Alsharqawi, M., Mohammadpour, A., & Salama, T. (2026). Evaluating lean construction impacts on waste, lead time, rework, and cost: a case study of a commercial building project. In F. Hamzeh, M. Poshdar, N. P. Garcia-Lopez, & V. Gan (Eds.), *Proceedings of the 34th Annual Conference of the International Group for Lean Construction* (IGLC34) (pp. 1642–1653). https://doi.org/10.24928/2026/0219

# EVALUATING LEAN CONSTRUCTION IMPACTS ON WASTE, LEAD TIME, REWORK, AND COST: A CASE STUDY OF A COMMERCIAL BUILDING PROJECT

**Mohammed Alsharqawi[1], Atefeh Mohammadpour[2], & Tarek Salama[3]**

## ABSTRACT

Construction projects often suffer from workflow variability, coordination breakdowns, and material waste that drive delays, rework, and avoidable environmental impacts. This study examines how lean planning and logistics interventions affect quality and environmental performance in a large commercial office building project. A mixed-methods case study was conducted using document review, stakeholder interviews, structured site observations, and a before-and-after comparison of performance indicators. The intervention combined Value Stream Mapping to redesign sequencing, Just-in-Time material handling to reduce shortages and excess inventory, and pull planning supported by the Last Planner System®, complemented by daily stand-ups and selective preassembly. Reported outcomes indicate that material waste decreased from approximately 50 tons (projected) to 37 tons (actual), lead time and average task duration improved by about 30%, and schedule reliability increased from roughly 55% to 80% Percent Plan Complete. Rework declined from 15 to 12 incidents, labor productivity improved by about 10%, and the project finished approximately 5% under budget, consistent with an estimated 15% cost improvement. These results suggest lean production control and logistics integration can improve reliability, quality, and resource efficiency when supported by leadership, training, and clear performance measurement.

## KEYWORDS

Lean construction, Last Planner System®, pull planning, Value Stream Mapping, Just-in-Time, sustainability.

## INTRODUCTION

Construction projects continue to face persistent variability in workflow, coordination loss across trades, and material and information waste that manifests as rework, delays, and reduced value delivery. Lean construction has been advanced as an alternative production management paradigm that treats planning reliability, constraint removal, and continuous learning as leading mechanisms for stabilizing flow and improving outcomes. Research has documented the evolution of lean construction practice, research, and education, indicating sustained interest in formalizing implementation pathways (Johansen & Walter, 2012). Recent synthesis research

[1] Assistant Professor, Department of Construction Management, California State University, Sacramento, USA, alsharqawi@csus.edu, orcid.org/0000-0001-8249-4718

[2] Associate Professor, Department of Construction Management, California State University, Sacramento, USA, a.mohammadpour@csus.edu

[3] Associate Professor, Department of Construction Management, California State University, Sacramento, USA, salama@csus.edu

indicates that lean adoption is associated with improvements in productivity, schedule performance, quality outcomes, and environmental indicators, while also highlighting barriers that impede scaling beyond pilot efforts (Babalola et al., 2019; Moradi et al., 2023). This paper investigates lean implementation in a commercial office building case, focusing on the relationship between production control practices, quality performance, and environmental outcomes. The main objective is to present an empirically grounded analysis of performance impacts and implementation challenges, and to contextualize these findings within the current body of peer-reviewed research on lean production control, process improvement, and lean sustainability integration.

The current literature provides strong evidence that lean construction can improve planning reliability, workflow stability, productivity, and quality, while also identifying recurring organizational barriers such as resistance to change, fragmented contracting, and insufficient leadership support. However, several gaps remain. First, much of the available evidence is either review-based or tool-specific, with fewer studies presenting project-level case evidence that links a clearly described intervention sequence to measured changes in performance. Second, the relationship between project context, implementation scope, and observed outcomes is often underreported, limiting the transferability of findings across project types and delivery environments. Third, performance metrics are not consistently defined or reported together, making it difficult to compare how lean interventions affect waste, planning reliability, rework, lead time, and cost within a single case. This study addresses these gaps by presenting a context-rich mixed-methods case of a commercial office building project, documenting both the intervention pathway and the measured performance changes associated with the lean implementation.

# CONCEPTUAL BACKGROUND FOR EVALUATING LEAN CONSTRUCTION IMPACTS

This section reviews existing research on lean construction practices, production control, waste reduction, quality improvement, and sustainability to provide a conceptual background for evaluating their impacts on project performance.

