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LEAN PRACTICES IN CONSTRUCTION: A COMPREHENSIVE LITERATURE REVIEW ON ENHANCING PROJECT PERFORMANCE

Syed Nasrul Fadzli Syed Mohamad[1*], Mohd Shahnaz Bin Mahbook Ali[2] & Amir Ahzlina Jasni[3]

[1,3] Arsyad Ayub Graduate Business School,Universiti Teknologi MARA Cawangan Kedah, Kampus Sungai Petani, Malaysia

[2] Bagan Electrical & Construction Sdn. Bhd

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Corresponding Author:
*nasrulfadzli@gmail.com

ABSTRACT

Despite the implementation of Lean Construction (LC) that has gained considerable attention in the construction industry, the sector continues to encounter similar problems of cost, time, quality and safety overruns repeatedly. However, implementation of Lean remains uneven as a result of superficial understanding of concepts, resistance to change and weak performance measurement systems. Therefore, this systematic review synthesises studies indexed in Scopus (2008-2025) to review the implementation of core Lean tools and barriers to implementation, as well as their respective impacts on project performance. Results reveal that the Last Planner System (LPS), Just-in-Time (JIT) delivery and Value Stream Mapping (VSM) have promising potential to enhance construction project cost, time, quality and safety performance, but their effectiveness is context-specific at both organisation and regional levels. The review also found that leadership commitment, supply chain integration and standardisation are enablers to implementation, while contractual misalignment and project environments remain major barriers. Additionally, the review identified the emergence of Lean 4.0, which refers to the integration of Lean with digital technologies such as Building Information Modelling (BIM), although the evidence base is still scarce. Overall, the results from the synthesis support the findings from previous studies on the importance of systems thinking and structured performance measurement, while also identifying gaps for future research, particularly in the long-term evaluation, cross-country comparisons and

integration of Lean-digital technologies. The results also provide useful information for industry practitioners, while contributing towards the development of a more cohesive theory of LC.

1. Introduction

The construction industry remains a key driver of the national economy, but it is also plagued by well-known and longstanding performance failures, including cost overruns, time overruns, poor productivity, and poor quality (Alarcón et al. 2008; Oguntona et al. 2019). The reasons for poor performance in construction are often attributed to the breakdown in the delivery system, poor coordination among the various stakeholders, and tenacious traditional practices that resist change. As a result, more and more industry players are now embracing Lean Construction (LC) as a holistic, structured, and value-focused management philosophy inspired by the Toyota Production System aimed at eliminating all forms of non-value-adding activities and improving the performance of a construction project (Plugge et al., 2023; Oke et al., 2021).

LC focuses on eliminating waste, stabilising workflow, and improving performance through continuous improvement using various LC tools, such as the Last Planner System (LPS), Just-in-Time (JIT), value stream mapping, and pull planning (Suseelan & Vadivel 2024; Aravindh et al. 2023). Results from many projects worldwide have demonstrated that LC can lead to better cost performance, more reliable schedules, higher quality, better safety, and higher levels of customer satisfaction (Zhu et al. 2025; Marhani et al. 2023). Nevertheless, LC adoption and implementation have been slow and sporadic. Many construction organisations face challenges such as resistance to change, weak top-down support, cultural mismatch, and a superficial understanding of Lean concepts beyond the use of tools (Oke et al. 2021; Hameed & Naimi 2023; Smith & Ngo 2017). This suggests that the persistent poor performance of the construction industry is the result of fundamental problems in the system, rather than a basic methodological gap.

Although prior studies have investigated aspects of Lean tools, critical success factors, and Lean-BIM integration for certain project types (Prasad & Vasugi, 2022; AL-Zubaidi & AlZaidi, 2025), most research remains superficial and context- or type-specific. Previous reviews have offered descriptive summaries of the use and benefits of Lean tools, but there is a lack of analytical synthesis, particularly in identifying contradictions across different regions, variations in adopted methodology or differences in outcomes reported. In addition, although Lean 4.0, which is a new paradigm that integrates the principles of Lean with digital technologies, has received academic attention (Limaylla-Santiago, 2024; Likita et al., 2024), evaluations of its practical implications and limitations are scarce. These gaps indicate a need for a more critical, comparative and thematically integrated analysis of the impacts of using Lean practices on construction project performance in different contexts.

