating the interactions between BIM tools and lean principles throughout the construction phase, validate the proposed guideline through expert interviews, and provide actionable guidelines and recommendations for construction managers and practitioners.

## 3. Research method

The study comprises a four-stage methodology to capture and validate the complex nature of the problem. Figure 1 illustrates the different stages of the methodology and their linkage. The four stages are described in detail in the following subsections.

### *3.1 Semi-structured interviews*

The first stage involved semi-structured interviews to explore potential concepts, practices and processes for a comprehensive guideline for implementing BIM and lean construction management practices in NZ (Doan *et al.*, 2021). The interviews were semi-structured to allow flexibility in the process and to discuss fresh ideas (Stage 1 in Figure 1). The interviews were performed until theoretical saturation was reached, with data collection ceasing once no new insights were gained (Babaeian Jelodar and Shu, 2021; Jelodar *et al.*, 2014). For each research question, visual diagrams, called conceptual maps, are created to connect related concepts and ideas around a central theme for better understanding.

Based on the literature review of the construction projects, case studies and frameworks comprising BIM and lean philosophies, interview questions for guideline development are formulated. This approach will highlight the issues with BIM and lean implementation (Gerber *et al.*, 2010; Ghosh *et al.*, 2013; Lapinski *et al.*, 2006) and helps identify examples of lean BIM interaction from past studies. The following questions were generated for the semi-structured interview:

- What issues influence lean implementation in modern construction practices in NZ?

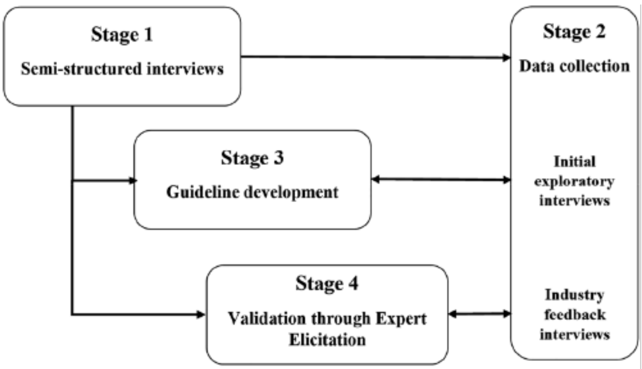


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**Figure 1.** Methodology stages and mapping

- What are the factors influencing/affecting lean implementation in an organisation?
- What strategies are created/planned to improve lean implementation in construction organisations in case of failure?
- What lean philosophies are used in construction organisations?
- How can BIM enhance lean construction?
- How can BIM and lean integrated practices be improved in the construction sector?

*3.2 Data collection*

Interviews help to gain broader and deeper perspectives of interview participants on a topic. The data collection stage involved two sets of interview questions. The first set was an exploratory interview, and the second set was conducted for industry feedback on the developed guideline (Stage 2 of Figure 1). For optimum tangibility and comprehension of responses, interviews were designed with key questions accompanied by follow-up questions (Chen and Partington, 2004). The interviewees' selection criteria included related work experience (at least five years) and a diverse group of practitioners. The second set of interviews, used to gather industry feedback as part of the validation process, involved expert elicitation. This method collects experts' insights, opinions and judgments to support decision-making, validate findings or refine guidelines, especially when data or evidence is limited (Das *et al.*, 2023).

The first set of interview participants was recruited through invitation via LinkedIn and using the chain referral method. The snowball sampling strategy was used to identify subsequent participants during interviews, effectively accessing hard-to-reach niche groups and experts.

Before the interview, an interview guide was given to each interviewee. Before recording interviews, the researcher briefly summarised the study's background and primary goals. The anonymity of the participants was assured by using pseudonyms (PE1–PE15). After reviewing each interview script several times, several themes from the respondents' common ideas and points of view were identified. Based on the replies, the codes used to create the themes were created, enabling analysis and the synthesis of facts to create a theme relevant to the given questions.

Based on the exploratory nature of this stage of the methodology, respondents' roles and experiences were critical. Every participant was qualified, held a prominent role and possessed more than five years of experience in BIM and lean construction management practices. Consequently, all informants have in-depth knowledge and experience in BIM and lean construction management practices. Information on the research participants, with whom semi-structured online interviews at various management levels were conducted, is provided in Table 1. Participants had diverse roles and levels of experience. Though based in NZ, experts brought international experience from various locations.

The number of interviewees was determined by achieving theoretical saturation, where further interviews cease to provide additional insights for the specific purpose of a study (Glaser and Strauss, 2017). As data collection progressed, each subsequent interview contributed to a richer understanding of the identified themes. By the 12th interview, no significant new themes emerged, suggesting that key categories had been thoroughly captured. After an iterative data collection and analysis process, theoretical saturation was achieved through 15 in-depth, semi-structured interviews. The subsequent three interviews reinforced existing patterns without adding new insights, signalling that additional data collection was unlikely to yield further information. Interviews were meticulously coded, allowing for the identification of emerging themes and patterns related to the research topic.

The literature review outcomes, alongside the theoretical replication logic provided through the analysis of the expert interviews, have provided a triangulation of knowledge and a measure of internal validity. To confirm saturation, data analysis employed constant comparison methods, where each new piece of data was compared against existing codes to ensure

**Table 1.** Profile of participants involved in guideline design

| No. | Pseudonyms | Working experience (years) | Position |
|---|---|---|---|
| 1 | PE1 | 10 | Engineer |
| 2 | PE2 | 10 | Facility Manager |
| 3 | PE3 | 22 | Project Supervisor |
| 4 | PE4 | 20 | Director |
| 5 | PE5 | 20 | Structural engineers |
| 6 | PE6 | 20 | Process Engineer |
| 7 | PE7 | 11 | Developer |
| 8 | PE8 | 8 | Site Engineer |
| 9 | PE9 | 5 | Project Manager |
| 10 | PE10 | 15 | Software Engineer |
| 11 | PE11 | 15 | Project Manager |
| 12 | PE12 | 13 | Asset Manager |
| 13 | PE13 | 24 | Civil Engineer |
| 14 | PE14 | 23 | Site Engineer |
| 15 | PE15 | 15 | Chartered Civil Engineer |

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consistency and completeness. This approach verified that the core categories and subcategories had sufficient depth and variability. Therefore, theoretical and methodological considerations supported the decision to conclude data collection at 15 interviews.

### *3.3 Guideline development*

The data obtained for this experiment was stored, interpreted and evaluated using the ATLAS.ti 9 software (Chang and Hsieh, 2020). ATLAS.ti is an advanced data analysis software that extracts valuable insights from qualitative data. It is highly regarded as a powerful tool for qualitative analysis, especially when dealing with large volumes of textual and graphical information. Thematic and content analysis, which involved categorising major themes and systematic analyses of critical concepts, was performed to identify patterns and trends from the transcribed interview data (Amirtash *et al.*, 2021; Jelodar and Yiu, 2012; Dauda *et al.*, 2024). After an initial study of textual data, the qualitative data from the participants and the interview were put into the ATLAS.ti 9 programme. ATLAS.ti 9 software package helped identify many words, phrases and other keywords connected to this article or topic of interest (Friese *et al.*, 2018). Descriptive coding was used to organise the collected data and create codes from the interview transcripts (Rasanjali *et al.*, 2024). The authors then employed pattern coding to analyse the first cycle codes, looking for similarities and patterns to address objectives. The emerging themes are depicted through diagrams and illustrations for each interview question (Stage 3 of Figure 1). A pictorial representation was created for clarity using the Atlast.ti9 software (Chang and Hsieh, 2020).