## PRODUCTION PLANNING AND CONTROL

Lean construction extends production management logic to construction by emphasizing value generation, workflow, and systematic waste reduction across design, supply, and site operations. A central premise is that production performance improves when variability is reduced and workflow reliability is increased. Empirical research demonstrates that lean project delivery can be operationalized through reliable planning and production control systems, where workflow stability is achieved via proactive constraint removal and collaborative commitment management (Ballard & Howell, 1998; 2003). Planning reliability is therefore conceptualized as a socio-organizational mechanism aligning stakeholders around feasible work packages, thereby improving predictability.

A key contribution in this area is the Last Planner System® (LPS), widely studied as a structured approach to collaborative planning and control. Evidence shows that LPS enhances lookahead planning, strengthens commitment reliability, and supports continuous learning cycles (AlSehaimi et al., 2014). Quantitative studies further associate constraint management with improved schedule performance, supporting planning reliability as a leading indicator of production outcomes (Lagos & Alarcón, 2021). Comparative analyses between push and pull systems indicate that pull-based planning improves crew performance when aligned with downstream readiness and location-based logic (Ghanem et al., 2022). More recently, data-driven approaches have leveraged LPS indicators for predictive analytics, including machine learning models that forecast schedule performance (Cawley et al., 2024).

## PROCESS TRANSPARENCY AND WASTE REDUCTION

Beyond production control, lean implementation relies on transparency and systematic process improvement. Value Stream Mapping (VSM) has been adapted to construction to visualize workflow and diagnose non-value-adding activities and bottlenecks. Methodological studies propose structured procedures for Value Stream Mapping implementation, linking current state waste drivers to implementable future state improvements (Patel et al., 2021). Recent work integrates VSM with simulation to represent process dynamics and evaluate improvement scenarios before implementation, reducing trial and error in complex project systems (Sreram & Thomas, 2025). Operational practices such as Just-in-Time (JIT) logistics and integrated planning have also demonstrated effectiveness in reducing waste and improving productivity, productivity when supported by managerial commitment and monitoring systems (Aziz & Hafez, 2013; Babalola et al., 2019).

## LEAN, QUALITY PERFORMANCE, AND REWORK REDUCTION

Quality performance is a frequently reported outcome of lean implementation. In construction, rework remains a major source of cost overruns and schedule delays, often driven by poor coordination, inadequate information, and weak process discipline (Love & Edwards, 2004; Zimina et al., 2012). Lean mechanisms that stabilize flow and improve handoffs are therefore expected to support quality outcomes because variability reduction decreases the probability of downstream defects and corrective work.

## LEAN AND SUSTAINABILITY INTEGRATION

Sustainability has become increasingly important dimension in lean construction research. Conceptual studies link lean practices to reductions in energy and material waste through improved flow efficiency and fewer corrective cycles (Francis & Thomas, 2020). Review studies highlight a growing convergence between lean and sustainability, while integrated models that jointly address operational efficiency and environmental performance, while noting challenges in consistent performance measurement (Solaimani & Sedighi, 2020).

Integration research emphasizes the complementary roles of Building Information Modelling (BIM), lean, and sustainability. BIM enhances transparency, coordination, and information reliability, thereby reinforcing lean workflows (Sacks et al., 2010; Saieg et al., 2018). Emerging digital technologies, including Digital Twins, AI, and IoT, further strengthen real-time decision-making and process control (Alsharqawi et al., 2025).

BIM-enabled implementations of lean production control have been proposed, including digital support for the LPS have been proposed to improve planning consistency and information flow (Heigermoser et al., 2019). Broader frameworks link model-based capabilities with lean routines and sustainability outcomes (Lou & Mellado, 2020). Additionally, research in adjacent production domains suggests that lean can support circular economy transitions when aligned with digitalization and resource efficiency (Ciliberto et al., 2021). Recent empirical studies confirm that lean practices can improve environmental performance in construction organizations (Bajjou & Chafi, 2024; Chen et al., 2024). Related work on modular and off-site construction highlights synergies between lean, waste reduction, and decarbonization goals (Salama et al., 2025; Salama, 2019).