This paper fills these gaps by conducting a more systematic and thematically structured review that (i) classifies the use of Lean principles in construction; (ii) critically examines their impacts on overall construction project performance, particularly with respect to the five KPIs of time, cost, quality, safety and stakeholder satisfaction; (iii) analyses related interrelated barriers, enablers and implementation challenges; and (iv) evaluates the emerging fields of digital integration and performance measurement systems. Unlike previous narrative reviews, this paper aims to provide deeper cross-study comparisons, highlighting contradictions in findings and identifying the

methodological differences that affect the outcomes reported. Through synthesizing dispersed empirical knowledge, the review makes a theoretical contribution by defining where and why Lean practices consistently succeed, where and why they consistently fail, and under what contextual conditions can meaningful performance improvements be achieved.

Their findings provide practical implications for construction practitioners and policymakers by suggesting effective strategies to promote Lean adoption, such as leadership-based cultural buy-in, capacity training, digital technology incorporation, and setting of measurable performance targets. In turn, this paper also has several future research directions that can contribute to a more predictive and evidence-based understanding of Lean's long-term impact on the construction industry (e.g., longitudinal studies, cross-regional studies, and more rigorous studies on the application of Lean 4.0).

2. Methodology

This paper uses a systematic literature review method to investigate how LC practices impact project performance in different construction contexts around the world. Compared to simple article screening, this method incorporates structured search protocols, multi-stage evaluation, explicit coding procedures, and thematic validation techniques to overcome the methodological gaps found in previous LC reviews. The design of the study is guided by the evidence-based synthesis principles proposed by Tranfield, Denyer and Smart (2003), ensuring analytical rigour and minimising reviewer bias.

2.1 Search Strategy and Data Sources

Scopus was chosen as the database due to its high inclusion of journals of relevance to construction engineering and project management that have high impact factors. An effective search string was developed, which incorporated both natural language and Boolean operators. This enabled the retrieval of naturally phrased research, as well as practitioners' studies. The final keyword string used was:

("Lean Construction" OR "Lean Practices") AND ("Project Performance") AND ("Construction Industry") AND ("Critical Success Factors" OR "CSFs") AND ("Systematic Review" OR "Literature Review").

The search was restricted to only peer-reviewed journal articles as well as conference papers, from 2008 until 2025, to ensure the papers were both recent as well as being at both early and advanced stages of evolution of Lean 4.0. Besides, Editorials, book chapters, duplicate records, and non-English publications were excluded.

2.2 Inclusion and Exclusion Criteria

To sharpen thematic alignment and ensure validity, the study applied clear inclusion and exclusion criteria:

Inclusion criteria:-

1. Studies that specifically investigate the use of Lean tools, principles, or frameworks in a construction context.
2. Studies that investigate project performance in terms of cost, time, quality, productivity or safety dimensions.
3. Studies that investigate CSFs that affect Lean implementation.
4. Empirical or conceptual work published in peer-reviewed Scopus-indexed outlets.

Exclusion criteria:-

1. Studies carried out outside the construction context (e.g. health, manufacturing).
2. Grey literature (lack of peer-review quality).
3. Papers without transparent methodology or unavailable full text.
4. Studies that only discuss Lean theoretically with no linkage to performance.

These criteria were applied rigorously to reduce subjectivity and ensure that only conceptually relevant and methodologically valid studies were included.

2.3 Screening, Evaluation, and Quality Assessment

The number of records identified from the first search was 312. Following duplicates removal and title and abstract screening, 87 potentially relevant publications remained, which decreased to 43 studies after a full-text assessment (guided by inclusion/exclusion criteria).