In addressing the detailed explanations of individual participants' viewpoints, emphasis will be on key insights derived from the diagrams and incorporate general insights from expert opinions. The findings from the literature review and observations are then combined with experts' opinions from the NZ construction industry to develop a BIM-based guideline for lean and BIM integration.

### *3.4 Validation through expert elicitation*

The developed guideline is then communicated and disseminated to construction industry professionals and experts through a formal expert elicitation process. The process involves conducting semi-structured interviews to obtain their perspective on it and find areas for improvement (Ren *et al.*, 2024). The validation process consists of two phases. First, experts reviewed the draft guideline, which included findings from the literature review, interviews and thematic analysis, assessing its clarity, applicability and industry alignment. Next, semi-structured interviews gathered detailed feedback on the framework's practicality, relevance and clarity, enabling experts to identify improvements and suggest enhancements (Stage 4 of Figure 1).

Subject matter experts (SMEs) were contacted via individual emails, and interviews were scheduled at mutually convenient times upon their acceptance. Participants were highly experienced construction professionals, with expertise ranging from 8 to 47 years. The selection involved background screening to ensure experience with BIM and lean applications for guideline validation. Interviews were conducted to test the study's findings, and each participant was anonymised with a code (e.g. SME 1 to SME 8) as listed in Table 2.

## 4. Results

This section presents the interview findings, structured across six key areas: issues influencing lean implementation in modern construction practices in NZ; factors affecting organisational lean implementation; strategies to improve lean implementation in construction organisations; lean philosophies in construction; the role of BIM in enhancing lean construction; and BIM tools used in organisations. Insights were gathered from fifteen experienced BIM and lean construction management professionals recruited via LinkedIn and chain referrals.

### *4.1 Issues influencing lean implementation in modern construction practices in NZ*

Figure 2 summarises the key identified issues affecting implementing lean practices within modern construction practices. At the core are various interconnected issues that collectively influence the adoption and efficacy of lean methods.

The complexity of construction projects in NZ poses significant challenges to lean implementation. Key issues include difficulties in coordinating resources, schedules and activities, along with management challenges that disrupt the consistent application of lean principles across project phases. Effective information management, a cornerstone of lean, is hindered by the lack of standardisation and the difficulty in sharing data among stakeholders, affecting the smooth flow of critical information for efficient execution. Additionally, the absence of industry-wide standardisation impairs consistency and reproducibility across projects. This is further compounded by resistance to change, as traditional practices remain deeply entrenched, limiting the acceptance of lean approaches in the NZ construction sector.

Coordination challenges within and between organisations create further inefficiencies, increasing the potential for rework and delays. The costs associated with implementing lean practices can also be prohibitive for some organisations, especially in a market where limited competition among subcontractors limits options and flexibility. Cultural and mindset barriers

**Table 2.** Profile of participants involved in the validation

| Participant profile | Years of experience |
|---|---|
| SME 1 Planning and scheduling/cost control | 18 |
| SME 2 Facility management expert | 10 |
| SME 3 Project supervisor/council planner | 22 |
| SME 4 Director, reinforcing company | 20 |
| SME 5 Structural engineer | 20 |
| SME 6 Process engineer/plasterboard manufacturer | 47 |
| SME 7 Developer | 11 |
| SME 8 Construction manager | 8 |

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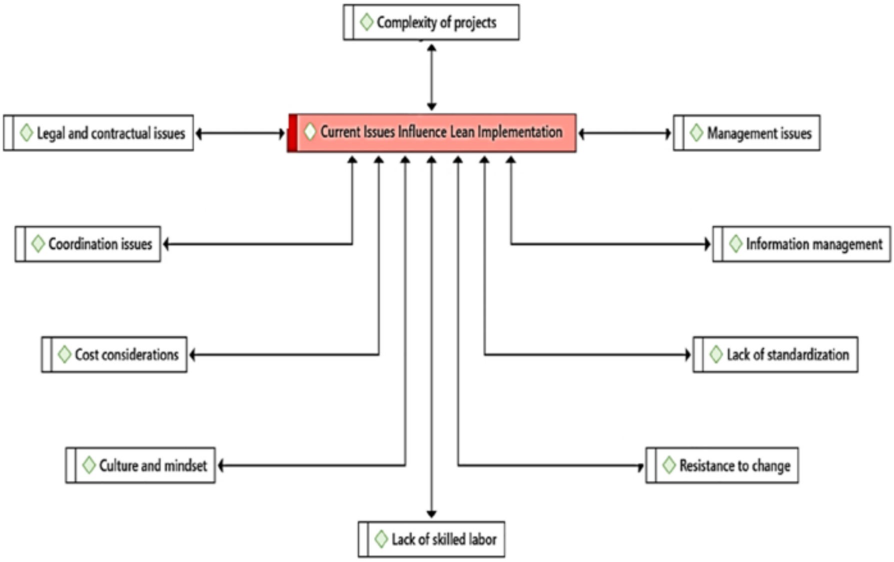


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**Figure 2.** Issues influencing lean implementation in modern construction practices

further complicate lean adoption, as shifting to lean requires a collective industry-wide change towards prioritising waste reduction and efficiency. This cultural shift is difficult to achieve in a traditionally conservative industry. Additionally, the shortage of skilled labour poses a major challenge, as implementing lean practices depends on a workforce well-versed in lean methods and processes.

Legal and contractual issues also pose challenges to lean implementation. Contracts often do not incentivise or support lean practices, and legal constraints, combined with the minor, fragmented nature of NZ's construction industry, make it challenging to leverage lean techniques fully. Experts underscore the synergy between lean principles and BIM tools to enhance lean construction, which can support waste reduction, process efficiency and continuous improvement. BIM's visualisation, coordination and simulation capabilities complement lean's focus on efficiency. Integrating BIM's 3D modelling and clash detection features with a lean strategy like just-in-time (JIT) delivery and visualisation and optimisation tools like value stream mapping can significantly improve project planning, execution and workflow efficiency while reducing rework. Addressing these challenges in lean implementation will require coordinated efforts in training, improved management practices, and fostering a culture that values lean principles.

*4.2 Factors that influence/affect lean implementation in an organisation*

Figure 3 presents a range of factors influencing the implementation of lean practices within organisations. These elements collectively impact the effectiveness of lean integration, with each factor uniquely shaping organisational readiness and adaptability to lean methodologies.