## IMPLEMENTATION CHALLENGES AND RESEARCH GAPS

Lean implementation faces persistent organizational and industry barriers, despite its substantial reported benefits. Key determinants include workforce capability, project characteristics, and client requirements (El-Sayegh et al., 2016). Systematic reviews identify common obstacles such as resistance to change, lack of lean expertise, fragmented contracting structures, and limited leadership commitment (Albalkhy & Sweis, 2020; Babalola et al., 2019). Sector-specific studies similarly emphasize cultural misalignment, inadequate training, and the absence of standardized implementation frameworks (Al Balkhy et al., 2021; Moradi et al., 2023). While digital transformation offers opportunities for data-enabled decision-making, its effectiveness depends on concurrent process redesign and workforce development (Villarreal et al., 2021).

A key gap in the literature is the lack of consistent, evidence-based performance measurement systems. Metrics remain fragmented and inconsistently defined, limiting benchmarking and cross-project comparison (Asmone et al., 2025). This gap indicates the need for integrated evaluation approaches linking planning reliability, process performance, quality, and sustainability outcomes.

# METHODOLOGY

A mixed-methods case study design was adopted, integrating qualitative and quantitative evidence to examine the relationship between lean interventions, production performance, quality outcomes, and environmental indicators (Figure 1). Qualitative evidence was derived from project documentation, stakeholder interviews, and structured site observations. Quantitative evidence was derived from project performance indicators recorded before and after the lean intervention, including waste, lead time, cost, rework, and labor productivity.

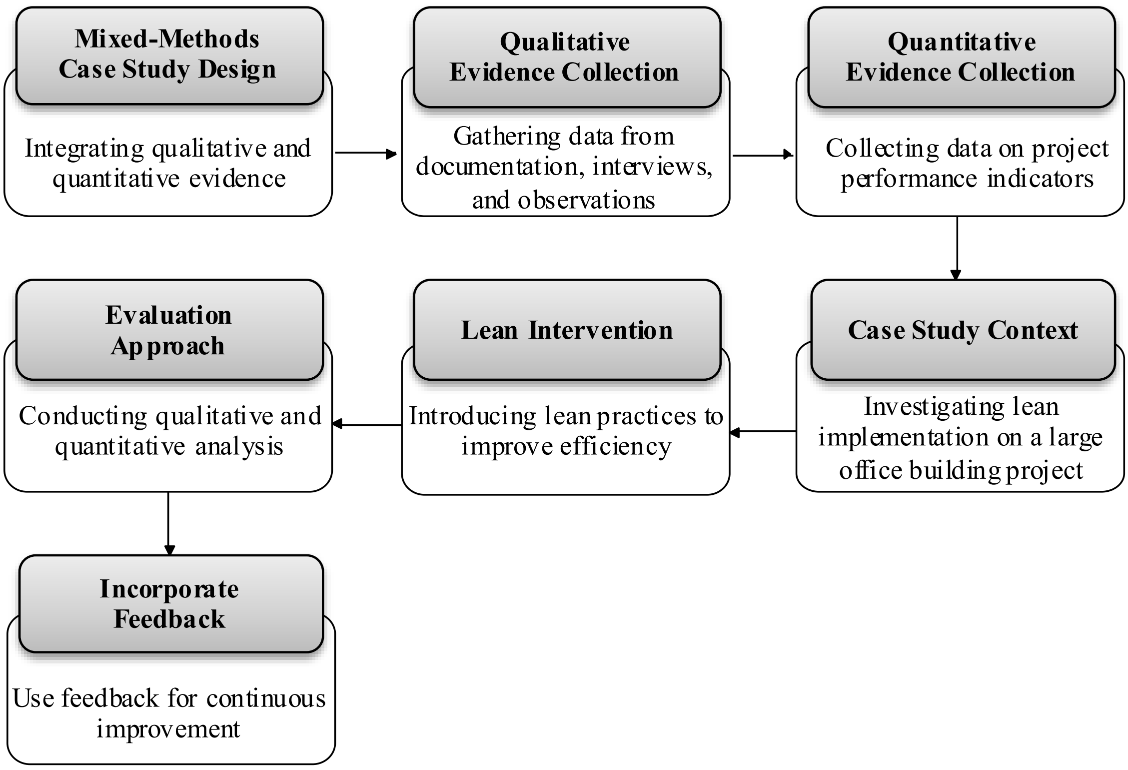


Figure 1: Research methodology connecting literature synthesis and case study evidence

The case study used multiple sources of evidence and explicit sampling criteria consistent with case research guidance emphasizing triangulation and traceability (Love et al., 2002; Runeson & Höst, 2009). The qualitative dataset comprised (1) semi-structured stakeholder interviews, (2) structured site observations, and (3) project document review. The quantitative dataset comprised performance records captured in routine project controls (waste, schedule reliability, lead time, rework, productivity, and cost).