To increase the academic validity of the review and address concerns regarding its reliability:-

- An assessment checklist was constructed to examine relevance, conceptual clarity, empirical robustness and the extent to which a study achieved its research objectives.
- Each study was coded individually and cross-checked to test the validity of judgments.
- Disagreements at the screening stage were addressed by comparing and justifying different findings throughout, a procedure similar to that recommended for addressing inter-coder reliability checks typically recommended in systematic reviews.

Despite the review being conducted by one research team, the multiple checking stages increased the internal validity of the review and minimised coding bias.

2.4 Data Extraction and Coding Process

A detailed coding protocol was designed to extract key analytical dimensions, including:-

- Publication metadata (authors, year, geographical focus)
- Lean tools or practices examined (e.g., LPS, JIT, VSM)
- Performance indicators operationalised
- Identified barriers, enablers, and contextual factors
- Research methods used (quantitative, qualitative, or mixed)
- Reported causal or correlational relationships

The coding process was an iterative process of open-axial-selective thematic development. Initial open coding involved identifying recurring patterns within and across studies. Axial coding then related these patterns to other similar patterns and assigned them to broader categories, such as Lean tools, implementation challenges, CSFs and performance outcomes. Selective coding then grouped these categories into broader thematic clusters aligned with the aims of the review.

This layered approach strengthened thematic validity and reduced concerns about superficial categorisation.

2.5 Thematic Synthesis and Analytical Rigour

In the final synthesis, a thematically aggregating strategy was adopted, that is, Lean practices were aggregated based on their functional intent (e.g., waste elimination, collaboration, workflow optimisation). The CSFs were aggregated into organisational, technical,

and contextual clusters. The performance outcomes were compared using a narrative comparison approach with empirical support from PLS-SEM studies, case studies and correlation analyses (Zhu et al., 2025; Aravindh et al., 2023).

To address reviewer concerns on analytical depth:-

- Contradictions in findings were explicitly noted (e.g., variability in Lean effectiveness across regions).
- Methodological diversity was examined by comparing qualitative and quantitative designs.
- Contextual dependencies (market maturity, cultural dynamics, institutional structures) were recognised as moderators of Lean outcomes.

This structured approach ensures that the review moves beyond descriptive summarisation toward deeper critical synthesis.

2.6 Summary of Methodological Contribution

By employing thorough screening, explicit coding guidelines, and cross-study thematic validation, this approach improves transparency, reliability, and analytical consistency. The methodological justification was shown to address past criticisms of weak methodological justification, limited critical comparison, and lack of thematic clarity in the Lean Construction literature, strengthening the present review's contribution and credibility.

3. Results and Discussion

The 43 reviewed studies were synthesised into three large thematic clusters corresponding to the coding framework developed within the methodology: (i) Critical Issues, (ii) Implementation Strategies, and (iii) Performance Measurement in Lean Construction. These themes emerged from the coding and validation processes and are illustrated in Figure 1 in conjunction with the integrated components of Lean practices in construction.

