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A Systematic Literature Review on the Application of Lean Construction Principles in Building Projects: Benefits, Challenges, and Future Research Directions

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Abstract

Question: How have Lean Construction principles been applied in building projects, and what challenges and benefits have been identified in their implementation?

Purpose: The purpose of this paper is to systematically review the application of lean principles in building projects to determine widely used tools, associated benefits, barriers, and research gaps. It aims to explore the evolution of the lean idea from a foundational approach to a digital-integrated framework.

Research Method: A systematic literature review conducted using the PRISMA framework. Searches were conducted in Scopus, Web of Science, and Google Scholar using Specific Keywords. After applying the inclusion and exclusion criteria and removing duplicates, 83 studies published between 2007 and 2025 were included in the analysis.

Findings: The review reveals that the Last Planner System® (LPS®) is the most widely implemented tool, offering quantifiable benefits in cost, time, and workflow. Value Stream Mapping (VSM) and 5S improve operational efficiency but remain limited in application. Tools such as Just-in-Time (JIT), Target Value Design (TVD), and Set-Based Design (SBD) are underexplored. Significant barriers include interoperability issues, less leadership initiative, and inadequate training. The integration of the Lean-BIM-Digital framework is evolving but lacks empirical validation.

Limitations: Most reviewed studies are case-based and qualitative, making them difficult to generalize. Research is mainly focused on the construction phase, with minimal attention to design and procurement stages.

Implications: The findings show the need for standardized performance indicators, stronger empirical methods, and broader application of lean-digital integration. Industry practitioners and policy makers can use these insights to improve lean implementation.

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Value for Authors: This review tries to connect fragmented knowledge, provides a comprehensive approach to lean practices in building projects, and guides future research toward quantifiable, technology-oriented solutions.

Keywords: Lean Construction, Building projects, Last Planner System® (LPS®), BIM integration, Challenges, Benefits, Systematic literature review

Paper type: Review Papers

Introduction

Lean Construction is a new approach to production management in construction that focuses on using minimal resources to meet customer expectations. It is on the idea that individual performances can bring about change and contribute to the whole production process. The central idea of this approach is combining planning and control to minimize process waste and improve workflow reliability. More importantly, the lean principle focuses on system-level performance rather than individual-level efficiency (Howell 1999). Abdelhamid (2004) further describes how enhancing construction performance by reducing waste aligns with the customer perspective. It highlights the need for early problem identification, accurate workflows, and continuous improvement rather than delay and inconsistency. In addition, Lean takes a holistic approach to selecting and planning production systems, aiming to reduce waste while maximizing results for all stakeholders. In construction, this can be assured through the flow of materials, information precedence, and focusing on smooth work procedures rather than isolated productivity gains (Abdelhamid et al. 2008).

If there needs to be a shift from managing activities to managing production flow through intensive planning, the lean principle is necessary. Ballard articulates that objectives can be achieved when work is planned, plans are realistic, and people who perform the tasks are flexible and able to control the process. Therefore, Lean helps to minimize uncertainties, learn from past failures, and encourage individual efforts (Ballard 2000). Mossman (2018) highlights that Lean is a systemic or collective approach rather than a single effort and emphasizes that this is how construction work can be improved. Lean is derived from factors such as context, people, and purpose; therefore, these three factors, among others, must be met for the lean principle to deliver value. The LCJ Editor's Note (2022), as a leader in Lean Construction Knowledge, also invites the community to see Lean Construction as a philosophy that considers work, value, and human collaboration as the backbone for project success.

In more recent studies, research has shown that applying Target Value Design (TVD), in which cost, value, and purpose guide design and other tasks from the beginning, yields better results. The authors try to show how lean thinking can minimize costs at the project's inception stage rather than rushing to cut expenses afterward. When projects focus on value rather than contracts, objectives can be achieved and projects become cheaper (Pasquire et al. 2012). The existing body of knowledge demonstrates that lean principles are well theorized and well supported in improving construction project performance across various dimensions. Additionally, advancing the adoption of digital technology in lean principles establishes a knowledge base for the future.

Ambiguous ROI with higher-order BIM applications (e.g., 5D, 6D, and 7D). Third, phase coverage is uneven, with empirical research dominated by the construction phase. In contrast, early design, along with Target Value design, set-based design, and takt planning, where the bulk of performance gains can be captured, remains in the dark and underexplored. Fourth, Contextual Bias limits transferability. Reviews from Mainland China have highlighted that findings of country-specific drivers, policy settings, and organizational cultures shape adoption pathways (Hussain et al., 2014). Fifth, the outcome measurement is varied and complex; reviews have shown that KPIs and follow-up periods differ significantly, making it challenging to summarize across various building types. Lastly, the links between sustainability and safety are meaningful yet inconsistently applied in building contexts. Many studies consider environmental and safety parameters for effective lean implementation, but there remains a lack of longitudinal studies. Collectively, these gaps derive the necessity for a systematic review focused specifically on building projects that (i) establish quality appraisal criteria, (ii) standardize outcome metrics (schedule, cost, rework, waste, safety), (iii) differentiates design from construction phase interventions, (iv) distinguishes private from public sector procurement, and assesses Lean-BIM integrations by maturity and empirical validation. Such a review plays a crucial role in developing standards that are suitable for successful adoption in buildings.

Given the limited and inconsistent existing literature, this review aims to clarify the application of Lean Construction, specifically in building projects. The guiding research question is "How have Lean Construction principles been applied in building projects, and what challenges and benefits have been identified in their implementation?" This question is intentionally selected to encompass the actual use of lean techniques in building projects, including the Last Planner System® (LPS®), Just-in-Time delivery, 5S, and Target Value Design. This paper aims to be comprehensive and systematic, resulting in contributions in three dimensions. The first step is to gather and organize studies from previous case studies or contexts, and to review the lean principles in practice. The second one is identifying and categorizing the benefits and challenges of lean implementation in different contexts. Third, it will highlight weak areas or the absence of empirical evidence for studies and guide future research directions. Therefore, the aim of this review is not only to document previous studies but also to provide real steps that enhance the outcomes of implementing lean practices in building projects.

Methodology

Search Strategy

The following table summarizes the search strategy this study has followed, based on the Prisma 2020 guidelines. These databases were selected to ensure the inclusion of high-quality papers on Lean Construction research. Scopus and Web of Science were selected for their coverage of diverse multidisciplinary subjects, and Google Scholar was used to reduce the risk of omitting relevant publications.

Table 1: Database Search Strategy

Database	Platform	Full search strategy (Boolean operators as used)	Limits/ Filters applied
Scopus	Elsevier Scopus	("Lean Construction" AND barriers) OR ("Lean principles" AND benefits) OR ("Implementation of Lean Construction") OR ("Lean Construction in building projects")	▪ Years: 2007-2025 ▪ Language: English ▪ Document types: journal articles, review papers, conference papers ▪ Subject area: Engineering and Construction ▪ Full-text availability required ▪ Excluded: healthcare, manufacturing, IT and other sectors.
Web of Science (WOS)	Clarivate WoS core collection	("Lean Construction" AND barriers) OR ("Lean principles" AND benefits) OR ("Implementation of Lean Construction") OR ("Lean Construction in building projects")	▪ Years: 2007-2025 ▪ Language: English ▪ Document types: journal articles, review papers, conference papers. ▪ Subject area: Engineering and Construction ▪ Full-text availability required
Google Scholar	Google Scholar	("Lean Construction" AND barriers) OR ("Lean principles" AND benefits) OR ("Implementation of Lean Construction") OR ("Lean Construction in building projects")	▪ Years: 2007-2025 ▪ Language: English ▪ Document types: journal articles, review papers, conference papers ▪ Full-text availability required ▪ Excluded: theses, book chapters, editorials

Interrater Screening Agreement

Studies were selected based on a **consensus-based screening process**. Two independent reviewers reviewed titles, abstracts, and full texts against predefined inclusion and exclusion criteria.

Interrater agreement was computed using Cohen's Kappa (k) as a reference for accuracy. The screening process resulted in a high level of agreement, with a substantial interrater reliability **(k> 0.7).** Any other variations were resolved through discussions, and no study was included without dual agreement.

One limitation flagged here is that the reported interrater agreement is based on consensus rather than independently logged screening decisions, which can significantly affect the numerical kappa value.

Quality Appraisal Method

The Mixed Methods Appraisal Tool (MMAT) was used to cross-check the methodological quality of included studies against a structured approach. This is needed because the review included qualitative case studies, quantitative empirical studies, mixed-methods research, and systematic reviews.