Successful lean implementation in construction relies on effective leadership and a supportive organisational culture. Leaders who actively endorse lean principles and promote a culture of continuous improvement lay the groundwork for success. Without strong leadership and a culture prioritising innovation and efficiency, lean initiatives risk losing momentum or failing to sustain over time. Skilled, well-trained employees actively involved in lean processes

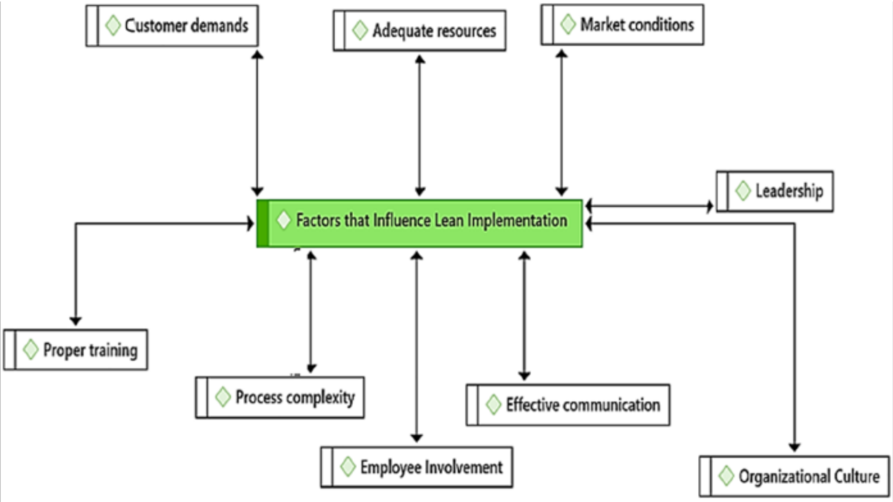


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**Figure 3.** Factors that influence lean implementation

foster ownership and reduce resistance, while inadequate training can leave them unprepared and disconnected, hindering adoption. Resource allocation and market conditions also influence lean's success. Sufficient budget, time and personnel must be dedicated to lean practices, while external pressures like customer demands and competitive forces often drive the need for efficiency. Without these resources or market drivers, lean may be deprioritised, hindering its full potential.

Clear, effective communication across teams and departments is crucial, ensuring alignment and preventing misunderstandings that can impede lean's objectives. Poor communication risks creating inefficiencies that counteract lean goals. Process complexity and project uniqueness within the construction industry present challenges for standardising lean practices. While lean relies on consistent processes, the variability in construction projects makes a uniform approach difficult. Striving to standardise where possible and adapting lean practices to each project's needs can improve consistency and effectiveness. Integrating the supply chain is critical for lean's success in construction, where supply chains are often fragmented. Close, continuous collaboration between suppliers, contractors and stakeholders is essential to ensure smooth material and information flows throughout the project lifecycle. Customer demands and project requirements drive organisations to adopt lean to achieve quality within budgetary and time constraints. However, the diverse needs of projects require organisations to adapt lean practices to meet specific client expectations and project goals.

In summary, the successful adoption of lean in construction is influenced by strong leadership, supportive organisational culture, employee engagement, adequate resources, clear communication, streamlined supply chain integration and responsiveness to customer demands. Addressing these factors enhances lean adoption, leading to greater efficiency, reduced waste and successful project outcomes.

### *4.3 Strategies to improve lean implementation in construction organisations*

Strategies focusing on leadership, training and technology integration have been developed to enhance lean implementation within organisations. Management is central in guiding senior and junior employees towards continuous improvement. A major challenge identified is the limited adoption of lean construction practices in NZ, prompting a shift in training approaches.

Traditionally, training focused on lean practices without addressing specific organisational problems. This ineffective approach led to a revised strategy where problem identification comes first. Participants now prepare problem statements before training, focusing on solving real-world issues and measuring outcomes rather than just teaching tools. Figure 4 illustrates strategies to improve lean implementation, which are effective in case of emerging signs of project failure.

Beyond training, some organisations have established communities of practice to encourage ongoing learning and implementation of lean principles in both work and personal settings. Social media platforms have also been introduced to share success stories, fostering broader engagement and promoting lean techniques. To further encourage lean adoption, some organisations have linked training to career progression, making it a requirement for promotions or internal transfers.

Training plays a crucial role in boosting confidence and enhancing performance. Offering incentives, such as promotions for completing lean training, motivates employees to engage actively and build a culture of continuous improvement within the organisation. BIM is mainly used in the planning phase, and its integration with lean principles remains underdeveloped. To fully leverage BIM's potential in supporting lean construction, a more modular system or collaboration with external providers may be needed to extend its use throughout the project lifecycle. Data management also plays a crucial role in lean implementation. Organisations have adopted consolidated data models to streamline workflows, reduce errors and ensure projects are delivered according to client specifications. These systems centralise key project data, such as procurement and vendor information, to improve accuracy and efficiency.

In conclusion, strategies to enhance lean implementation focus on practical, problem-based training, continuous learning and better use of technology like BIM and centralised data systems to improve project outcomes and reduce waste.

### *4.4 Lean philosophies used in construction organisations*

Lean principles are increasingly adopted in the construction sector to improve efficiency, reduce waste and enhance project management. The Last Planner System (LPS) is commonly

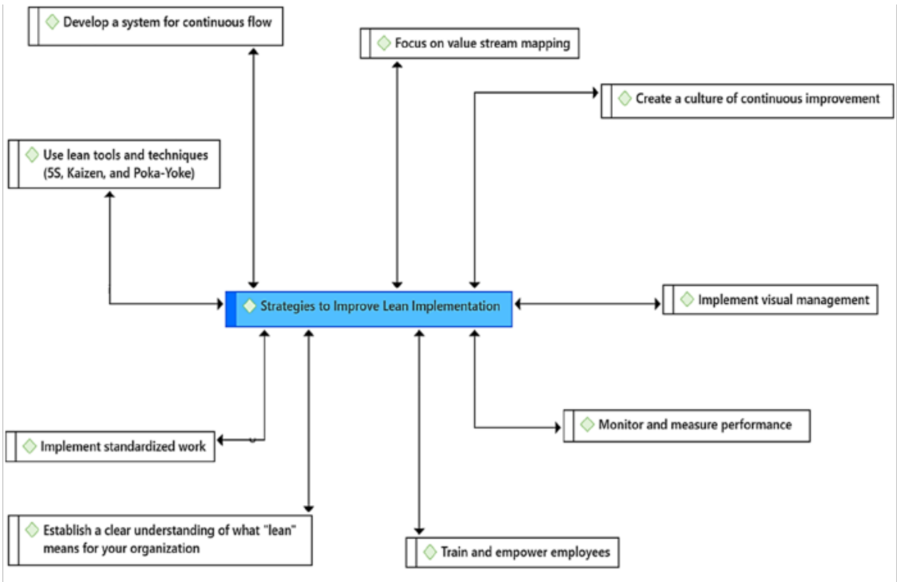


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**Figure 4.** Strategies to improve lean implementation

used in production, planning and scheduling, and it, combined with 3D modelling, provides visualisation for project operational stages (Heigermoser *et al.*, 2019). Many organisations also incorporate lean Six Sigma principles, using continuous improvement techniques such as Kaizen, Fishbone diagrams, five whys and process mapping. Failure mode and effects analysis (FMEA) is employed to address operational problems effectively for complex issues. Figure 5 maps the current application of lean philosophy in the construction organisation.