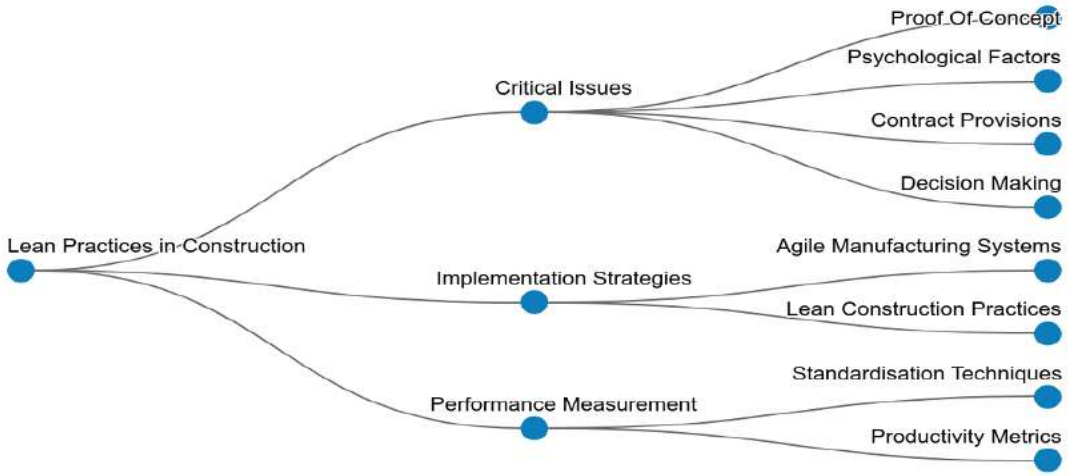

Figure 1 shows a conceptual mind map of the important thematic of Lean Practices in Construction.

Figure 1 shows three main domains. These include Critical Issues, Implementation Strategies, and Performance Measurement. The domains contain components such as factors relating to psychological aspects, provisions in contracts, techniques for standardisation, and measures of productivity. This structure provided the basis for analysis. It allowed categorising studies and identifying patterns of interaction across themes relating to Lean.

3.1 Lean Practices and Their Influence on Project Performance Across Construction Settings

Studies examining Lean practices show a positive influence on performance in projects. This occurs particularly in reducing waste, improving reliability of workflow, and increasing delivery of value (Plugge et al., 2023; Oguntona et al., 2019). Tools such as the Last Planner System (LPS), delivery using a JIT approach, and Value Stream Mapping (VSM) show outcomes that can be measured. These outcomes relate to cost, time, and quality of performance (Suseelan & Vadivel, 2024; Aravindh et al., 2023). Findings appear consistent across different countries. These include the U.S., China, New Zealand, and Malaysia. This consistency suggests that principles at the core of Lean may be applicable in various contexts (Alarcón et al., 2008; Oke et al., 2021).

However, comparison at a more detailed level reveals differences between contexts. These differences make the idea of success that applies in all cases more complex.

Examples include:-

- Several areas indicate substantial gains in schedule reliability with LPS, while others report no noticeable impact due to the division into subcontracts or the unreliability of the supply chain.
- JIT delivery improves material flow in higher maturity markets, but represents a greater risk factor in logistics.
- The degree of Lean adoption is highly variable across project types (residential, EPC, infrastructure). Thus, transferability is not straightforward.

Previous reviews tended to describe benefits from Lean without critically analysing why the impacts vary. This review identifies that organisational culture, project maturity, and regulatory variables act as moderating variables to the impact of Lean.

An increasing number of studies also recognise that Lean integrates with digital technologies, often termed Lean 4.0, which includes real-time monitoring, BIM-enabled coordination, and digital pull planning (AL-Zubaidi & AlZaidi, 2025; Limaylla-Santiago, 2024). While these suggest encouraging potential, the number of empirical studies is limited, and it remains unclear how much digital tools multiplicator Lean performance varies between studies.

3.2 Critical Issues Hindering Lean Implementation

The first thematic domain, Critical Issues, corresponds to the upper branch of Figure 1. The literature identifies numerous systemic, behavioural, and procedural factors that obstruct Lean implementation.

3.2.1 Limited Conceptual Understanding and Psychological Resistance

Literature reports that practitioners' awareness is often at the "tool-level" and that they lack understanding of Lean as an ongoing improvement system (Bajjou & Chafi, 2018; Herrala et al., 2012). This results in superficial implementation and varying implementation by project teams.

Psychological factors such as resistance to change, risk-aversion, and preference for traditional practices further diminish Lean's transformative potential.

3.2.2 Contract Provisions and Institutional Constraints

Despite some improvements, contractual misalignment remains a key issue. Traditional contracts incentivise delivering tasks to meet individual performance, rather than delivering value through good flow and collaboration (Smith & Ngo, 2017). This conflict between Lean and project legal obligations results in poor alignment.