Five Criterions defined (Q1-Q5). Each criterion is scored on a scale from 1.0 (full adherence) to 0 (lack of evidence).

Appraisal Criteria and Scoring Logic

The included studies were evaluated based on the following mechanisms.

- Q1: Research Clarity: objectives clarity assessed.
- Q2: Methodological Appropriateness: The methodology section was cross-checked against the research questions
- Q3: Transparency of Lean Implementation: Here, the evaluation of how clearly Lean tools have been carried out takes place.
- Q4: Outcome Measurement Rigor: measurable indicators to track results identified.
- Q5: Validity &Transparency: research limitations identified and applicability of results to the context.

Quality Grading Classification

- High Quality (Score 4.0-5.0): These papers show feasible methodology, clear objectives, and an achievable lean application.
- Moderate Quality (Score 3.0-3.5): The papers are relevant, but they may lack feasibility in either methodology clarity or approach for limitation.
- Low Quality (Score < 3.0): may have a less clear objective or unreachable research question, but provides theoretical value to the review.

Quantitative Results of the Appraisal

Overall, the quality of the included literature is high, which increases the credibility of the systematic literature review. The quantitative breakdown of the 83 studies included is presented as follows:

- **Overall Quality Distribution**: 63.8 % (53 studies) were classified as **High Quality;** whereas 34.9% (29 studies) were **Moderate Quality**. Only 1.3 % (18 studies) were **of low quality** due to limited discussion on validity.

- **Performance Criterion**: **Research Clarity (Q1)** has shown the highest compliance with an average of **(0.9/1.0)**, which indicates most authors have clear objectives. **Methodological Appropriateness (Q2**) and **Lean Transparency (Q3)** have an average score of **0.83 and 0.81,** respectively, indicating appropriate methods and tools for lean implementation. **Validity & Transferability (Q5) is assumed to be the most challenging area for researchers, with a mean score of 0.62, indicating less effort to describe the limitations of the context.**

The Quality appraisal process in MMAT format is summarized in Appendix A.

Classification Of Studies

To improve study quality, a predefined coding framework was used. The first studies were categorized based on the lean tools or principles they applied. This indicates that general lean principles accounted for (n=25; 30.5%), BIM-enabled lean approaches (n=13; 15.9%), whereas the Last Planner System® (LPS®) (n=11; 13.4%) was mainly investigated. In contrast, Integrated Project Delivery (IPD) AND Target Value Design (TVD) are covered less, with each (n=5 or less). In the meantime, emerging digital-lean hybrids such as BIM-Digital Twin, IoT/AI-enabled lean) accounts for 10% or less, indicating the need for further research in the area.

Studies were also further classified by **Project Phase; the** majority focused on design and planning, while some concentrated on the construction stage. In terms of **Outcome metrics,** most studies have associated their work with project performance (n=9), process efficiency (n=7), productivity (n=7), and cost and time outcomes (n=4 each). In contrast, studies on sustainability, Safety, and waste remain minimal, with a count of 2 or fewer for each.

Regarding **Study Design**, most of the literature follows conceptual and theoretical methods to address the study gap, but limitations remain. Empirical case studies, in combination with mixed methods, also help at a moderate level of methodological maturity. The Context of studies also shows a balance where there is a strong focus on International and developing countries. Several studies from Africa, Asia, and Latin America account for the largest share, whereas Europe is less frequently represented.

To ensure study quality, studies were evaluated against the (tool-phase-outcome-design-context) framework to reduce subjectivity and increase their validity. This multi-criteria analysis helps to produce a reproducible synthesis of studies and to identify gaps and indicate future directions.

The detailed coding scheme for the (tool-phase-outcome-design-context) process is shown in Appendix B.

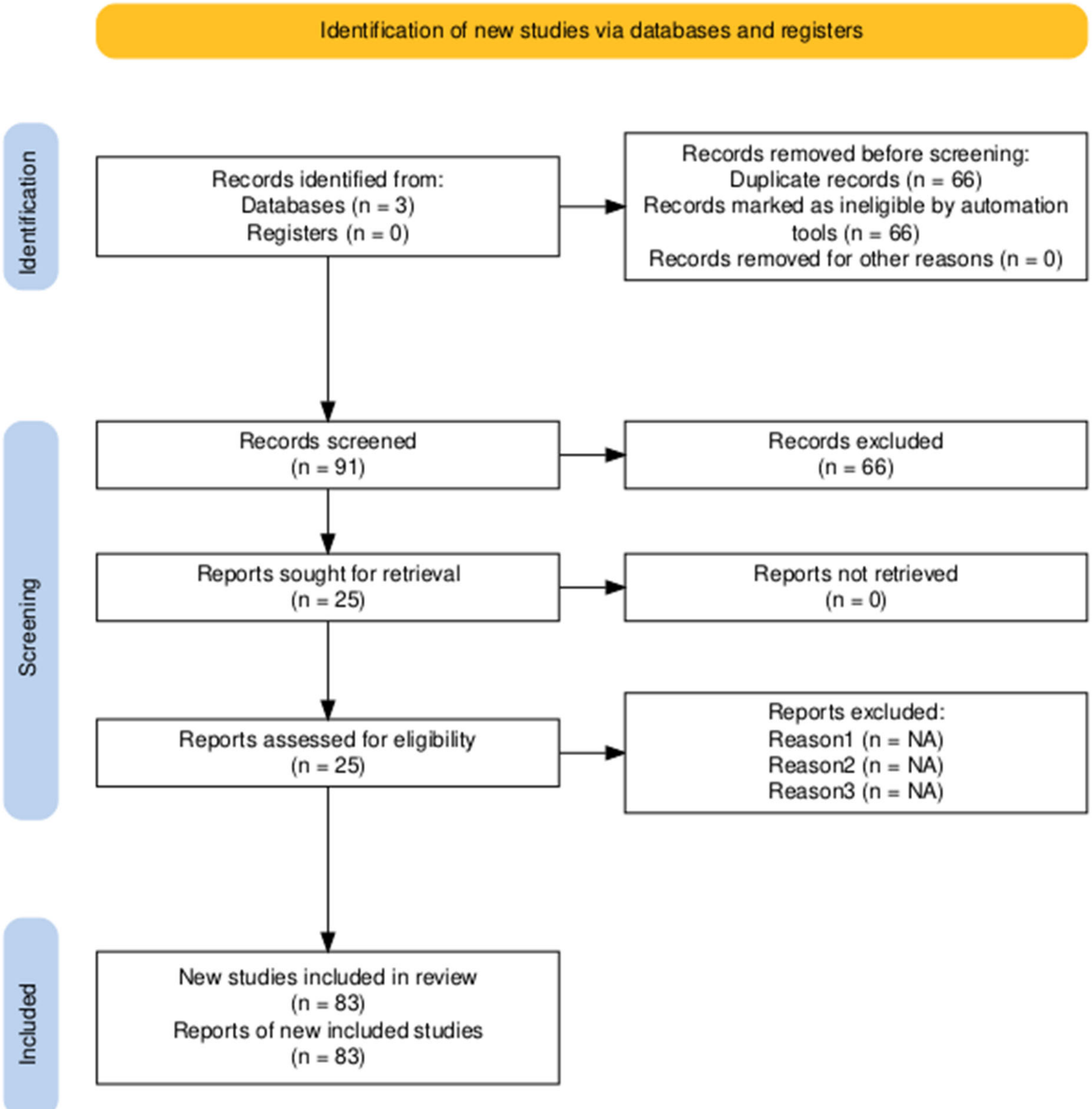

Figure 1: Prisma 2020 flow diagram

Result and Interpretation

Descriptive Overview of the Evidence Base

Publications by Year

The publications over the years reveal two phenomena: a period from 2007 to 2016 characterized by slow and exponential growth, and from 2017 onwards, considerable growth, peaking in 2023 in both volume and breadth.