While LPS is widely used, it is not the only tool; another standard tool used is value stream mapping (VSM), and waste removal is also an essential tool in lean construction, helping to identify inefficiencies and streamline processes (Ramani and KSD, 2021). VSM enables organisations to visualise material and information flows, while waste removal focuses on eliminating non-value-adding activities (Rosenbaum *et al.*, 2014). Despite these tools being widely implemented, challenges remain in fully standardising lean workflows. A lack of in-depth understanding of lean principles beyond tools like LPS limits its full integration. Nevertheless, organisations continue to apply these lean philosophies, contributing to better project outcomes and fostering continuous improvement within the sector.

### *4.5 The role of BIM in enhancing lean construction*

BIM and lean construction principles are increasingly seen as complementary approaches to improve project outcomes. Figure 6 demonstrates how this is carried out in current construction practices. Both focus on reducing costs, enhancing transparency and boosting

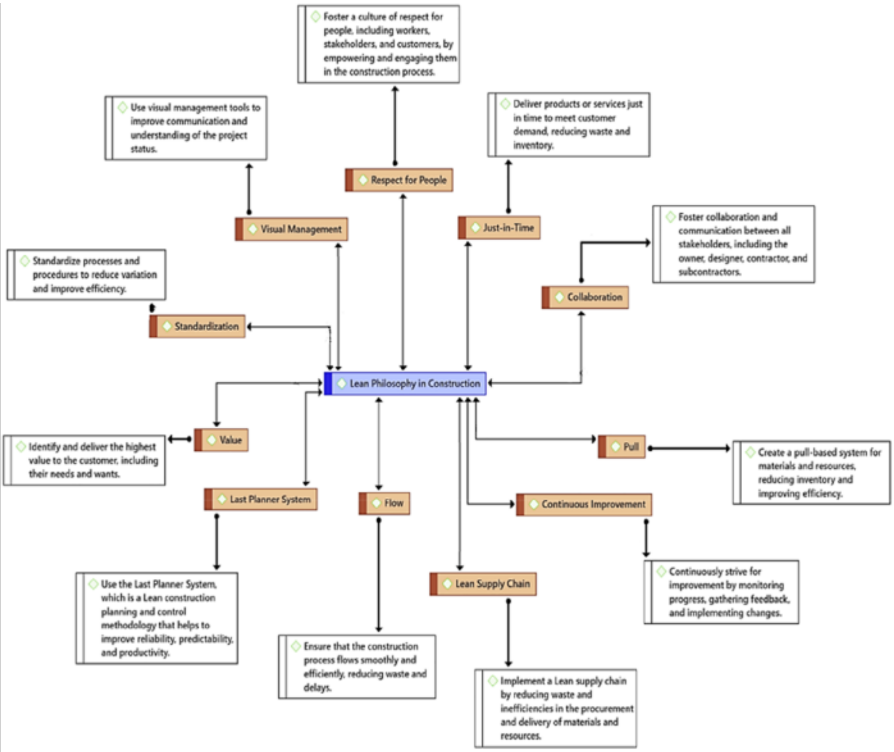


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**Figure 5.** Lean philosophy in construction

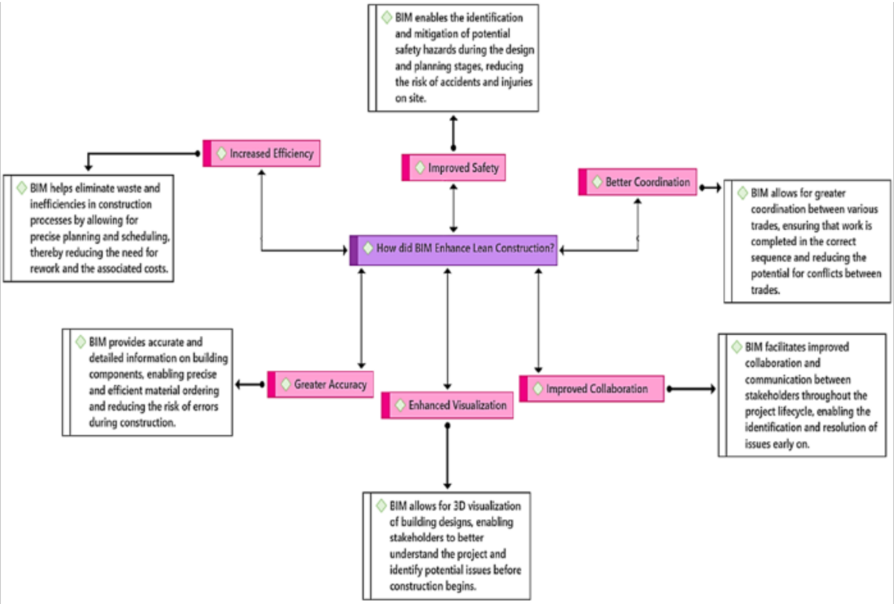


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**Figure 6.** How BIM enhances lean construction

overall performance, making them a natural fit when integrated. By aligning their objectives of reducing waste and improving efficiency, the combination of BIM and lean can drive significant benefits throughout the construction process. BIM enhances lean construction by improving design and planning, providing a clear project view before construction. This early visualisation identifies conflicts, reduces costly revisions and aligns with lean's goal of minimising waste and maximising value.

BIM also enhances stakeholder collaboration by providing a shared platform that improves communication and coordination, which is essential for lean implementation. Better data sharing and visualisation help projects run smoothly, reducing delays and disruptions. However, the adoption of BIM in NZ is still limited. While increasingly used for asset management, many organisations do not fully utilise BIM during construction due to high costs and limited expertise (Moyo and Chigara, 2023).

In summary, BIM can provide valuable platforms for enhancing lean construction by improving productivity, reducing waste and supporting better project outcomes. When strategically applied, BIM and lean can work together to increase efficiency and optimise performance in construction projects.