Lean implementation formally started at Month 6 of the project schedule (relative to mobilization at Month 0) with a structured kick-off involving the project leadership team and key trade partners. The implementation followed a staged rollout: an initial diagnostic phase focused on VSM to identify bottlenecks and redesign sequencing; next phase focused on deploying pull planning routines and LPS practices (weekly work planning, constraint screening, and daily stand-ups); and last phase focused on stabilizing planning routines and logistics protocols (JIT deliveries, material staging rules, and workface readiness checks).

# DATA COLLECTION AND ANALYSIS

## CASE STUDY CONTEXT

This study investigates lean implementation on a large mid-rise commercial office building project delivered in a mid-sized city in Eastern Ontario, Canada. The project is representative of a locally delivered private-sector commercial development characterized by multiple trade interfaces, recurring logistics dependencies, and schedule sensitivity during active construction. As summarized in Table 1, the project involved a four-floor office building of approximately 9,000 m² (97,000 ft²), with an estimated construction budget of CAD $34M and a planned duration of about 18 months from mobilization to substantial completion.

The case is analytically relevant because it combines a moderately complex building typology with operational conditions that frequently challenge lean implementation in practice: multiple stakeholders, material-flow variability, trade handoff dependency, and the need to coordinate planning decisions across design, procurement, and site execution. The project team included architects, contractors, suppliers, engineers, and client-side representation, creating a setting in which both technical coordination and organizational alignment were necessary for implementation success. Prior to lean adoption, the project experienced recurring material shortages, excessive on-site inventory, and unsynchronized scheduling that delayed critical activities and reduced workflow reliability.

The scope of the lean intervention in this study was not the entire project delivery system in the broadest sense, but rather the set of planning, logistics, and coordination practices most directly linked to workflow instability and waste. Accordingly, the evaluation focused on interventions affecting task sequencing, materials staging and delivery, planning reliability, and trade coordination, with particular attention to how these practices influenced waste, lead time, rework, labor productivity, and cost.

Table 1: Commercial office building case study project characteristics

| Attribute | Representative Value |
|---|---|
| **Type of structure** | Mid-rise (4 floors) commercial office building |
| **Gross floor area** | ~9,000 m² (97,000 ft²) |
| **Structural system** | Cast-in-place reinforced concrete foundations with a structural frame and a conventional building envelope and interior fit-out |
| **Time for completion** | ~18 months from mobilization to substantial completion |
| **Budget (estimate)** | CAD $34M |

### LEAN INTERVENTION

Lean practices were introduced to stabilize workflows, eliminate non-value-adding activities, and resolve logistics inefficiencies across planning and execution. The intervention utilized a suite of Lean tools and collaborative routines to optimize the project lifecycle:

- VSM was used to identify bottlenecks and redesign task sequencing, effectively reducing lead times. Site layout optimization further enhanced productivity by minimizing unnecessary travel.
- JIT material handling was adopted to reduce inventory and improve flow, while increased preassembly activities shifted labor off-site to reduce waste and bolster quality control.
- The LPS and pull planning were integrated to improve commitment reliability and coordination among trades.
- Collaborative planning sessions and daily stand-up meetings were established to maintain communication, reduce rework, and ensure continuous alignment across the team.

At the time of study close-out, the lean implementation was completed for the core intervention package assessed in this paper. Specifically, VSM-based resequencing, pull planning supported by the LPS, daily stand-ups, and the JIT-oriented logistics routines were operationalized as standard practices and maintained through the subsequent project phases evaluated. However, lean implementation is inherently iterative; therefore, continuous improvement activities continued beyond the stabilization period. In addition, several advanced practices were identified as candidates for a later implementation phase but were not fully introduced within the evaluation window, including: (1) digital integration of planning and constraint management (for example BIM-enabled production planning dashboards), (2) expanded supplier collaboration mechanisms (for example supplier Kanban or vendor-managed replenishment for recurring materials), and (3) broader standardization of preassembly workflows across additional trades. These items are noted as future rollout actions rather than evaluated interventions. The performance impacts reported in the next section are based on the mixed-methods evidence base and before-and-after indicator comparison described in the Methodology section.