3.2.3 Proof-of-Concept and Decision-Making Challenges

Many construction companies are unable to provide evidence of Lean's overall benefits. This hampers their willingness to scale up Lean in settings where management pressure is weak and short-term financial pressures are high (Hyarat et al., 2022).

Decision-making is often reactive rather than based on evidence, reducing the effectiveness of pull planning and improvement loops.

Critical Comparative Insight

Across regions, studies highlight similar barriers but differ in intensity:-

- High-income markets report cultural inertia as the primary challenge.
- Emerging markets cite structural issues such as a lack of training, insufficient technology, and fragmented subcontracting.
- EPC megaprojects experience the greatest difficulty in sustaining Lean practices due to scale and complexity.

This comparative lens demonstrates that barriers are not uniform; they are shaped by market maturity, workforce capability, and institutional frameworks.

3.3 Implementation Strategies for Successful Lean Adoption

Implementation strategies form the second thematic strand in Figure 1. The literature identifies a range of approaches with varying degrees of empirical support.

3.3.1 Organisational Leadership and Cultural Alignment

Across all studies, Strong top management commitment is the most frequently mentioned enabler across all the studies. Without top-down cultural alignment, Lean tools are frequently misapplied or dropped partway through a project (Valente et al., 2020).

3.3.2 Lean Construction Practices and Standardisation Techniques

Babalola et al. (2019) report 32 Lean techniques applied in practice, such as standardised workflow, takt planning and pull-based scheduling.

Standardisation diminishes variability and increases predictability, but implementation is much more successful when accompanied by:-

- clear communication channels
- multi-level training programs
- collaborative planning involving contractors and subcontractors

Variations are found across markets:-

- Standardisation is the focus in Asia-Pacific studies, due to the weak link between contractors and their suppliers.
- Collaborative planning and team accountability are the focus in U.S. and European studies.

3.3.3 Integration with Agile and Digital Manufacturing Systems

The integration of BIM, mobile planning tools and digital dashboards is a prominent implementation trend. The integration of Lean digital improves construction's visibility in real time, minimises rework and improves coordination according to studies (Likita et al., 2024; Limaylla-Santiago, 2024).

However, evidence is uneven:-

- Some studies report strong synergy between BIM and Lean.
- Others find that BIM adoption alone does not improve Lean outcomes without cultural readiness and training.

Critical Comparative Insight

The review findings indicate that the degree of implementation success does not depend on the number of Lean tools applied but depends on the degree of consistency, integration and commitment in the long term. The implementation that is tool-focused in the short term, with set benchmarks, will show minimal improvements.

3.4 Performance Measurement Systems Supporting Lean Construction

The third branch of Figure 1 (Performance Measurement) reflects how the effectiveness of Lean implementation is measured.

3.4.1 Productivity Metrics and KPI Systems

Common performance measurement methods include:-

- Balanced Scorecard (BSC)
- Key Performance Indicators (KPIs)
- EFQM Excellence Model (Hatzigeorgiou & Manoliadis, 2017)

Lean-relevant KPIs such as rework rate, flow efficiency, cycle time, and material waste offer measurable evidence of Lean's direct benefits.

3.4.2 Evidence from Empirical Studies

Zhu et al. (2025) applied PLS-SEM to measure Lean's impact in EPC projects and confirmed that Lean implementation significantly improved efficiency, safety, and stakeholder satisfaction. However, the review identifies several gaps:-

- Performance metrics used in different studies are not consistent, hindering cross-comparison studies
- Few studies evaluate long-term outcomes
- KPI systems are often implemented inconsistently
- There is limited research that addresses digital performance measurement systems in Lean 4.0 contexts.

Critical Comparative Insight

Performance measurement is one of the weakest practical aspects of Lean Construction. Despite its importance, most firms use some form of ad-hoc or traditional KPIs that do not align with the principles of Lean and thus hinder evidence-based decision-making.