### *4.6 BIM tools used in organisations*

Figure 7 illustrates some of the identified BIM tools used in construction organisations. BIM tools such as Synchro and Primavera are increasingly utilised in construction planning and facilities management to enhance efficiency and project outcomes. Synchro stands out for its ability to create detailed 3D models that help visualise the construction process, identify potential issues and improve sequencing. While Primavera is also used, Synchro is often preferred for its more comprehensive planning capabilities. In facilities management, BIM's 3D models play a key role in asset identification and the development of maintenance plans. These models support more informed decision-making and improve the efficiency of ongoing

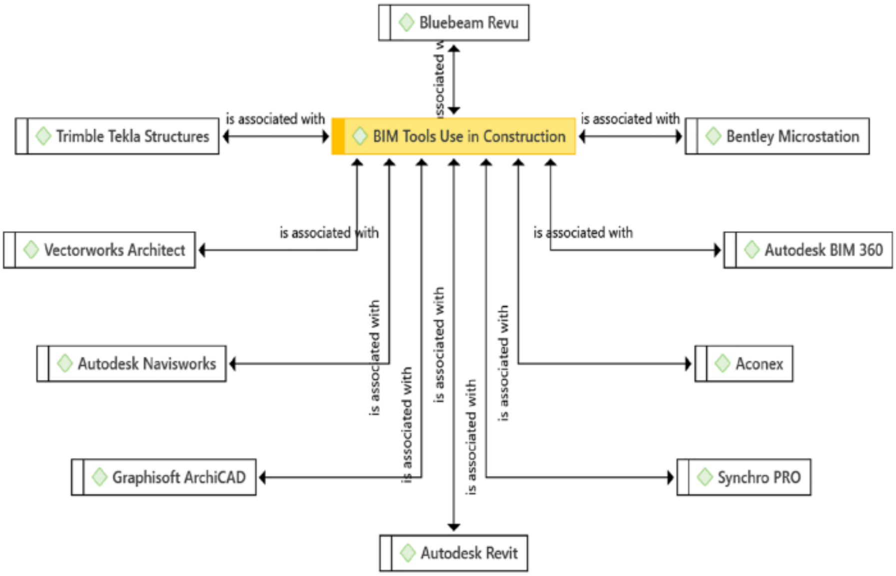


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**Figure 7.** BIM tools used in construction organisations

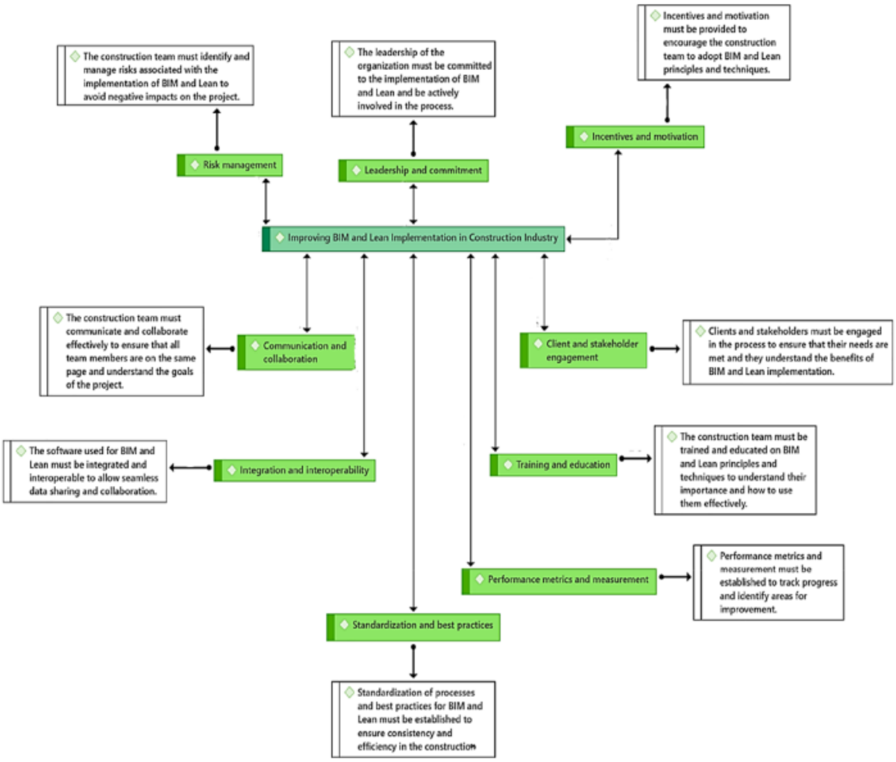
building management tasks. However, while 3D modelling is widely used in maintenance, its application in construction planning is still evolving, with challenges such as high costs and limited expertise hindering broader adoption.

Integrating BIM with lean construction principles offers significant potential for enhancing project outcomes. BIM supports lean's objectives by improving transparency, reducing waste and identifying inefficiencies early in the project. Although BIM adoption faces barriers, particularly in terms of cost and skilled professionals, its strategic implementation can streamline processes and contribute to more efficient, value-driven construction projects. Combining BIM and lean principles can improve project performance and deliver greater value across the construction lifecycle.

## 5. Summary of interviews

The interviews found consensus viewpoints regarding the transformative potential of combining BIM and lean construction practices on NZ projects. The interview findings highlight critical insights into integrating lean practices and BIM in NZ's construction industry and how BIM and lean-integrated practices can be improved in the construction sector. Figure 8 summarises the key findings of the interviews as a comprehensive mapping of BIM and lean construction practices. These findings are further developed into a guideline in the next section.

Key challenges in lean implementation include coordination difficulties, resistance to change and a fragmented industry, further exacerbated by resource constraints, cultural inertia and a lack of standardised processes. Despite these obstacles, BIM is a crucial enabler of lean practices, offering tools like 3D modelling and clash detection that align with lean's focus on reducing waste and improving efficiency. A study in Turkey highlighted how 4D BIM enhances labour productivity by integrating lean principles, particularly in scheduling and labour management. These findings echo interview observations about BIM's transformative potential and underscore the need for expanded BIM training and integration into project




**Source(s):** Authors' own creation

**Figure 8.** Comprehensive mapping of BIM-lean integration practices in construction

management workflows (Karatas and Budak, 2023). Despite its potential, BIM adoption remains limited, with most organisations utilising it primarily in planning stages and for asset management.

Organisations are shifting towards problem-focused lean training, fostering employee engagement through incentives and linking training to career progression. Communities of practice and using social platforms to share success stories have also gained traction. Furthermore, organisations are exploring modular BIM systems to extend their application across project lifecycles. Lean philosophies, including the Last Planner System (LPS), Value Stream Mapping and waste reduction, are commonly employed, though a lack of deeper understanding limits their full potential. Collectively, these strategies aim to enhance lean and BIM integration, driving greater efficiency, collaboration and project success in NZ's construction sector (Figure 8).

The discussions underscored the complementary nature of lean principles and BIM, both aimed at reducing costs, improving transparency and achieving KPIs to enhance performance. Strategic integration of both can significantly improve project outcomes. However, BIM is often used for isolated tasks rather than fully integrated with lean methodologies. Organisations must establish transparent, repeatable processes to ensure a clear understanding of lean principles. The unique nature of projects and fragmented supply chains complicate continuous improvement. Therefore, standardised workflows and an integrated network optimising the flow of goods, information and services are essential for effective lean practices and a cohesive supply chain. In the study of residential construction projects, Pérez *et al*. (2024), also echoed the recommendation to focus on early involvement of experienced managers and standardised workflows for consistency. They also suggested applying lean tools like value stream mapping in residential projects to enhance profitability.

Training and incentivising employees are vital for fostering a culture of continuous improvement. Managers need to help senior and junior employees utilise lean principles effectively by identifying problems before training to ensure the practical application is identified. Additionally, making lean training mandatory for promotions and internal transfers can ensure widespread adoption and understanding of lean principles. This includes training and empowering employees to use lean tools and techniques like 5S, Kaizen and Poka-Yoke to measure performance and meet goals continuously.