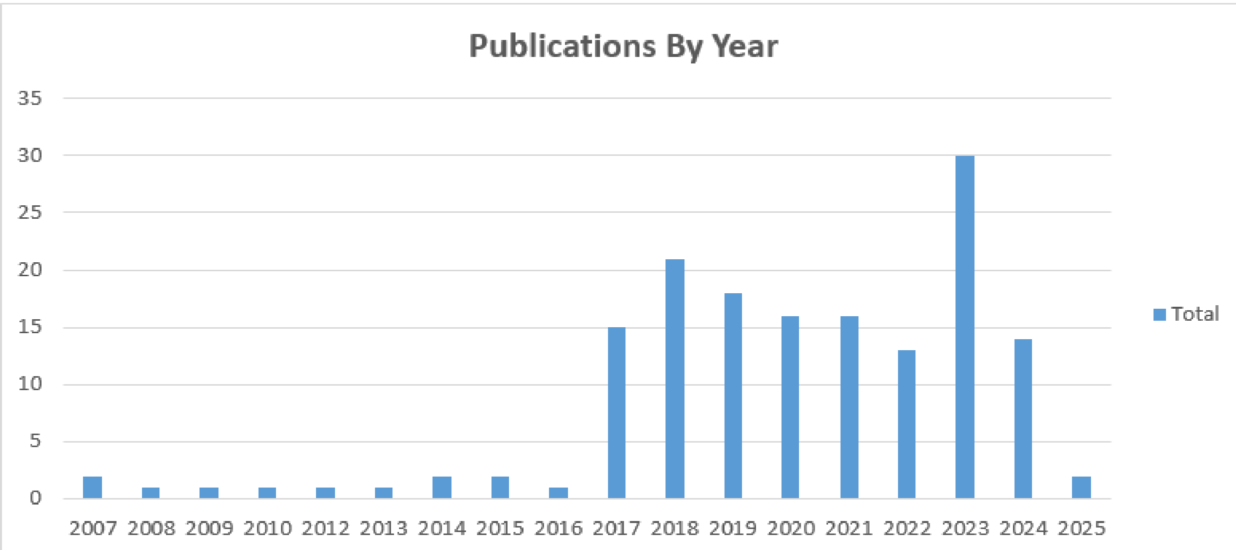

Figure 2: Trend of Publications over time

A total of 83 studies were included in the final synthesis. A significant upward trend in publication volume is observed from 2017 onwards, with 60% of the corpus ($n=50$) published between 2017 and 2025. This surge signifies a fundamental transition in the field's "frontier": moving away from conceptual frameworks toward implementation-focused, digitally integrated Lean Construction research.

Lean Outcomes Linked to Production Control Metrics

To reduce subjectivity bias, studies were further classified based on production control metrics commonly used in Lean Construction: Percent Plan Complete (PPC), Constraint removal rate, rework reduction, work-in-progress (WIP), throughput, and workflow reliability.

- Workflow reliability (PPC): comparatively widely reported in about n=18 studies, where the Last Planner System® (LPS®) is effectively used. PPC values ranged from 55% to 85%, with a median improvement of 15-20% due to lean adoption.
- Constraint removal: n= 11 studies have identified constraints during planning phases, which can substantially help PPC gains. In addition, a reported increase in performance, with a 20% to 45% reduction in unresolved constraints.

- Rework reduction: 14 studies show rework outcomes, especially when LPS® combines with BIM-based coordination, reporting decreases of 10% to 35%.
- Work-in-Progress (WIP): n= 9 studies have reported that lean logistics and JIT –enabled implementations have shown 15 to 30% WIP reduction, particularly in recurring building projects.
- Throughput and cycle time: 12 studies show that projects emphasizing work packaging and takt-informed planning achieve a 10-25% reduction in cycle time.

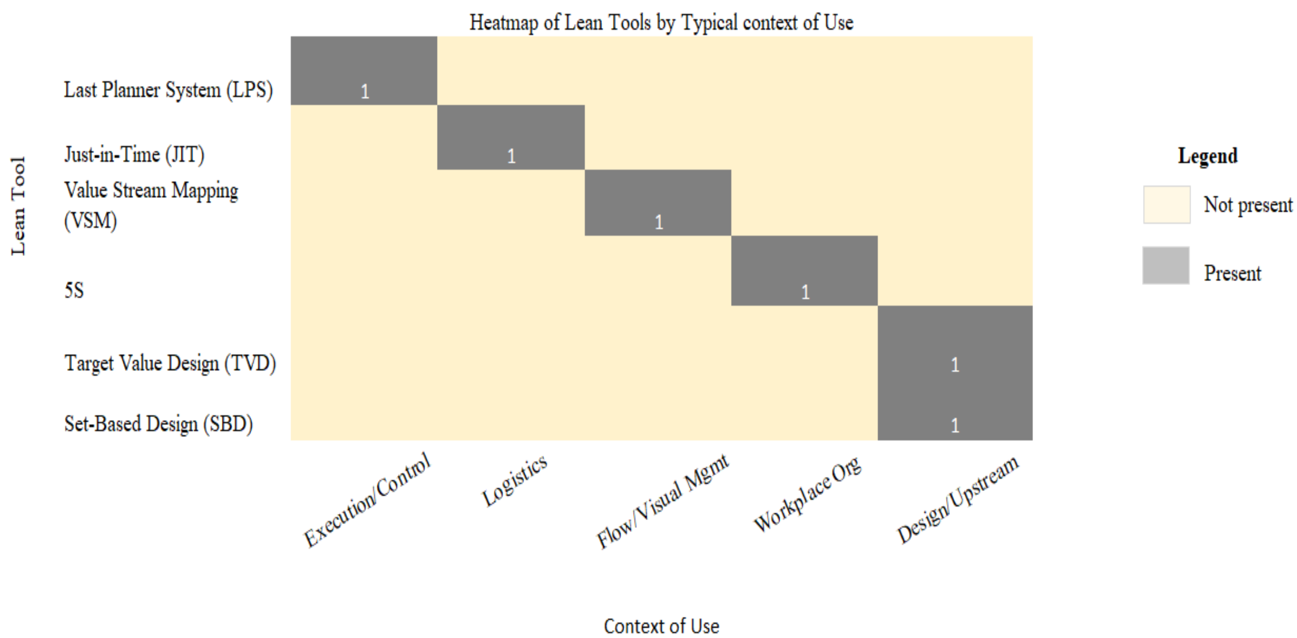

Figure 3: Heat map of Lean tools by typical context of use

Phase-Based Comparison: Design, Construction, and Procurement

Studies have shown a varied lean performance by project phase:

- Design phase (n=17): studies that focus on Target value design (TVD) AND Set-Based Design (SBD) reported an 8-15% increase in cost balance and earlier constraint reduction. However, production control metrics were less evident.
- Construction phase (n=48): the quantitative metrics shown are higher than in any other stage, with the median PPC improvement outcome showing 18% rework reduction and a schedule update of approximately 10% to 20%.
- Procurement and Logistics (n=18): lead-time has reduced between 12-30% when Lean-JIT and digital logistics were implemented. As a result, it has been evident that there has been a reduction in WIP and material storage waste.

Contextual Comparison: Public Vs. Private Projects

- Public – sector projects (n=26): a report shows that most public-sector projects are characterized by tight procurement processes and decentralized contract types, which result in 5 to 15% PPC gains, indicating further improvement.
- Private-Sector Projects (n=34): PPC improvements have drastically increased, exceeding 20%, and a constant rework reduction.
- Mixed or unspecified contexts (n=23): contain mixed results and applied a few standardized metrics.

Thematic Categorization of Lean Practices

The reviewed literature highlights the application of a limited number of LEA tools for implementation, as clearly shown in Table 2. The Last Planner system® (LPS®) is the tool used frequently, with an approximate adoption rate of 13-14% of the total sample or (n=11). This may indicate the focus towards site-level production control, workflow smoothness, and short-term planning.

Table 2: Frequency of Lean tools used in reviewed studies

Lean Tools	Frequency
5S	4
Just-in-Time (JIT)	4
Last Planner System (LPS)	26
Set-Based Design (SBD)	1
Target Value Design (TVD)	4
Value Stream Mapping (VSM)	2
Grand Total	**41**

Value Stream Mapping (VSM) and 5S are infrequently used in the reviewed literature, where their application is more common in support systems than in production processes. It further describes principles such as waste minimization and workplace coordination, which are known in theory but rare in practice.

Design-phase lean tools are applied modestly. Target Value Design (TVD) and Set-Based Design (SBD) appear 5(five) or fewer times. This indicates the imbalance in the empirical evidence presented about the importance of these tools, especially in the early stages of a project's life cycle.

Digital lean integrations, such as BIM-Digital Twin, IoT, or AI-enabled lean, account for only 10% or less in the reviewed literature. This clearly articulates that there is still a gap in data-driven lean approaches, and that the field is still in its infancy and needs further research.