3.5 Summary of Thematic Synthesis

This review demonstrates that LC provides benefits in practice, but effectiveness varies because of context, culture and institution. The main challenges identified in implementation research are persistence of psychological inertia, weak conceptualisation and contract alignment. Successful implementation strategies have been enabled by strong leadership and standardisation, and greater integration with digital tools. The adoption metrics that are essential to widespread implementation remain underdeveloped across the industry.

Their findings encourage more methodologically rigorous research, longitudinal research, cross-region comparison, and further integration between Lean and digitalisation, particularly in the new context of Lean 4.0.

4. Conclusion

This review critically synthesised the contemporary literature on Lean Construction (LC), highlighting the relationships between Lean practices, implementation challenges and performance measurement systems. Although consistent recognition of the potential for Lean to improve project outcomes (e.g. minimise waste, stabilise workflow, enhance coordination) is found in the existing literature, the empirical results show that the benefits of Lean are not ubiquitous across different regions, projects or organisations. Furthermore, the review shows that the performance impact of Lean is context-sensitive, with substantial variations arising in terms of leadership culture, contractor involvement, maturity of the supply chain and levels of technology readiness.

One of the main contributions of this paper is that it can then consolidate the critical issues, implementation mechanisms, and performance measurement systems, and thus provides a more coherent and analytically meaningful view of LC's performance impact in different settings. Previous LC reviews mainly focused on aggregating the lean tools and provided summarised cross-study comparisons. This paper addresses the gap by identifying the contradictions in reported outcomes and the variations in implementation approaches and analytical methods that affect review outcomes. The synthesis confirms that LC knowledge gap, resistance to change, poor contract design, and inadequate performance tracking remain persistent constraints that hinder LC's success.

The review further confirms the importance of leadership-driven cultural alignment, structured standardisation, multi-level training and consistent use of performance indicators as fundamental enablers of LC success. By contrast, the digital integration required for new digital twin models, including BIM-enabled coordination, real-time monitoring and data analytics, are changing the way LC is implemented in the emerging LC 4.0 context. However, empirical evidence for LC–digital integration is still limited, and hence any claims of alignment and interoperability must be treated cautiously.

From a theoretical perspective, this paper has advanced the LC discourse by confirming the relevance of systems thinking, continuous improvement and socio-technical alignment. The findings also suggest the need for more robust conceptual models that integrate Lean practices, behavioural factors and digital tools into a single coherent model that can explain LC success and failure across different settings.

From a practical perspective, the review has important implications for contractors, project owners, policymakers and industry regulators. To achieve effective LC implementation, the industry needs to invest in capability development, leadership commitment, contract reform and the adoption of performance measurement systems that track LC performance rather than conventional performance measurement reporting structures. Policymakers can also consider using these findings to design industry-wide LC incentives and procurement approaches.

This review has several limitations. First, it is based on secondary data, and the reviewed studies exhibit heterogeneous study designs, making cross-study comparisons difficult. Most of the reviewed studies focus on short-term project outcomes, and there is a gap in understanding LC's organisational outcomes over longer time frames. There is also a lack of longitudinal, multi-country comparative studies, and the reviewed studies have limited examination of the empirical validity of LC 4.0 tools.

Future research should therefore prioritise:-

1. Longitudinal studies to assess the sustainability of Lean throughout the entire life cycle of projects and organisations.
2. Cross-regional comparative studies to explore the influence of culture, regulations, and markets on these differences.
3. Empirical studies on the validity of Lean 4.0, such as BIM, AI, IoT, and digital performance dashboards.
4. Integration of behavioural and contractual theories to explain resistance, incentives, and decision-making in Lean environments.
5. Development of unified performance measurement frameworks that capture both operational and strategic impacts.

In conclusion, Lean Construction still has the potential to improve project performance, but it must be strategically, contextually, and evidence-based. This review has synthesised the current available literature and identified the gaps to provide a stronger and more useful basis for future academic research and Lean Construction implementation in practice.

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Conflict of Interest
The authors state that there are no conflicts of interest in regards to publication of this manuscript.

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