## FINDINGS

Reported performance outcomes following the lean intervention indicate improvements across material waste, schedule performance, cost, rework, and labor productivity. These outcomes are consistent with lean theory that associates workflow stabilization and constraint removal with improved production reliability and reduced corrective cycles.

Table 2: Performance metrics before vs. after lean implementation (case study project)

| Key Performance Metric | Before Lean | After Lean | Improvement |
|---|---|---|---|
| **Material waste (tons)** | ~50 (projected total) | ~37 (actual total) | ≈ 25% reduction |
| **Avg. task duration (days)** | Baseline (planned) | Actual (after pull) | ≈ 30% reduction (on avg) |
| **Percent Plan Complete (schedule reliability)** | ~55% (initial phases) | ~80% (later phases) | + 25 percentage points |
| **Rework incidents (count)** | 15 (estimated) | 12 (recorded) | 20% reduction |
| **Labor productivity (units/hr)** | 1.0 (baseline index) | 1.1–1.2 (index) | ≈ 10–20% increase |
| **Project cost variance** | On budget (baseline) | ~5% under budget | ≈ 15% cost savings* |

To summarize the case study's quantitative outcomes, Table 2 provides a comparison of selected performance metrics before and after lean implementation on the project. Implementation challenges were also recorded. Resistance to change among staff required targeted training and sustained leadership support. Upfront investments in training and tools were required, along with increased coordination efforts across stakeholders. The need to define key performance indicators to measure lean success emerged as a critical requirement for sustaining adoption beyond pilot efforts.

The lean intervention was associated with improvements across all tracked indicators (Figure 2). Material waste declined by approximately 25%, which is consistent with tighter material flow control and reduced excess inventory resulting from JIT handling and the increased use of preassembly. Project lead time decreased by about 30%, indicating that VSM supported the identification of bottlenecks and enabled resequencing that reduced waiting between dependent activities, while pull planning improved handoff timing. Total project cost decreased by roughly 15%, reflecting the combined effect of lower waste, higher labor efficiency, and fewer delay-related indirect costs. Rework was reduced by approximately 20%, suggesting improved coordination and stronger commitment to reliability among trades under the LPS and routine coordination practices. Labor productivity increased by an estimated 10%, which aligns with reduced unnecessary travel and more efficient site layout and workface planning, enabling a larger share of labor time to be spent on value-adding activities. Percent Plan Complete (PPC), a key metric included in the LPS for measuring the percentage of weekly activities completed as planned, increased by 25 %, which indicates effective planning after applying lean principles.

These results from the case study clearly illustrate that lean construction techniques, when applied in a coordinated manner, can lead to significant performance improvements. The next

* Cost savings include contributions from waste reduction, productivity gains, and avoided delay costs; the project finished ~5% under budget relative to baseline, corresponding to an approximate 15% cost improvement over business-as-usual expectations.

section will discuss these findings in the context of broader industry experience and theory, examining why such improvements were achieved and how the challenges were navigated.