In a nutshell, the reviewed literature identifies an inadequate scope of lean implementation, with the application of LPS® and construction-stage adoptions taking the primary role. I contrast the design level and digital-oriented lean tools, which still exhibit a slow adoption rate and fewer discoveries. These identified study gaps will serve as the foundation for future performance measurement studies within building projects.

Benefits and Challenges: A categorized view

Benefits

The application of lean principles in building projects has demonstrated tangible operational benefits, including cost savings, time reductions, and waste reduction. Cost savings are the primary results of site-level lean practices. Recent studies have shown that by facilitating workflow and minimizing rework through the Last Planner System® (LPS®), projects can benefit from reductions in variation-driven costs (Sepulveda et al. 2023). Studies have shown that applying lean principles has led to fewer schedule overruns, less rework, and more flexible procurement practices, thereby reducing deliberate orders and ultimately contributing to significant monetary savings on Projects (Gil Sebastian et al. 2025).

Time reduction is the most visible benefit on the ground. Various papers have suggested that integrating LPS®, work packaging, and integrated planning will improve the percentage of completed plans and the look-ahead schedule, resulting in shorter construction durations and fewer late finishes (Sepulveda et al. 2023). In addition, when lean principles are supported by logistics innovation (an updated version of Just-in-Time), it helps reduce lead time. It facilitates fast material transactions, which, in turn, support site activity and handover (Raza et al. 2021).

Waste minimization – a 2D recurring benefit in (material and process waste). Papers that apply Value Stream Mapping (VSM) and waste-reduction exercises have made considerable progress in minimizing material waste, reducing site idle time, and reducing non-priority activities (Tezel et al., 2022). In practice, simpler tools such as 5S help minimize small daily losses (e.g., tool search time, misplaced materials), which, in turn, contribute to meaningful waste reduction.

Challenges

Technical barriers: Several studies indicate that digital interoperability is a significant challenge. For instance, when teams try to practice LPS® using AR or location mechanisms, they often face data standardization problems that affect expected efficiency (Reinbold et al., 2019). In short, even though technology exists, incorporating it into everyday work routine remains a technical shortcoming.

Organizational barriers: these are the most common barriers and include a lack of awareness of lean principles, resistance to change, leadership willingness, and training gaps. Many studies show that when management support for training and development is weak, the likelihood of human error is highest (Haghsheno et al. 2020). Resistance to change is characterized as slow compliance to standards (to use the old way of doing things) (Dargham et al. 2019).

Policy and contractual barriers: many papers call for proper procurement procedures, organized contracting guidelines, and good incentives to prevent structural drawbacks.

Research on IPD across countries has indicated that without proper contractual forms and payment systems, lean initiatives could be at risk (Gomez et al. 2018). Additionally, limited procurement capacity also restricts the ability and willingness to develop entirely new delivery frameworks (Huaman-Orosco et al. 2022).

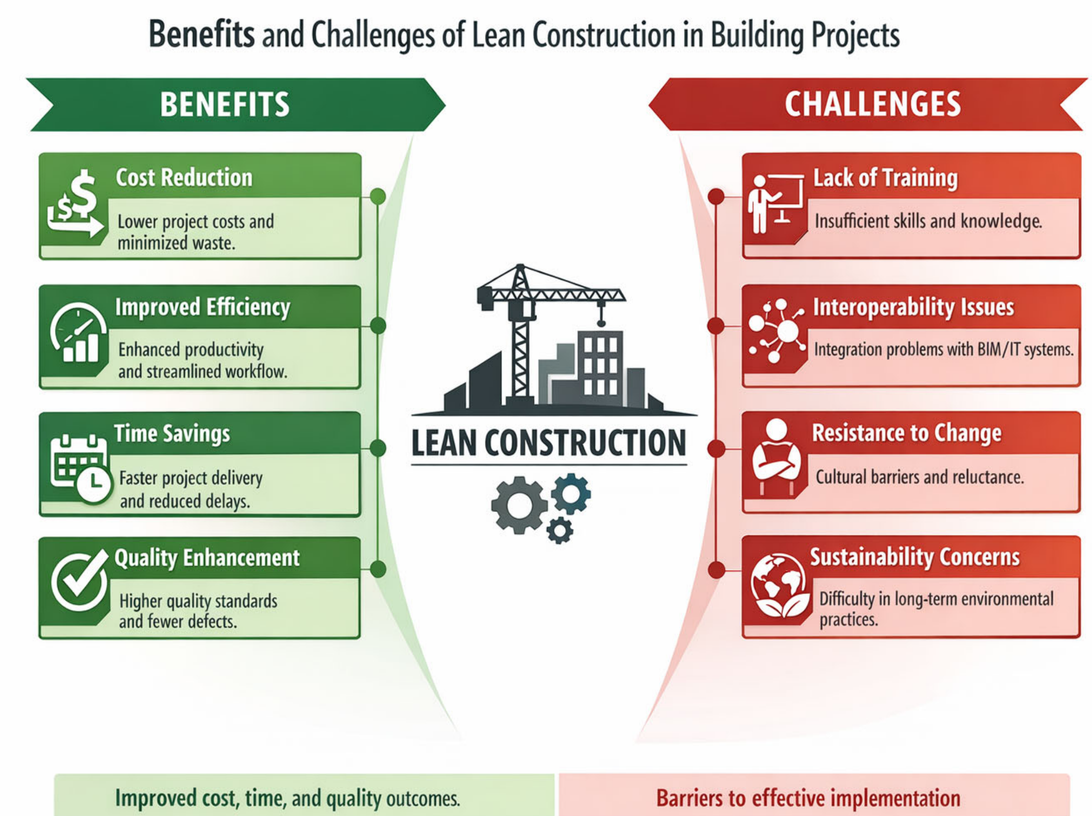

Figure 4: Key Benefits and Challenges associated with Lean Construction implementation in building projects

The logical connection between the benefits and barriers is straightforward: the process that creates savings and time gains (smooth workflow, adequate supply, and early design decisions) requires technical capacity, leadership commitment, and aligned payment provisions. Where projects are completed within reasonable cost and time constraints, it substantially indicates leadership capacity and willingness (Gil Sebastian et al. 2025). In contrast, if gains are absent or poor, it is primarily due to adoption resistance, inadequate training, or interoperability issues (Raza et al. 2024).

Conclusion

This review can direct immediate, practical implications for building project participants in two main ways. First, practitioners can facilitate the organized implementation of fundamental lean tools, such as the Last Planner System® (LPS®), as a basis for lean implementation in conjunction with basic production metrics, including Percent Plan Complete (PPC), constraint removal, and rework rates. The findings showed that accurate and consistent planning can bring in cost and time benefits through the adoption of digitally oriented lean processes.

Second, Companies should exercise lean efforts at early design stages by incorporating tools such as Target Value Design (TVD) and Set-Based Design (SBD). Where cost balance and value can be added before construction activity commences.

Future research should first address these gaps by employing a quantitative, longitudinal approach, mainly focusing on the design and planning stages, where lean's systematic priorities remain undiscovered. Scholars should also place greater emphasis on Lean-BIM-Digital frameworks, focusing on interoperability tools and empirical validation. Furthermore, studies should examine different project scenarios, both public and private, across countries and regions, to gain a broad understanding of diverse settings. Ultimately, future studies should incorporate digital technologies, sustainability innovations, and lean principles to address the existing gaps.

Beyond its academic contribution, this study aims to deliver practical improvements to site-level activities for practitioners. The evidence can be applied to a field-oriented playbook that integrates frequently used lean tools (such as LPS, JIT, VSM) into standard building project parameters. Case vignettes are another practical enhancement this study can offer, as the findings from the reviewed studies indicate that the application of lean principles has improved project outcomes. Additionally, a Validation checklist can be proposed to ensure project teams are ready to implement lean principles, tools, and processes, and to assess training capacity and leadership initiation.

References

Abdelhamid, T. S. (2004). The Self-Destruction and Renewal of Lean Construction Theory: A Prediction from Boyd's Theory. In Bertelsen, S., & Formoso, C. T. (Eds.), 12th Annual Conference of the International Group for Lean Construction.

Abdelhamid, Tariq & El-Gafy, M.A. & Salem, Ossama. (2008). Lean Construction: Fundamentals and principles. Am. Prof. Constructor. 32. 8-19.

Ballard, Glenn. (2000). The Last Planner System of Production Control.

Mossman, Alan. (2018). What Is Lean Construction: Another Look - 2018. 1240-1250. 10.24928/2018/0309.