The most used lean tools are the Last Planner System, Value Stream Mapping and Waste Removal, indicating a need for broader lean education and application (Pérez *et al*., 2024). Using the Last Planner system and detailed scheduling for construction projects is an effective process. However, most organisations in NZ using the Last Planner system have limited knowledge of other lean principles. This aligns with the case study research on Dammam University's new Administrative Sciences and Computer College building conducted by Eldeep *et al*. in 2022 in Egypt. The study demonstrated BIM's potential as a lean tool to reduce waste, avoid cost overruns (11% of total contract price) and minimise delays (25% of contract time). It also complements the interview findings for early conflict identification to reduce waste and improve project timelines (Eldeep *et al*., 2022). Another recommendation was to focus on problem identification and project management principles tailored to each stage and the design process for off-site construction despite a lack of standardised workflow. These interview findings align well with the Solar Decathlon China (SDC) project in Dezhou, Shandong province, which emphasises standardised workflows and value stream mapping, demonstrating that BIM can enhance lean's waste minimisation and sustainability objectives (Hei *et al*., 2024). Some other common and effective lean six-Sigma principles used in the construction sector involve employing physical boards for activity timelines, fishbone diagrams, five whys, process mapping, FMEA and brainstorming sessions, integrating lean with project management tools to enhance efficiency. Participants highlighted that bottleneck analysis, the just-in-time approach and the systematic testing and optimising approaches like Design of Experiments (DOE.) are also useful. Also, weekly coordination meetings would be helpful to prevent interference among subcontractors (Disney *et al*., 2024). As cost reduction and performance enhancement are significant drivers in government construction projects, implementing lean methodology through a top-down approach has benefited (Moradi and Sormunen, 2024).

Establishing a community of practices and using social media to share success stories were also suggested to foster engagement and create a culture of continuous improvement. Sharing success stories and KPIs helps motivate staff and promote integrated uptake of BIM lean models. Hence, effective management during the early stages of construction, such as integration and early involvement of experienced management in design and scheduling, is crucial for project success.

Participants suggested that BIM is integral to the lean process, providing insights into projects before construction begins, streamlining and enhancing the design and construction process. Since BIM helps identify conflicts early in the design phase, this enhances process waste minimisation objectives, which is the focus of lean during construction activities. Considerable time savings can be achieved with early identification of problem areas. For example, ISO (International Organisation for Standardisation) systems and consolidated data models streamline project management, reduce errors, standardise work processes and ensure quality and safety. Mapping value streams and creating flow is essential for eliminating waste. Visual management tools and early clash detection through BIM can save time and money (Bhattacharya and Mathur, 2023). Meanwhile, an organisation in the early stages of lean implementation employs tools such as takt time and continuous flow, along with bottleneck analyses, to identify areas for improvement and modernise construction methods. Takt time, which aligns production pace with customer demand to ensure smooth and efficient workflows (Power *et al.*, 2024), helps balance output with demand. Similarly, applying the principle of continuous flow is a strategy aimed at reducing inventories and streamlining the construction process, serving as a mechanism to enhance the entire production system (Avelar *et al.*, 2020). The Martin Army Community Hospital in Georgia, USA case study by Zhang *et al.* (2018) also reflects interview findings on BIM's role in improving project transparency and reducing bottlenecks. The study validated BIM's use to achieve lean principles, reducing rework, inventory and clashes. BIM enhanced safety and operational efficiency. This also supports the promotion of lean tools like the Last Planner System and enhanced coordination through BIM in NZ's projects (Zhang *et al.*, 2018).

Participants highlighted that lean principles and BIM aim to reduce costs, improve transparency and meet performance goals. Organisations are adopting lean practices, refining methods and using tools like takt time and continuous flow. However, challenges in NZ, including limited BIM usage and high associated costs, hinder its widespread adoption.

## 6. Guideline for lean and BIM integration in construction

This section conceptualises the integration of BIM and lean construction principles based on the feedback received from industry experts. It also validates the findings and maps the interview results and concepts identified through the previous exploratory stage. This guideline consolidates expert insights and provides practical steps for effectively integrating BIM and lean principles throughout the construction phase, emphasising the complementary nature of these methodologies. By drawing on global best practices and acknowledging the specific challenges of BIM implementation in NZ, this guideline offers prescriptive recommendations suitable for organisations at various maturity levels in BIM and lean practices.

As highlighted in key studies (Das *et al.*, 2023; Mollasalehi *et al.*, 2018), the current practices in NZ reveal improvement opportunities due to varying maturity levels in BIM and lean applications. Rashidian *et al.* (2024) further support the need for guidelines that can be adopted by organisations with different levels of BIM, Integrated Project Delivery (IPD), and lean Construction (LC) maturity. The following recommendations address these needs using a structured approach to implementing BIM–lean strategies in construction projects.

This guideline aims to facilitate a more cohesive, efficient, and sustainable construction process by leveraging the strengths of BIM and lean methodologies to address common challenges in the NZ construction sector. This guideline offers a multi-layered approach for integrating lean and BIM principles into construction project phases. It is based on current best practices and is a practical guide rather than a rigid framework. Unlike a framework, which provides a structured, often theoretical model for understanding or addressing complex systems, a guideline is a step-by-step, operational tool designed for immediate application in real-world scenarios. While a framework outlines overarching principles or strategies, a guideline provides specific instructions and roles for achieving practical objectives. The guideline shown in Table 3 acknowledges the complementary strengths of lean and BIM methodologies and provides a structured pathway to improve efficiency, productivity and sustainability. It also accommodates varying maturity levels among stakeholders, offering adaptable practices to suit different organisations. The guideline is divided into several layers to clarify responsibilities and focus areas for different stages of construction, including key participants such as clients, contractors, consultants and other stakeholders.

The proposed guideline provides a practical and adaptable approach to integrating BIM and lean methodologies into construction projects, focusing on accountability, collaboration and continuous improvement. It addresses the specific challenges of the NZ construction sector while accommodating organisations at varying maturity levels in adopting BIM and lean practices.