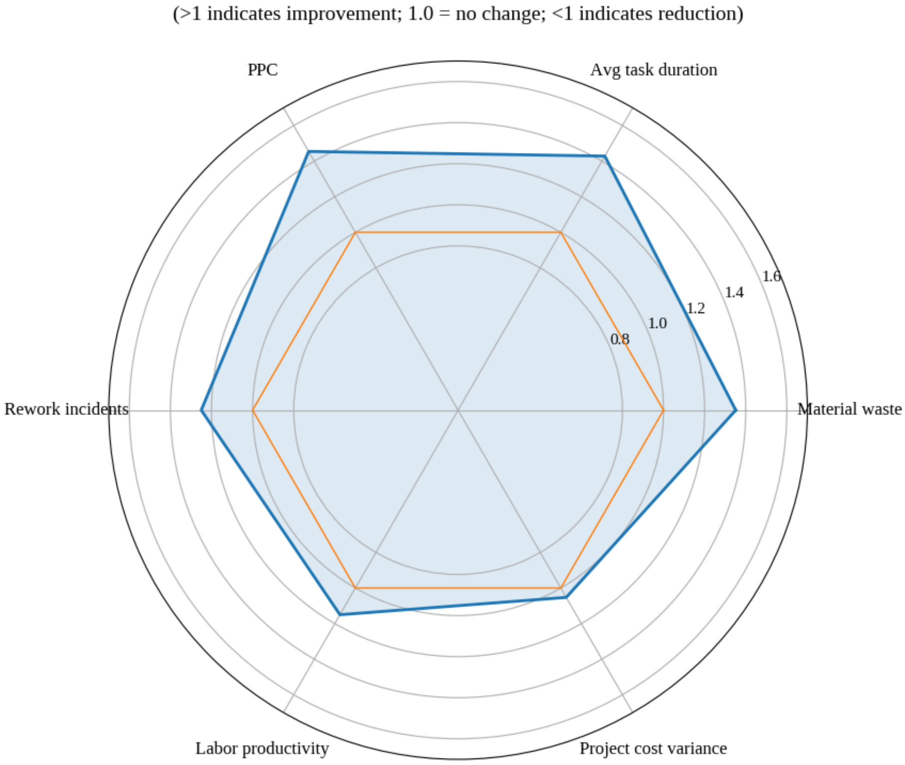


Figure 2: Lean implementation improvement factors across six performance metrics

# DISCUSSION

The reported reductions in waste, lead time, and rework observed in this case study are broadly consistent with prior lean construction research. Improvements in Percent Plan Complete (from ~55% to ~80%) support findings by Ballard & Howell (1998; 2003), AlSehaimi et al. (2014), and Lagos & Alarcón (2021), which identify planning reliability and constraint removal as key drivers of schedule performance. The relatively strong improvement suggests that combining the LPS with daily coordination practices may enhance outcomes beyond levels typically reported.

The reduction in rework aligns with studies by Love & Edwards (2004) and Zimina et al. (2012), confirming that improved workflow reliability can reduce quality failures. However, the modest decrease indicates that lean practices may not fully address root causes such as design or information deficiencies, as noted in the literature.

Findings related to VSM and JIT logistics are also consistent with prior research (Patel et al., 2021; Aziz & Hafez, 2013; Babalola et al., 2019). The observed ~30% reduction in lead time provides quantitative support for claims that process transparency and workflow redesign improve efficiency, while also reinforcing that JIT effectiveness depends on reliable planning and coordination. From a sustainability perspective, the reduction in material waste (from ~50 to 37 tons) supports existing evidence linking lean practices to improved environmental performance (Francis & Thomas, 2020; Bajjou & Chafi, 2024). Consistent with Solaimani & Sedighi (2020), the case also highlights ongoing challenges in measuring environmental impacts, as carbon effects were not directly quantified despite likely reductions in energy use.

Implementation challenges, including resistance to change and the need for training and leadership, mirror those widely reported in the literature (El-Sayegh et al., 2016; Albalkhy &

Sweis, 2020). The case suggests that structured routines and performance tracking can help address these barriers, reinforcing the socio-technical nature of lean implementation. Finally, this study responds to calls for improved performance measurement (Asmone et al., 2025) by integrating multiple indicators, PPC, waste, rework, productivity, and cost, within a before-and-after framework. While this provides a more holistic assessment than many prior studies, the lack of standardized metrics remains a limitation.

The findings confirm that integrating production control, process transparency, and logistics can deliver measurable improvements, while highlighting the importance of implementation rigor and measurement consistency in achieving and evaluating these outcomes.

# CONCLUSION AND FUTURE DIRECTIONS

Lean implementation on the commercial office building project indicates that coordinated production control and logistics redesign can deliver measurable gains in project performance and quality. VSM, JIT material handling, and pull planning supported by the LPS were associated with a 25% reduction in material waste, an approximately 30% reduction in lead time, and an improvement in schedule reliability as Percent Plan Complete increased from about 55% in early phases to about 80% in later phases. These improvements coincided with an estimated 15% overall cost improvement, a 20% reduction in rework, and an estimated 10% increase in labor productivity. The overall pattern is consistent with lean theory emphasizing constraint removal, commitment reliability, and workflow stabilization. In this case, the strongest supported inference is that lean routines improved production reliability, quality performance, and resource efficiency. While these outcomes may also carry environmental implications, such implications were not directly measured in the study and should therefore be interpreted cautiously. Project objectives for examining the relationship between lean interventions, production performance, quality outcomes while using VSM, JIT and LPS were demonstrated by concluding that the ~30% reduction in lead time can be directly connected to bottlenecks identified in the VSM current-state map, especially waiting times between trade handoffs and delays in material availability , that were recognized through pull planning and JIT logistics.