Abdelhamid, Tariq & Copeland, Katherine. (2022). Lean Construction Journal Editors' Note: 2022 Issue. Lean Construction Journal. 2022. i-iv. 10.60164/g0e6c7e1h.

Dargham, S.A., Bou Hatoum, M. & Tohme, M. et al. (2019) 'Implementation of integrated project delivery in Lebanon: Overcoming the challenges', Proceedings of the IGLC, pp. 917–928. doi: 10.24928/2019/0242.

Gil Sebastián, J. J., & Soler Severino, M. J. (2025). Real estate owners' early thoughts on Lean IPD implementation in Spain. *Buildings, 15*(4), 626. https://doi.org/10.3390/buildings15040626

Gomez, S., Ballard, G. & Naderpajouh, N. et al. (2018) 'Integrated Project Delivery for infrastructure projects in Peru', Proceedings of the IGLC, 1, pp. 452–462. doi: 10.24928/2018/0506.

Howell, G. A. (1999). What is Lean Construction - 1999? https://iglcstorage.blob.core.windows.net/papers/attachment-616a489a-8e13-46a6-85b3-34eedd72ac8b.pdf

Haghsheno, S., Budau, M.R.D. & Russmann, E. (2020) 'Collaboration barometer – Development of a tool for measuring collaboration during design and construction', Proceedings of the IGLC, pp. 325–336. doi: 10.24928/2020/0073.

Huaman-Orosco, C., Erazo-Rondinel, A. A., & Herrera, R. F. (2022). Barriers to adopting Lean Construction in small and medium-sized enterprises — the case of Peru. *Buildings, 12*(10), 1637. https://doi.org/10.3390/buildings12101637

Hussain, S.M.A.M., Sekhar, T.S. and Fatima, A. (2014), "Analysis of Lean Construction by Using Last Planner System", International Journal of Engineering Research and Technology, ESRSA Publications, Vol. 3 No. 5.

Koskela, Lauri & Ballard, G. & Howell, Gregory & Tommelein, Iris. (2002). The foundations of Lean Construction. Design and Construction: Building in Value.

Raza, M. H., & Zhong, R. Y. (2024). Integration of additive manufacturing, lean, and green construction: A conceptual framework. *Procedia CIRP, 128*, 180–185. https://doi.org/10.1016/j.procir.2024.06.018

Reinbold, A., Seppänen, O. & Peltokorpi, A.V. et al. (2019) 'Integrating indoor positioning systems and BIM to improve situational awareness', Proceedings of the IGLC, pp. 1141–1150. doi: 10.24928/2019/0153.

Sepúlveda, I., Alarcón, L. F., & Barkokebas, B. (2023). Can advanced work packaging become a lean method? In *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)* (pp. 1475–1486). https://doi.org/10.24928/2023/0129

Tezel, A., Kifokeris, D., Formoso, C. T., Koskela, L., & Koch, C. (2022). A Conceptual Framework for Lean Construction and Blockchain Synergy. In *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)* (pp. 576–587). https://doi.org/10.24928/2022/0162

Zimina, Daria & Ballard, Glenn & Pasquire, Christine. (2012). Target value design: using collaboration and a lean approach to reduce construction cost. Construction Management and Economics. 30. 383-398. 10.1080/01446193.2012.676658.

APPENDIX A

This Appendix contains the quality appraisal list for studies included in the review process.

Title	Author	Year	Q1	Q2	Q3	Q4	Q5	Total	Rating
Lean construction: fundamentals and principles.	Abdelhamid, T., El-Gafy, M. and Salem, O	2008	1	1	1	1	1	5	High
Target value design: using collaboration and a lean approach to reduce construction cost	Zimina, D., Ballard, G. and Pasquire, C	2012	1	1	1	1	1	5	High
The Usefulness of Adopting the Last Planner System in the Construction Process of Addis Ababa Road Projects	Z.M., Limenih, Zenawi Mehari; B.A., Demiss, Belachew Asteray; A.T., Haile, Abenezer Tariku	2022	1	1	1	1	1	5	High
Lean Integrated Project Delivery for Construction Procurement: The Case of Sri Lanka	N., Hettiaarachchige, Nadeesha; A.P., Rathnasinghe, Akila Pramodh; K.A.T.O., Ranadewa, Kottahachchi Arachchige Tharusha Oshadee; N., Thurairajah, Niraj	2022	0.5	0.5	1	1	0	3	Moderate
Integrated Project Delivery for infrastructure projects in Peru	S., Gomez, Sulyn; G., Ballard, Glenn; N., Naderpajouh, Nader; S., Ruiz, Santiago	2018	1	1	1	0.5	0.5	4	High
BIM-based and AR application combined with location-based management system for the improvement of the construction performance	J., Ratajczak, Julia; M., Riedl, Michael; D.T., Matt, Dominik T.	2019	0.5	1	0.5	1	1	4	High
Optimized Integration of Lean Construction, Building Information Modeling, and Facilities Management in Developing Countries: A Case of Qatar	F., Musharavati, F.	2023	1	1	1	1	1	5	High

Lean Construction Practice on Toll Road Project Improvement: A Case Study in Developing Country	M.A., Berawi, Mohammed Ali; M., Sari, Mustika; P., Miraj, Perdana; Mardiansyah; G., Saroji, Gunawan; B., Susantono, Bambang	2023	0.5	1	0.5	1	1	4	High
Investigating the integration of design and construction from a “lean” perspective	B., J∅rgensen, Bo; S.B.A., Emmitt, Stephen B.A.	2009	1	0	1	0	1	3	Moderate
Real Estate Owners’ Early Thoughts on Lean IPD Implementation in Spain	J.J., Gil Sebastián, José Javier; M.J., Severino, Manuel J.Soler	2025	0.5	1	0	1	0.5	3	Moderate
Lean construction techniques and individual performance	S., Li, Shuquan; M., Fan, Meng; X., Wu, Xiuyu	2019	1	1	1	1	0.5	4.5	High
Phoenix's first net-zero energy office retrofit: A green and lean case study	A., Ladhad, Akash; K.D., Parrish, Kristen D.	2013	1	1	0.5	0.5	1	4	High
POTENTIAL OF GAMIFICATION FOR LEAN CONSTRUCTION TRAINING: AN EXPLORATORY STUDY	C., Pütz, Carla; G.J., Lühr, Gunnar Jürgen; M., Wenzel, Mona; M., Helmus, Manfred	2021	1	1	0.5	1	0	3.5	Moderate
Building Information Modelling, Integrated Project Delivery, and Lean Construction Maturity Attributes: A Delphi Study	S., Rashidian, Sara; R.M., Drogemuller, Robin M.; S., Omrani, Sara	2023	0.5	0.5	1	0.5	1	3.5	Moderate
Lean in the public sector in Finland; Lean en el sector público en Finlandia	P., Petäjäniemi, Pekka	2023	1	1	1	0.5	1	4.5	High
Improving construction management practice with the Last Planner System: A case study	A.O., AlSehaimi, Abdullah Owaimer; P.T., Fazenda, Patricia Tzortzopoulos; L.J., Koskela, Lauri Jaakko	2014	1	1	0.5	0.5	1	4	High
Benefits and challenges to applying IPD: experiences from a Norwegian mega-project	M.R., Rodrigues, Monique Rieger; S.M.M., Lindhard, Søren M. Munch	2023	1	1	0.5	0.5	1	4	High
A case study on the success factors of Target Value Design	P.A., Tillmann, Patrícia André; D., Do, Doanh; G., Ballard, Glenn	2017	1	1	1	0.5	0.5	4	High

