

Critical Factors in the Implementation of Lean Construction: A Literature Review 2015–2025

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Abstract

The adoption of Lean Construction has become established as an effective strategy for improving efficiency and reducing waste in construction projects; however, its implementation faces numerous challenges. The objective of this study is to analyze, through a systematic literature review, the critical factors that influence the implementation of Lean Construction, based on the analysis of 52 articles published between 2015 and 2025. The search was conducted in the Scopus database, and the selection of studies followed the PRISMA methodology. The results are organized into six key aspects that influence the execution of construction projects, grouped into three main categories: human, which includes managerial (42.3%) and educational (21.2%) factors; technical, which encompasses technological (23.1%) and safety (5.8%) factors; and management-related factors, comprised of financial (1.9%) and logistical (5.8%) factors. The evidence shows a greater relevance of human-related factors, followed by associated technical factors and, to a lesser extent, management-related factors. Taken together, these results highlight the need to address these factors through integrated strategies, training programs, and committed leadership to achieve a successful and sustainable implementation of Lean Construction.

Keywords: Lean Construction; critical factors; construction project management; emerging technologies

1. Introduction

The construction sector is experiencing constant growth. According to the Global Status Report for Buildings and Construction 2024/2025 [1], between 2022 and 2023 alone, the area of constructed space worldwide increased by an estimated five billion square meters, representing a 2% increase over the total built area, exceeding 260 billion square meters. However, despite this growth, only between 20% and 30% of construction activities are productive, highlighting inefficiencies in construction processes, primarily caused by the over-allocation of personnel or unnecessary tasks. This situation underscores the urgent need to find more efficient construction methods that minimize waste, cost overruns, and delays, while maximizing productivity.

In this context, Koskela [2] proposes a shift in approach to construction project management through the application of Lean Construction philosophy, which focuses on process optimization and delivering greater value to the customer. However, this methodology has evolved over time, and its implementation has been hampered by various factors. These factors have become critical, as they determine the success or failure of its adoption.



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Therefore, it is essential to study, update, and consolidate existing knowledge through a thorough analysis of academic sources and scientific literature.

Over the past few years, several studies have focused on investigating the critical factors affecting the implementation of Lean Construction in the construction industry. For example, recent studies highlight that the involvement and leadership of senior management, the limited cooperation between academia and industry, and adequate education on this methodology are key factors in overcoming the barriers to the successful adoption of Lean Construction [3–5]. Furthermore, conceptual models, such as the transformation-flow-value creation model, are recognized as helpful in optimizing costs, time, and quality in projects [2]. On the other hand, the prevailing methodologies for analyzing these factors include statistical studies, surveys of industry professionals, and bibliographic analysis, which allow for the identification and prioritization of barriers and facilitators to implementation [6,7]. Furthermore, a trend toward technological integration has been observed in recent years, with Building Information Modelling (BIM) being a key and outstanding tool that facilitates decision-making by considering data generated in real time [8,9].

The literature review and analysis reveal factors that are explicitly presented, as well as others that are implicitly mentioned by researchers, which can be grouped into three categories: human, technical, and management-related factors. Among these, the human factor stands out, emerging as one of the most recurrent elements in the literature related to the critical factors influencing the implementation of Lean Construction. This factor was statistically identified in 34% of the reviewed cases, exceeding the frequency of the other four factors present in the analyzed studies. This finding suggests that subcategories associated with the human factor, such as collaboration, resistance to change, cultural perspective, communication deficiencies, and internal conflicts among the people involved in construction projects, play a determining role in the success or failure of implementing this methodology.

However, significant knowledge gaps persist. While some studies address barriers through a technology-oriented approach, others focus on limitations through a human-centered approach [10,11]. Methodological limitations associated with studying unexplored populations, resulting from geographical restrictions, are also identified. For example, the studies by Viana et al. [12] and Zhang et al. [13] focus exclusively on specific regions, limiting the generalizability of their findings to other geographical contexts. Temporally, there is a notable scarcity of recent studies that systematically review or integrate the accumulated findings in the literature on critical factors. New research needs are also emerging, linked to the rapid changes in digital technologies. These gaps justify the need for a systematic review to update existing knowledge and provide a holistic understanding.