Limitations should be considered when interpreting these results. The study is based on a single case and, therefore, generalizability is limited, and some performance indicators were derived from project records and estimates rather than controlled measurement, which introduces uncertainty and potential confounding from concurrent managerial or contextual changes. Environmental benefits were inferred from reductions in waste, lead time, and rework rather than quantified through direct measures such as energy use or carbon emissions, and post-project persistence of lean routines was not assessed. Future research could strengthen inference through multi-project and longitudinal designs that use standardized lean production metrics, including Percent Plan Complete, constraint logs, and rework taxonomy, combined with consistent environmental KPIs. Additional work could examine how digital supports for production control, such as BIM-enabled LPS tools and data-driven predictive methods, improve decision quality and sustain adoption in fragmented delivery environments, and how simulation-supported VSM can be used to test improvement scenarios before implementation.

**Declaration of AI-Assisted Language Editing:** The manuscript writing and development are fully completed by the authors. During the preparation of this work, the authors utilized Grammarly to enhance spelling, grammar, clarity, and overall academic writing quality. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

# REFERENCES


Albalkhy, W., & Sweis, G. (2020). Barriers to adopting lean construction in the construction industry: A systematic literature review. *International Journal of Lean Six Sigma*. https://doi.org/10.1108/IJLSS-12-2018-0144

Al Balkhy, W., Lafhaj, Z., & Sweis, G. (2021). Enablers and barriers to implementing lean construction in the building construction industry: A systematic review. *Buildings*, *11*(6), 222. https://doi.org/10.3390/buildings11060222

AlSehaimi, A. O., Koskela, L., & Tzortzopoulos, P. (2014). Improving construction management practice with the Last Planner System: A case study. *Engineering, Construction and Architectural Management*, *21*(1), 51–64. https://doi.org/10.1108/ECAM-03-2012-0032

Alsharqawi, M., Heath, T., Panchal, N., Chawla, A., & Sackey, B. (2025). Lean construction in the digital age: Optimizing processes, reducing waste, and driving sustainable project outcomes. In *Proceedings of the Joint CSCE Construction Specialty & CRC Conference 2025* (Montreal, Canada). International Association for Automation and Robotics in Construction. https://doi.org/10.22260/CRC-CSCE-2025/0147

Asmone, A. S., Pal, A., Murguia, D., Rathnayake, A., & Middleton, C. (2025). Where is the evidence of performance improvement in the lean construction literature? In O. Seppänen, L. Koskela, & K. Murata (Eds.), *Proceedings of the 33rd Annual Conference of the International Group for Lean Construction* (IGLC33) (pp. 1–12). https://doi.org/10.24928/2025/0128

Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. Alexandria Engineering Journal. https://doi.org/10.1016/j.aej.2013.04.008

Babalola, O., Ibem, E. O., & Ezema, I. C. (2019). Implementation of lean practices in the construction industry: A systematic review. *Building and Environment*, *148*, 34–43. https://doi.org/10.1016/j.buildenv.2018.10.051

Bajjou, M. S., & Chafi, A. (2024). Enhancing environmental sustainability through lean construction: A structural equation modelling approach. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-06-2024-0705

Ballard, G., & Howell, G. A. (1998). Shielding production: Essential step in production control. *Journal of Construction Engineering and Management*, *124*(1), 11–17. https://doi.org/10.1061/(ASCE)0733-9364(1998)124:1(11)

Ballard, G., & Howell, G. A. (2003). Lean project management. *Building Research and Information*, *31*(2), 119–133. https://doi.org/10.1080/09613210301997

Cawley, J., et al. (2024). Predicting construction schedule performance with Last Planner System indicators and machine learning. *Automation in Construction*. https://doi.org/10.1016/j.autcon.2024.105716

Chen, L., et al. (2024). Lean and green construction: The synergy of lean management for delivering sustainable development goals. *Sustainability*, *16*(21), 9387. https://doi.org/10.3390/su16219387

Ciliberto, C., Szopik-Depczyńska, K., Tarczyńska-Łuniewska, M., Ruggieri, A., & Ioppolo, G. (2021). Enabling the circular economy transition: A sustainable lean manufacturing recipe for Industry 4.0. *Business Strategy and the Environment*, *30*(7), 3255–3272. https://doi.org/10.1002/bse.2801