A survey on production planning system in construction projects based on Last Planner System	H.D., Khanh, Ha Duy; S., Kim, Sooyong	2016	1	1	1	1	1	5	High
A SYSTEM DYNAMIC MODELLING APPROACH FOR INTEGRATED LEAN-BIM PLANNING AND CONTROL METHODS	M., Karaz, Mahmoud; J.M.C., Teixeira, José Manuel Cardoso	2023	1	1	1	1	0.5	4.5	High
Integrating indoor positioning systems and BIM to improve situational awareness	A., Reinbold, Ana; O., Seppänen, Olli; A.V., Peltokorpi, Antti Veikko; V., Singh, Vishal; E., Dror, Erez	2019	1	0.5	0.5	1	0.5	3.5	Moderate
Innovation in the New Zealand construction industry - Diffusion of the Last Planner System	R.J., Hunt, Richard J.; V.A., Gonzalez, Vicente A.	2018	1	1	1	1	1	5	High
REPEATABLE, SCALABLE, GLOBAL IMPLEMENTATION OF OPTIMIZED CYCLE TIME FLOW (OCF)	D.S., Gabai, Doron S.; N.S., Kennard, Nikita S.; R., Sacks, Rafael; M.K., Miera, Mark K.; T.D., Cloyd, Tabitha D.	2023	0.5	0.5	0.5	1	0.5	3	Moderate
Collaboration barometer - Development of a tool for measuring collaboration during design and construction	S., Haghsheno, Shervin; M.R.D., Budau, Maximilian Rolf Dieter; E., Russmann, Eduard	2020	1	1	1	1	0.5	4.5	High
RBL-PHP: Simulation of Lean Construction and Information Technologies for Prefabrication Housing Production	X., Li, Xiao; G.Q., Shen, Geoffrey Qiping; W., Peng, Wu; H., Fan, Hongqin; H., Wu, Hengqin; Y., Teng, Yue	2018	1	1	1	1	1	5	High
Success factors and barriers of last planner system implementation in the gaza strip construction industry	B.A., Tayeh, Bassam A.; K.A., Al-Hallaq, Khalid A.; A.H., Al Faqawi, Abdulla H.; W.S., Alaloul, Wesam Salah; S., Kim, Sooyong	2018	1	1	1	1	0.5	4.5	High
Integrating lean construction with BIM and sustainability: a comparative study of challenges, enablers, techniques, and benefits	S., Moradi, Sina; P., Sormunen, Piia	2023	1	1	1	1	1	5	High

Lean and BIM implementation in Colombia; interactions and lessons learned	J.M., Gómez-Sánchez, Juan Martín; J.L., Ponz-Tienda, José Luís; J.P., Romero-Cortés, Juan Pablo	2019	1	1	1	1	0.5	4.5	High
Enabling productivity goals through construction 4.0 skills: Theories, debates, definitions	S.D., Siriwardhana, Senuri Disara; R.C., Moehler, Robert Christian	2023	1	1	0	0.5	0.5	3	Moderate
DIGITAL SHOPFLOOR MANAGEMENT IN CONSTRUCTION - A CASE STUDY	D.P., Heller, Darius P.	2023	1	1	1	1	0.5	4.5	High
THE TOYOTA KATA METHODOLOGY FOR MANAGING THE MATURITY LEVEL OF LAST PLANNER® SYSTEM	F., Perez-Apaza, Fernando; A., Ramírez-Valenzuela, Andre; J.D., Perez-Apaza, Juan D.	2021	1	1	1	1	1	5	High
Implementation of lean practices among finishing contractors in the US	J.P., Smith, James P.; K., Ngo, Khoi	2017	1	1	1	1	1	5	High
The impact of construction labour productivity on the renovation wave	S., Wandahl, Søren; C.T., Pérez, Cristina Toca; S.T., Salling, Stephanie T.; H.H., Neve, Hasse Højgaard; J., Lerche, Jon; S., Petersen, Steffen	2021	1	1	1	0.5	0	3.5	Moderate
The impact of adopting lean construction in Egypt: Level of knowledge, application, and benefits	E.N., Shaqour, E. N.	2022	1	1	1	1	1	5	High
The Development of a BIM-Based Interoperable Toolkit for Efficient Renovation in Buildings: From BIM to Digital Twin	B., Daniotti, Bruno; G., Masera, Gabriele; C.M., Bolognesi, Cecilia Maria; S., Lupica Spagnolo, Sonia; A., Pavan, Alberto; G., Iannaccone, Giuliana; M., Signorini, Martina; S., Ciuffreda, Simone; C., Mirarchi, Claudio; M.N., Lucky, Meherun Nesa	2022	1	1	1	1	1	5	High
The role of BIM as a lean tool in design phase	R.M., Aziz, Rania Mohsen; T.I., Nasreldin, Tark Ibrahim; O.M.,	2024	1	1	1	1	1	5	High

	Hashem, Omnia Mamdouh								
Digital Horizons in Construction: A Comprehensive System for Excellence in Project Management	S., Santos Fonseca, Salazar; P.A., Benito, Patricia Aguilera; C., Piña Ramírez, Carolina	2024	1	0.5	1	1	1	4.5	High
Implementation of the Lean Construction Methodology in the Management of the Material Transportation Process- A Review	O., Iparraguirre-Villanueva, Orlando; B., Taico-Valverde, Bryan; L., Velezmoro-Abanto, Lesly; M.A., Cabanillas-Carbonell, Michael A.	2023	1	0.5	1	1	1	4.5	High
Lean and Sustainable Project Delivery in Building Construction: Development of a Conceptual Framework	S., Moradi, Sina; P., Sormunen, Piia	2022	1	1	1	0.5	1	4.5	High
Lean practices using building information modeling (Bim) and digital twinning for sustainable construction	S.M.E., M.e Sepasgozar, Samad M.E.; F.K., Peng Hui, Felix Kin; S., Shirowzhan, Sara; M., Foroozanfar, Mona; L., Yang, Liming; L., Aye, Lu	2021	1	1	1	0.5	1	4.5	High
LEVERAGING BIM AND MIXED REALITY TO ACTUALIZE LEAN CONSTRUCTION	A., Carbonari, Alessandro; M., Pirani, Massimiliano; A., Giretti, Alberto	2023	1	1	1	1	1	5	High
Lean construction principles and railway maintenance planning	D., Ivina, Daria; N.O., Olsson, Nils O.E.	2020	1	1	1	0.5	1	4.5	High
Cause Analysis of Hindering On-Site Lean Construction for Prefabricated Buildings and Corresponding Organizational Capability Evaluation	Z., Yuan, Zhenmin; Z., Zhang, Ziyao; G., Ni, Guodong; C., Chen, Chen; W., Wang, Wenshun; J., Hong, Jingke	2020	1	1	1	0.5	0.5	4	High
BIM critical factors and benefits for public sector: from a systematic review to an empirical fuzzy multicriteria approach	C.A., Diaz Schery, Carlos Alejandro; Y.R., Vignon, Yiselis Rodriguez; R.G.G., Caiado, Rodrigo Goyannes Gusmão; R.S., Santos, Renan S.; M., Congro, Marcello; E.T.L., Corseuil, Eduardo	2023	1	1	1	0		3	Moderate

	Thadeu Leite; D.M., Roehl, Deane Mesquita								
Lean construction practice: Culture, standardization and informatization -A case from China	L., Jiang, Lixuan; H., Zhong, Hua; J., Chen, Jianghong; Z., Su, Zhenmin; J., Zhang, Jinhua; X., Wang, Xiao	2019	1	1	1	1	1	5	High
Application of Selected Lean Manufacturing Tools to Improve Work Safety in the Construction Industry	T., Małysa, Tomasz; J., Furman, Joanna; S., Pawlak, Szymon; M., Šolc, Marek	2024	1	1	1	0.5	1	4.5	High
REDUCING CONSTRUCTION LOGISTICS COSTS AND EMBODIED CARBON WITH CCC AND KITTING: A CASE STUDY	F., Berroir, Fabrice; P., Guernaccini, Pierre; C., Boje, Calin; O., Maatar, Omar	2021	1	0.5	0.5	1		3	Moderate
Offsite construction: Developing a BIM-Based optimizer for assembly	A.Q., Gbadamosi, Abdul Quayyum; A.M., Mahamadu, Abdul Majeed; L.O., Oyedele, Lukumon O.; O.O., Akinade, Olugbenga O.; P., Manu, Patrick; L., Mahdjoubi, Lamine; A.O., Clinton, Aigbavboa Ohis	2019	1	0.5	0.5	1		3	Moderate
Ensuring Efficient Implementation of Lean Construction Projects Using Building Information Modeling	S.S., Uvarova, Svetlana S.; A.K., Orlov, Alexandr K.; V.S., Kankhva, Vadim S.	2023	1	1	1	1	1	5	High
LEAN DESIGN IN HYDRAULIC INFRASTRUCTURE - RIVER DEFENSES AND DIKES - A CASE STUDY FROM PERU	F., Chuquín, Frank; C., Chuquín, Cristhian; R., Saire, Romina	2021	1	1	1	0.5	0.5	4	High
Diffusion of lean construction in small to medium-sized enterprises of housing sector	M.(., Poshdar, Mani (Mani); V.A., Gonzalez, Vicente A.; R., Antunes, Ricardo; N., Ghodrati, Nariman; M., Katebi, Milad; S., Valasiuk, Sviataslau; H.E.,	2019	1	1	1	0.5	1	4.5	High