**Table 3.** Guideline for BIM and lean integration for organisations in the construction phase

| Layer | Action | Parties involved | Expected outcome | Assessment/ Evaluation metrics |
|---|---|---|---|---|
| 1. Assessment, awareness, readiness and adoption | Conduct readiness assessments to evaluate organisational and project team capability for BIM–lean adoption | Contractors, BIM Manager, Project Manager | Baseline understanding of organisational readiness for integration | Readiness score (using surveys or checklists) and gap analysis report |
| | Organise workshops on BIM and lean principles and benefits | Contractors, Clients | Improved stakeholder awareness and alignment | Participation rate and post-workshop feedback scores |
| | Develop an adoption strategy tailored to project-specific needs | BIM Manager, Lean Facilitators | Strategic alignment with organisational objectives | Documented strategy reviewed by stakeholders |
| 2. Training and skill development | Deliver hands-on, problem-based training sessions focused on practical tools | HR, BIM Manager, Lean Facilitators | Workforce equipped with practical BIM–lean integration skills | Training participation rate and skills assessment scores |
| | Link skill certifications and proficiency to career advancement | HR, Senior Leadership | Enhanced motivation for upskilling and engagement | Certification completion rate and career progression metrics |
| 3. Stakeholder collaboration | Establish forums and professional communities for knowledge sharing | Industry Associations, BIM Managers | Stronger collaboration and shared best practices across stakeholders | Number of forums held and documented outcomes |
| | Implement real-time communication platforms for streamlined updates | All Project Stakeholders | Improved coordination and issue resolution | User engagement on communication platforms and feedback scores |
| 4. Lean implementation strategies | Embed problem identification and resolution exercises in training | Lean Facilitators, Project Managers | Proactive issue resolution and bottleneck mitigation | Frequency of identified and resolved issues |
| | Make lean training mandatory for leadership roles | Senior Leadership | Consistent lean practices across the organisation | Training compliance and leadership engagement scores |
| 5. Lean tools application | Apply early stage lean tools (e.g. takt time, value stream mapping) | Project Managers, Lean Specialists | Reduced inefficiencies and waste | Reduction in waste and process cycle times |
| | Promote comprehensive adoption of the lean tool, including Kaizen and bottleneck analysis | All Team Members | Broader lean understanding and application | Diversity of lean tools applied and team feedback |

(*continued*)

**Table 3.** Continued

| Layer | Action | Parties involved | Expected outcome | Assessment/ Evaluation metrics |
|---|---|---|---|---|
| 6. BIM–lean Integration | Develop and implement BIM-supported lean strategies | BIM Manager, Project Manager, Lean Facilitator | Effective alignment of BIM and lean objectives | Number of BIM–lean processes integrated and reviewed |
| | Address challenges like interoperability and user training | BIM Coordinators, IT Teams | Seamless BIM adoption and lean support | Reduced BIM-related delays and user satisfaction rates |
| 7. Risk management | Use BIM tools for early risk identification and mitigation | BIM Coordinators, Risk Management Teams | Proactive risk reduction and project stability | Number of risks identified and mitigated through BIM |
| | Apply lean principles to cost optimisation strategies | Cost Analysts, Project Managers | Cost-effective project delivery | Cost savings achieved through lean implementation |
| 8. Scheduling and continuous improvement | Use just-in-time (JIT) scheduling to optimise resource allocation | Project Managers, Site Supervisors | Timely and efficient project execution | Schedule adherence and reduction in delays |
| | Embed Kaizen principles for iterative improvements | All Team Members | Enhanced productivity and quality through continuous improvement | Frequency of Kaizen initiatives and measurable improvements |
| 9. Preconstruction visualisation | Use BIM to simulate and optimise designs before construction | Design Teams, BIM Managers | Reduced errors and enhanced stakeholder alignment | Number of identified and resolved clashes during preconstruction |
| 10. Monitoring and evaluation | Establish feedback-driven monitoring systems using BIM data | Quality Assurance Teams, BIM Coordinators | Improved quality control and performance tracking | Frequency of monitoring updates and issue resolution rates |
| | Use BIM visualisation to maintain accuracy and standards | BIM Managers, Quality Assurance Teams | High-quality outputs meeting design specifications | Frequency of quality audits and compliance rates |
| 11. Sustainability and regulatory alignment | Align BIM–lean integration with sustainability objectives | Environmental Teams, Regulatory Authorities | Reduced environmental impact and enhanced compliance | Waste reduction metrics and sustainability audit results |
| 12. Collaboration, communication, and coordination | Promote effective multi-stakeholder collaboration through structured BIM processes | Contractors, BIM Managers, Supply Chain Managers | Streamlined coordination and resource allocation | Number of coordination meetings and clash resolutions |
| | Ensure real-time communication and transparency throughout projects | All Project Stakeholders | Improved decision-making and issue resolution | Response times and stakeholder feedback scores |

**Source(s):** Authors' own creation

Structured across multiple layers, the guideline begins by emphasising assessment, awareness and readiness, ensuring stakeholders understand the benefits and are prepared for integration. Training and skill development initiatives foster a knowledgeable workforce and incentivise continuous learning, while collaboration and communication layers promote alignment through professional forums and real-time platforms. The guideline also details strategies for implementing lean tools and BIM-supported workflows to optimise processes, reduce waste and improve project outcomes. Layers dedicated to risk management, scheduling and continuous improvement leverage BIM's visualisation and data capabilities to identify risks, enhance efficiency and support iterative process enhancements.

By integrating sustainability goals and regulatory alignment, the guideline ensures that construction processes meet environmental standards and remain forward-thinking. It offers a cohesive pathway to enhance efficiency, productivity, and sustainability through actionable steps, addressing both immediate and long-term goals for construction organisations. This comprehensive framework is tailored to help stakeholders achieve effective BIM–lean integration, driving value and success across construction projects.

### *6.1 Validation of the proposed guideline*

The proposed guideline for integrating BIM and lean methodologies was validated through a structured expert elicitation process involving draft reviews and semi-structured interviews. Eight professionals (SME1 to 8), presented in Table 2 participated in the process. Discussions focused on three key areas: evaluating organisational readiness for BIM and lean integration, enhancing sustainability and regulatory alignment, and strengthening leadership and stakeholder collaboration. The diversity of participants ensured that the guideline was rigorously assessed across multiple dimensions of construction management, providing actionable insights to enhance its practical implementation and alignment with industry needs. The validation criteria results are included in this section:

(1) *Clarity:*

- Experts agreed that the guideline was well-structured and comprehensible. One expert noted, *"The logical flow and clear identification of responsibilities and actions make the guideline easy to follow."*
- Methodology Justification: Clarity is essential for ensuring the guideline is accessible to stakeholders at various organisational levels, reducing the risk of misinterpretation (Eastman, 2011).

(2) *Applicability:*

- Experts emphasised the practicality of the guideline in addressing common construction challenges, such as waste reduction and process inefficiencies. A BIM coordinator remarked, *"The inclusion of readiness assessments and incremental implementation steps makes this guideline highly relevant."*
- Methodology Justification: Applicability ensures that the guideline can be effectively implemented to solve real-world problems (Azhar *et al.*, 2012; Salem *et al.*, 2006).

(3) *Alignment with industry practices:*

- Feedback highlighted the guideline's alignment with industry priorities, including sustainability, cost optimisation and stakeholder collaboration. A facility manager noted, *"The focus on BIM for risk mitigation and lean for process improvement aligns with best practices."*
- Methodology Justification: Industry alignment ensures the guideline reflects contemporary standards and practices, enhancing its credibility and acceptance (Abanda *et al.*, 2017).

(4) *Adaptability:*

- The layered approach was praised for allowing phased adoption. One project supervisor stated, *"The guideline's flexibility to scale up or down is critical for organisations with varying levels of maturity."*
- Methodology Justification: Adaptability ensures the guideline is versatile and inclusive, accommodating diverse organisational capabilities and contexts (Lu *et al.*, 2014).