El-Sayegh, S. M., Alsharqawi, M., Kashif, M., Nikoula, N., & Alhimairee, M. (2016). Significant factors affecting the size and structure of project organizations. In *2016 International Conference on Industrial Engineering, Management Science and Application* (*ICIMSA*), Jeju, Korea (pp. 1–5). https://doi.org/10.1109/ICIMSA.2016.7504032

Francis, A., & Thomas, A. (2020). Energy waste under the ambit of lean construction philosophy: A conceptual framework and future directions. *Journal of Cleaner Production.* https://doi.org/10.1016/j.jclepro.2019.119913

Ghanem, M., Hamzeh, F., Seppänen, O., Shehab, L., & Zankoul, E. (2022). Pull planning versus push planning: Investigating impacts on crew performance from a location-based perspective. *Frontiers in Built Environment*, *8*, 980023. https://doi.org/10.3389/fbuil.2022.980023

Heigermoser, D., García de Soto, B., Abbott, E. L. S., & Chua, D. K. H. (2019). BIM-based Last Planner System tool for improving construction project management. *Automation in Construction*. https://doi.org/10.1016/j.autcon.2019.03.019

Johansen, E., & Walter, L. (2012). Exploring lean construction practice, research, and education. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/09699981211259595

Lagos, C., & Alarcón, L. F. (2021). Assessing the relationship between constraint management and schedule performance in construction projects. *Journal of Management in Engineering*, *37*(5), 04021046. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000942

Lou, E. C. W., & Mellado, F. (2020). Building information modelling, lean and sustainability: An integration framework to promote performance improvements in the construction industry. *Sustainable Cities and Society*, *61*, 102355. https://doi.org/10.1016/j.scs.2020.102355

Love, P. E. D., & Edwards, D. J. (2004). Determinants of rework in building construction projects. *Engineering, Construction and Architectural Management*, *11*(4), 259–274. https://doi.org/10.1108/09699980410547612

Love, P. E. D., Holt, G. D., & Li, H. (2002). Triangulation in construction management research. *Engineering, Construction and Architectural Management*, *9*(4), 294–303. https://doi.org/10.1046/j.1365-232x.2002.00226

Moradi, S., et al. (2023). Implementing lean construction: A literature study of barriers, enablers, and implications. *Buildings*, *13*(2), 556. https://doi.org/10.3390/buildings13020556

Patel, S., Mistry, D., & Shah, M. (2021). A process improvement methodology for effective implementation of value stream mapping in construction. *Innovative Infrastructure Solutions*. https://doi.org/10.1007/s41062-021-00512-1

Runeson, P., & Höst, M. (2009). Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, *14*(2), 131–164. https://doi.org/10.1007/s10664-008-9102-8

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). Interaction of lean and Building Information Modeling in construction. *Journal of Construction Engineering and Management*, *136*(9), 968–980. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203

Saieg, P., Sotelino, E. D., Nascimento, D., & Caiado, R. G. G. (2018). Interactions of Building Information Modeling, lean and sustainability on the AEC industry: A systematic review. *Journal of Cleaner Production*, *174*, 788–806. https://doi.org/10.1016/j.jclepro.2017.11.030

Salama, T. (2019). Optimized planning and scheduling for modular and offsite construction [Doctoral dissertation, Concordia University]. Montreal, Canada.

Salama, T., Sadoughi, A., Miller, J., Alsharqawi, M., & Sawa, Y. (2025). Decarbonization of modular construction and LEED v5 certification. In *Modular and Offsite Construction (MOC) Summit Proceedings* (pp. 25–33). https://doi.org/10.29173/mocs310

Solaimani, S., & Sedighi, M. (2020). Toward a holistic view on lean sustainable construction: A literature review. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.119213

Sreram, P. K., & Thomas, A. (2025). A discrete event simulation-based value stream mapping framework to support digital lean construction. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-02-2025-0311

Villarreal, B., Garza-Reyes, J. A., & Kumar, V. (2021). Lean thinking in the era of digital transformation. *Production Planning and Control*, *32*(13), 1081–1095. https://doi.org/10.1080/09537287.2020.1736307

Zimina, D., Ballard, G., & Pasquire, C. (2012). Target value design: Using collaboration and a lean approach to reduce construction cost. *Construction Management and Economics*. https://doi.org/10.1080/01446193.2012.676658