	Alqudah, Hamzah E.; S., Talebi, Saeed								
BIM and agent-based model integration for construction management optimization	F.L., Rossini, Francesco Livio; G., Novembri, Gabriele; A., Fioravanti, A.	2017	1	0.5	1	0.5	0.5	3.5	High
STATUS QUO OF DIGITALISATION IN THE SRI LANKAN CONSTRUCTION INDUSTRY	W.S.D., Perera, W. S.D.; K.A.T.O., Ranadewa, Kottahachchi Arachchige Tharusha Oshadee; A., Parameswaran, Agana; D., Weerasooriya, Dilan	2023	1	1	1			3	Moderate
EVALUATING THE USABILITY OF THE LEANBUILD SOFTWARE APPLICATION AFTER THE DESIGN STAGE	M.M., Musa, Muktari M.; E.I., Daniel, Emmanuel Itodo; N.S., Ahmed, Namadi S.; I.C., Enedah, Ifeatu C.	2023	1	1	1	1	0.5	4.5	High
Barriers to Adopting Lean Construction in Small and Medium-Sized Enterprises—The Case of Peru	C., Huaman-Orosco, Cristian; A.A., Erazo-Rondinel, Andrews A.; R.F., Herrera, Rodrigo F.	2022	1	1	1	1	0.5	4.5	High
An exploratory study on lean teaching adoption rate among academia and industry in Indian scenario	A., K. S, Anandh; K., Prasanna, K.; K., Gunasekaran, Kandaswamy; K.S., Aravinth, K. S.	2018	1	1	1			3	Moderate
Unveiling Effectiveness of Lean Construction Practices: A Comprehensive Study through Surveys and Case Studies	M., Aslam, Mughees; E., Baffoe-Twum, Edmund; M., Ahmed, Muhammad; A., Ulhaq, Aman	2024	1	0.5	0.5	0.5	1	3.5	Moderate
Optimizing security in architecture by design. Risk prevention in construction with a Lean perspective;	P., Flores Peluffo, Patricia; M.D., Martínez-Aires, María Dolores	2024	1	0.5	1	0.5	1	4	High
BIM and procurement data integration in industrialized construction using artificial intelligence	T.E., Pino Álvarez, Thomas E.; B., Barkokebas, Beda; A.J., Prieto, Andrés José; D.B., Bastos Costa, Dayana Bastos	2024	1	1	1			3	Moderate

Construction-Oriented Architectural Design in Off-Site Construction Towards Lean Construction and Management	J., Luo, Jianing	2022	1	1	1	1	1	5	High
A framework for understanding the dynamic nature of value in design and construction	S., Khalife, Salam; F., Hamzeh, Farook	2019	1	1	0.5	1		3.5	Moderate
Teaching choosing by advantages: Learnings & Challenges	G., Devkar, Ganesh; J.S., Trivedi, Jyoti Snehal; D., Pandit, Devanshu	2018	1	1	0.5	0.5		3	Moderate
An exploration of BIM and lean interaction in optimizing demolition projects	A., Elmaraghy, Ahmed; H.T., Voordijk, Hans T.; M.M., Marzouk, Mohamed M.	2018	1	1	0.5	0.5		3	Moderate
Integration of lean construction and building information modeling in a large client organization in Massachusetts	M., Bolpagni, Marzia; L., Burdi, Luciana; A.L.C., Ciribini, Angelo Luigi Camillo	2017	1	1	1	1	1	5	High
Managing concrete wastes by implementing contemporary construction practices in sri lanka	D.R., Senarathna, D. R.; B.L.S.H., Perera, Binendri L.S.H.	2021	1	1	0.5	1		3.5	Moderate
Barriers to implementing lean construction practices in the Kingdom of Saudi Arabia (KSA) construction industry	J.G., Sarhan, Jamil Ghazi; B., Xia, Bo; S., Fawzia, Sabrina; A.A., Karim, Azharul Azharul; A.O., Olanipekun, Ayokunle Olubunmi	2018	1	1	1	1		5	High
Statistical Analysis of Lean Construction Barriers to Optimize Its Implementation Using PLS-SEM and PCA	R., Romo, Rubén; A., Alejo-Reyes, Avelina; F., Orozco, F.	2024	1	1	1	0.5	1	4.5	High
Study on the construction workforce management based on lean construction in the context of COVID-19	L., Jiang, Lixuan; H., Zhong, Hua; J., Chen, Jianghong; J., Cheng, Jiajia; S., Chen, Shilong; Z., Gong, Zili; Z., Lun, Zhihui; J., Zhang, Jinhua; Z., Su, Zhenmin	2023	1	0.5	0.5	1		3	Moderate
Development of lean approaching sustainability tools (Last) matrix for achieving integrated lean	M., Aslam, Mughees; Z.J., Gao, Zhili Jerry; G.R., Smith, Gary R.	2021	1	0.5	0.5	1		3	Moderate

and sustainable construction									
Current Status and Future Research Trends of Construction Labor Productivity Monitoring: A Bibliometric Review	T.Y., Lee, Tsu Yian; F., Ahmad, Faridahanim; M.A.B., Sarijari, Mohd Adib Bin	2023	1	0.5	0.5	1		3	Moderate
MATURITY MODELS IN OFF-SITE CONSTRUCTION AND ANALYSIS OF LEAN INCORPORATION: REVIEW	J., Ortega, Jesús; A., Vásquez-Hernández, Alejandro; H.A., Mesa, Harrison A.; L.F., Alarcón, L. F.	2023	1	1	1			3	Moderate
Sensor adoption in the construction industry: Barriers, opportunities, and strategies	Z., Wang, Zhong; V.A., Gonzalez, Vicente A.; Q.G., Mei, Qipei Gavin; G., Lee, Gaang	2025	1	1	1			3	Moderate
Adoption of Lean Construction and AI/IoT Technologies in Iran's Public Construction Sector: A Mixed-Methods Approach Using Fuzzy Logic	M.N., Ugural, Mehmet Nurettin; S., Aghili, Seyedarash; H.I., Burgan, Halil Ibrahim	2024	1	1	1	1	1	5	High
Envisioning a Human Centric Approach to C4.0 Technologies	K., Noueihed, Karim; F., Hamzeh, Farook	2022	1	1	1			3	Moderate
A COGNITIVE REVIEW FOR IMPROVING THE COLLABORATION BETWEEN BIM AND LEAN EXPERTS	S., Davoudabadi, Soudabeh; B., Pedo, Barbara; A., Tezel, Algan; L.J., Koskela, Lauri Jaakko	2022	1	1	1	1	1	5	High
Barriers to adopting lean construction in the construction industry—the case of jordan	W., Al Balkhy, Wassim; R.J., Sweis, Rateb J.; Z., Lafhaj, Zoubeir	2021	1	1	1	1	1	5	High
Lean construction and sustainability through IGLC community: A critical systematic review of 25 years of experience	S., Sarhan, Saad; A., Elnokaly, Amira; C.L., Pasquire, Christine L.; S.E.C., Pretlove, Stephen E.C.	2018	1	0.5	1	1	1	4.5	High
Assessment of organizational culture in construction - A case study approach	S.M., Simon, S. Manna; K., Varghese, Koshy	2018	0.5	0.5	1	0.5	1	3.5	Moderate
Integration of additive manufacturing, lean and green construction: A conceptual framework	M.H., Raza, Muhammad Huzaifa; R.R., Zhong, Ray Runyang	2024	0.5	0.5	1	0.5	1	3.5	Moderate

Implementing Lean Construction: A Literature Study of Barriers, Enablers, and Implications	S., Moradi, Sina; P., Sormunen, Piia	2023	1	1	1	1	1	5	High
The barriers of the implementation of lean construction in Klang Valley, Malaysia	M.E.A., Ahmed, Mohammed Elhaj Alsoufi; W., Leong Sing, Wong	2020	1	1	0.5	0.5	1	4	High
When a business case is not enough, motivation to work with lean	R.M., Christensen, Randi M.; S., Greenhalgh, Stephen; A.O., Thomassen, Anja O.	2019	1	1	0.5	0.5		3	Moderate

Appendix B

This Appendix includes the classification in codes of the studies based on lean tools, project phase, outcome metrics, study design and context