The validation process confirmed that the proposed guidelines for integrating BIM and lean methodologies are clear, applicable, aligned with industry practices and adaptable to diverse organisational contexts. Experts praised its logical structure, highlighting the inclusion of readiness assessments and incremental pathways for phased adoption as particularly valuable. The guideline effectively addresses real-world construction challenges, such as waste reduction, process inefficiencies and stakeholder collaboration, while aligning with contemporary industry priorities like sustainability and cost optimisation. Its flexibility to accommodate organisations with varying levels of BIM and lean maturity ensures broad applicability, making it a robust, practical and versatile framework for enhancing efficiency, productivity and sustainability in the construction industry.

### *6.2 Recommendations for industry*

NZ's construction sector faces several challenges, including a lack of popularity and understanding of BIM and lean applications, especially in the early planning and design stages. Management often overlooks the importance of early-stage IT improvements. Additionally, supply chain issues, with limited subcontractors and external factors like weather and COVID-19, complicate the adoption of lean techniques. Resistance to change is a significant barrier, as traditional methods dominate site mobilisation and equipment handling. This unfamiliarity leads to hesitation in adopting lean practices, which are viewed as risky without guaranteed returns. Political issues, material scarcity and a fragmented industry structure hinder lean implementation. A significant disconnect between design and construction teams leads to inefficiencies and wasted time-resolving clashes and modifications. The consensus among participants is that the strategic integration of lean and BIM leads to improved project outcomes by increasing value, minimising waste and streamlining processes. This is also in line with previous literature available where other integration challenges were discussed (Kordestani Ghalenoei *et al.*, 2024; Likita and Jelodar, 2019).

Additionally, traditional thinking and a disconnect between the design and construction teams hinder the efficient implementation of lean practices. Other factors include political considerations, scarcity of building materials and a lack of understanding of lean construction. To overcome these challenges, the industry must invest in training and adopt modern construction methods, such as prefabrication and BIM, to increase productivity and efficiency while reducing energy costs and ensuring safety and well-being.

The findings indicate that NZ construction industry organisations use lean construction tools and principles to improve their processes and outcomes. By addressing the specific challenges identified in NZ's construction sector and drawing on global best practices, the proposed guideline aims to facilitate a more cohesive and efficient construction process. This section provides specific recommendations for the industry based on the identified challenges, developed guidelines and findings from the literature:

- *Training and education:* Developing comprehensive training programs to enhance understanding and skills in integrating BIM and lean in practice. This includes training in methodologies such as fishbone diagram analysis, bottleneck analysis, Just-In-Time (JIT) delivery and Six-Sigma principles, as highlighted by McDermott *et al.* (2024). Their work underscores that effective education programs are vital for building deep knowledge and facilitating the practical integration of lean-BIM practices in construction projects.

- *Leadership and support:* Ensuring strong leadership and management support to drive the implementation of an integrated approach as emphasised by Mellado and Lou (2020).
- *Collaboration and communication:* Promoting a culture of collaboration and open communication between project parties to facilitate seamless integration and continuous improvement during construction as Najafi *et al.* (2024) emphasise the importance of building trust, fostering knowledge sharing and utilising communication tools to align project goals and drive collective success.
- *Collaborative training initiatives:* Encourage cross-disciplinary collaboration among architects, engineers, contractors and project managers through specialised training sessions to enhance mutual understanding and cooperation. Develop industry-specific training programs in collaboration with educational institutions, integrating practical lean and BIM modules into construction-related courses to ensure a skilled workforce (Tezel *et al.*, 2020).
- *Lean communities of practice:* Establish lean communities of practice within organisations and at the industry level to facilitate knowledge-sharing, experiences and best practices, fostering a culture of continuous improvement (Tezel *et al.*, 2020).
- *Incentivised lean training:* Collaborate with industry associations to incentivise lean training for career advancement, motivating professionals to acquire and apply lean expertise (Aziz and Zainon, 2023).
- *Standardised BIM adoption:* Promote BIM as a standard practice in construction projects globally, fostering collaboration between BIM software providers, government bodies, and construction firms to address challenges and enhance integration (Zhan *et al.*, 2022; Evans and Farrell, 2021).
- *Government-industry collaboration:* Initiate pilot programs in collaboration with government bodies to overcome specific challenges unique to the NZ context, with insights gained informing policy changes and industry-wide improvements (Likita *et al.*, 2024), like UK, Denmark, Netherlands, Norway and Finland, that require BIM for public works (ul Hassan *et al.*, 2023).
- *Diverse BIM-lean implementation strategies:* Encourage organisations to adopt a problem-centric lean approach beyond the Last Planner System while advocating for widespread adoption and integrating lean principles into global project management practices and BIM-based projects (Polat and Demirkesen, 2024).
- *Industry-wide collaboration:* Foster a culture of continuous improvement through Kaizen principles globally, emphasising standardised BIM usage for communication and engaging in industry alliances for collective problem-solving.
- *Action drivers:* Action drivers refer to the key sectors or stakeholders that play a crucial role in successfully integrating lean principles and BIM during the construction phase. These action drivers include the government, the construction sector, regulatory authorities, manufacturers and insurance companies, as indicated by van der Heijden (2024).

## 7. Conclusion

The study highlights the significant role of lean construction and BIM in the construction industry, as reported by the participants. BIM offers a range of benefits, including better collaboration and communication, improved design and planning and better asset management. However, there are challenges associated with its implementation, such as a lack of understanding and awareness of its benefits, high implementation costs and the absence of a skill set to maintain and use it effectively. Therefore, construction organisations must carefully evaluate the trade-off between the upfront cost of BIM implementation and its potential long-term benefits.

The participants' experiences and insights indicate that adopting BIM and lean principles can significantly benefit the construction industry. Emphasising detailed planning and risk identification through BIM can improve productivity and minimise delays. BIM can also help with sustainable practices, asset management and stakeholder collaboration. However, challenges still exist, such as adopting BIM by smaller constructors and using different BIM platforms, which can pose hurdles to effective collaboration. The participants in the study shed light on various approaches to implementing new construction management tools and techniques in their organisations, such as using dashboard techniques to monitor project progress, forming working groups or hiring external consultants to provide fresh perspectives and customised guidelines for implementing new tools and creating a separate department focused on modernising construction methodology. These diverse approaches highlight the importance of continuous improvement and innovation in the construction industry to enhance efficiency, quality, and sustainability. The study emphasises the value of implementing BIM and lean principles in the construction industry to achieve better outcomes. Overall, implementing lean principles and tools in the NZ construction industry shows promise in improving the efficiency and effectiveness of construction projects. Although highly beneficial, NZ does not fully realise the full potential of combining BIM with lean.

The study also acknowledges the limited adoption of BIM in NZ due to high costs and lack of expertise, which could hinder the proposed integration with lean practices. The evolving nature of BIM and lean methodologies suggests that the findings and guidelines may require regular updates to remain relevant. The reliance on expert opinions introduces potential bias. Although rich in detail, the study's regional focus on NZ might restrict the applicability of its findings to other regions with different industry practices, regulations and cultural contexts. Addressing these limitations in future research could improve the robustness and broader applicability of the proposed integration guideline.

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