Authors	Year	Lean Tools	Project Phase	Outcome Metrics	Study Design	Context
Abdelhamid et al.	2008	General Lean	General	Operational Efficiency	Theoretical	International
Zimina et al.	2012	TVD	Pre-construction	Cost	Conceptual	International
Limenih et al.	2022	LPS	Deign/ Planning	Cost, Time, Waste, Quality	Conceptual	Ethiopia
Hettiaarachchige et al.	2022	IPD	Design/ Planning	Productivity	Conceptual	Sri Lanka
Gomez et al.	2018	IPD	General	Operational Efficiency	Conceptual	Peru
Ratajczak et al.	2019	BIM	Construction	Cost, Time, Productivity	Conceptual	International
Musharavati et al.	2023	General	General	Productivity	Survey	International
Marut et al.	2023	General	General	Cost, Time, Waste, Product	Survey	International
Ballard et al.	2009	General Lean	Pre-construction	Operational Efficiency	Literature review	International
Gil Sebastian et al.	2025	LPS, IPD, TVD	Pre-construction	Cost, Time, Quality	Survey	Spain
Li et al.	2019	LPS	Construction	Time, Quality, Productivity	Survey	Dublin
Ladhad et al.	2013	LPS	Design/Planning	Cost, Time, Quality	Case Study	USA
Pütz et al.	2021	LPS,5S	Design/Planning	Operational Efficiency	Theoretical	Lima
Rashidan et al.	2023	BIM, IPD	Design/Planning	Productivity	Survey	Australia
Petäjäniemi, P.	2023	IPD	Design/Planning	Cost, Time	Empirical	Finland
AlSehaimi et al.	2014	LPS	Design/Planning	Time	Survey	Saudi Arabia
Rodrigues et al.	2023	BIM, IPD	Design/Planning	Cost	Empirical	Norway
Tilmann et al.	2017	IPD, TVD	Design/Planning	Cost	Case Study	Greece

Khanh et al.	2016	LPS	Design/Planning	Cost, Time, Productivity	Survey	Vietnam
Maillet et al.	2023	LPS, BIM	Design/Planning	Waste Reduction	Empirical	France
Reinbold et al.	2019	BIM	Design/Planning	Water, Quality, Productivity	Literature review	Finland
Hunt et al.	2018	LPS	Construction	Operational Performance	Literature review	New Zealand
Gabi et al.	2023	LPS	Design/Planning	Time	Literature review	International
Haghsheno et al.	2020	IPD	Design/Planning	Cost, Quality	Theoretical	Germany
Li et al.	2018	BIM	Design/Planning	Cost, Time, Quality, Product.	Survey	China
Tayeh et al.	2018	LPS	Construction	Time, Productivity	Survey	Gaza Strip
Moradi et al.	2023	BIM	Design/Planning	Cost, Quality, Product, Safety	Literature review	International
Gómez-Sánchez et al.	2019	BIM	Construction	Cost, Time, Waste, Product.	Literature review	Columbia
Sirwadhana et al.	2023	Lean Principles	Design/Planning	Time, Waste, Productivity.	Literature review	International
Heller, D. P.	2023	Lean Principles	Construction	Productivity	Case Study	International
Fauchier et al.	2021	LPS	Construction	Operational Performance	Case Study	France
Smith & Ngo	2017	LPS	General/Management	Cost, Time, Knowledge	Theoretical	USA
Wandahl et al.	2021	Lean Construction	Construction /Renovation	Productivity	Case Study	Denmark
Shaqour, E.	2022	Lean Construction	Design Phase	Cost, Time, Knowledge	Theoretical	Egypt
Daniotti et al.	2022	BIM, Digital Twin	Construction /Renovation	Time	Theoretical	Italy
Azizi et al.	2024	BIM	Design Phase	Cost, Time	Theoretical	Egypt
Fonseca et al.	2024	BIM	General/Management	Productivity	Survey	Spain
Iparaguirre et al.	2023	Lean Construction	Construction /Renovation	Productivity	Literature review	Peru

Moradi & Sormunen	2022	Lean Constructio n	General/Man agement	Project Performance	Literature review	Finland
Sepasgozar et al.	2021	BIM, Digital Twin	Design Phase	Project Performance	Literature review	Australia
Azhar et al.	2023	BIM	Design Phase	Project Performance	Theoretical	USA
Ivina & Olsson	2020	Lean Principles	Planning/ Maintenance	Project Performance	Theoretical	Railway/ Global
Yuan, Z. et al.	2020	Prefab/ Modular	Assemebly	Project Performance	Empirical	China
Diaz Schery et al.	2023	BIM	General	Project Performance	Literature review	International
Jiang, L. et al.	2019	Lean Principles	General	Org. Capability	Theoretical	China
Małysa, T. et al.	2024	Lean Principles	General	Work Safety	Theoretical	International
Berroir, F. et al.	2021	JIT/ Kitting	General	Carbon, Cost	Case study	International
Gbadamosi et al.	2019	BIM, Prefab	Assembly	Project Performance	Technical	International
Uvarova, S.S. et al.	2023	BIM	General	Process Efficiency	Theoretical	International
Chuquin, F. et al.	2021	Lean Principles	Design/Eng.	Project Performance	Case Study	Peru
Poshdar, M. et al.	2021	Lean Principles	General	Project Performance	Theoretical	International
Rossini et al.	2017	BIM, ABM	General	Process Optimization	Empirical	Italy
Perera et al.	2023	Lean Principles	General	Tech Adoption Rate	Empirical	Sri Lanka
Musa, M.M. et al.	2023	Lean Software	General	System Usability	Empirical	Nigeria
Huaman-Orosco et al.	2022	Lean Principles	General	Adoption Barriers	Empirical	Peru
Anandh, A.K.S. et al.	2018	Lean Principles	General	Teaching/ Adoption	Exploratory	India
Aslam, M. et al.	2024	Lean Principles	General	System Effectiveness	Survey	Pakistan
Flores Peluffo et al.	2024	Lean Principles	Design Phase	Security/ Risk	Empirical	Spain
Pino Álvarez et al.	2024	BIM, AI	Procurement	Process Efficiency	Empirical	Chile
Luo, J.	2022	Lean Principles	Design Phase	Design efficiency	Empirical	China

Khalife, S. et al.	2023	Lean Principles	General	Value Generation	Theoretical	International
Devkar et al.	2018	CBA	Education	Implementation Readiness	Theoretical	International
Elmaraghy et al.	2018	BIM	Deconstruction	Process Efficiency	Empirical	International
Bolpagni et al.	2017	Lean Principles	Management	Process Efficiency	Theoretical	USA
Senarathna et al.	2021	Lean Principles	Management	Waste management	Theoretical	Sri Lanka
Sarhan et al.	2018	Lean Principles	Management	Implementation Readiness	Theoretical	Saudi Arabia
Romo et al.	2024	Lean Principles	Management	Implementation Readiness	Survey	International
Jiang, L. et al.	2023	Lean Principles	Execution	Process Efficiency	Empirical	International
Lee, T.Y. et al.	2023	Lean Principles	Execution	Labor Productivity	Literature review	International
Ortega, J. et al.	2021	Modular/Off-site	Organizational	Process Efficiency	Theoretical	International
Wang et al.	2025	IoT/Sensors	Strategic Planning	Implementation Barriers	Theoretical	international
Ugural et al.	2024	IoT/Sensors, AI	Public Sector	Tech Readiness	Mixed-Methods	Iran
Noueihed & Hamzeh	2022	Lean Principles	Human Factors	Tech Readiness	Theoretical	International
Davoudabadi et al.	2022	BIM	Human Factors	Team Synergy	Systematic Review	International
Al Balkhy et al.	2021	Lean Principles	Strategic Planning	Implementation Barriers	Theoretical	Jordan
Sarhan, S. et al.	2018	Lean Principles	Strategic Planning	Sustainability	Systematic Review	International
Simon, S.M. et al.	2018	Lean Principles	Organizational	org. Culture	Case Study	International
Raza, M.H. et al.	2024	3D Printing/AM	Strategic Planning	Sustainability	Theoretical	International
Moradi & Sormunen	2023	Lean Principles	Strategic Planning	Implementation Barriers	Systematic Review	International
Christensen et al.	2019	BIM	Lean Planning	Cost	Mixed-Methods	International
Ahmed et al.	2020	LPS	Construction	Time	Conceptual	Sweden
Aslam, M. et al.	2021	TVD	Planning	Process Efficiency	Case Study	International