Therefore, the overall objective of this research is to analyze the literature published between 2015 and 2025 on the critical factors in the implementation of Lean Construction. The specific objectives are: (a) analyze the effect of the human factor on the implementation of Lean Construction; (b) analyze the effect of the technical factor on the implementation of Lean Construction; and (c) analyze the effect of the management-related factors on the implementation of Lean Construction.

The scope of the review considers studies published in the Scopus-indexed database, which, under the framework of the PRISMA 2020 methodology and its methodological rigor, were selected using inclusion and exclusion criteria defined to ensure the quality, relevance and currency of the information analyzed.

This study expands the existing knowledge on critical factors in Lean Construction implementation in three key ways. First, it provides an updated synthesis of the literature covering the period 2015–2025, capturing recent developments related to digital construction, BIM adoption, and the integration of Lean technology. Second, this review

proposes a refined and theoretically grounded taxonomy that consolidates critical factors into three coherent categories: human, technical, and management-related factors, thereby improving conceptual clarity and analytical consistency throughout the manuscript. Third, beyond a descriptive aggregation of factors, the study offers an integrated evidence map that combines geographic distribution, methodological trends, keyword co-occurrence analysis, and an examination of the interrelationships among factor categories, contributing to a more explanatory and systems-level understanding of the challenges of Lean Construction implementation.

2. Materials and Methods

This study was conducted following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol guidelines to ensure a transparent and rigorous methodology in the search, analysis, and selection of included studies. The process consisted of three phases: identification, screening and final inclusion.

In the identification phase, the Scopus database was consulted, selected for its academic relevance and breadth in topics related to Lean Construction and construction projects. The literature search was performed using the following Boolean equation:

“Lean Construction” OR “Lean building” OR “Waste-Free Construction” OR “Efficient Construction” OR “Value-Driven Construction”) AND (“construction projects” OR “project management”) AND (“waste reduction” OR “process improvement” OR “productivity” OR “resistance” OR “barriers” OR “skills” OR “Implementation” OR “Technology” OR “innovation” OR “transformation”).

The keywords were combined using the logical operators “AND” and “OR” to maximize coverage and ensure consistency with the study’s objective. Subsequently, automatic filters were applied based on the year the research was published (2015–2025), document type (peer-reviewed scientific articles), full-text availability (open access), and language (English or Spanish). Articles that could be duplicated were checked; at this stage, no duplicate articles were found since we are working with a single Scopus database. This resulted in an initial database of highly relevant articles.

In the screening phase of the first stage, a screening process was conducted using titles and abstracts, eliminating records not strictly related to construction projects. For the second stage, the full text of the articles was analyzed to confirm their relevance, excluding those that did not address critical factors for implementing Lean Construction or whose approach was purely theoretical without practical application.

Finally, in the inclusion phase, studies that fully met the relevance and quality criteria defined at the beginning of the study were selected. Table 1 summarizes the guidelines used for the inclusion and exclusion of the analyzed sources.

Table 1. Inclusion and Exclusion Criteria.

Type	Criterion	Code	Inclusion	Exclusion
Search filters	Year of publication	FB-01	Articles published between 2015 and 2025	Articles published before 2015 and after 2025
	Document type	FB-02	Peer-reviewed scientific articles	Theses, reviews, work sessions, conference proceedings, editorial notes.
	Document access	FB-03	Documents available for full text access	Documents without full text access
	Idioma	FB-04	Publications in Spanish or English	Publications in languages other than Spanish or English

Table 1. Cont.

Type	Criterion	Code	Inclusion	Exclusion
Thematic Relevance: Eligibility	Thematic area	RT-01	Studies related to construction projects	Studies unrelated to construction projects, different projects
	Critical Factors in Construction Projects	RT-02	Studies that are strictly related to critical factors	Studies that are not related to critical factors
	Practical approach	RT-03	Studies that specify the application of Lean Construction	Studies other than the applicability of Lean Construction

The study selection process, aligned with the PRISMA 2020 framework, is summarized in the PRISMA 2020 flow diagram (Figure 1), which describes the identification, selection, and final inclusion of studies. The review protocol was not registered in PROSPERO or any other review registry. The PRISMA 2020 checklist is provided as Supplementary Materials.

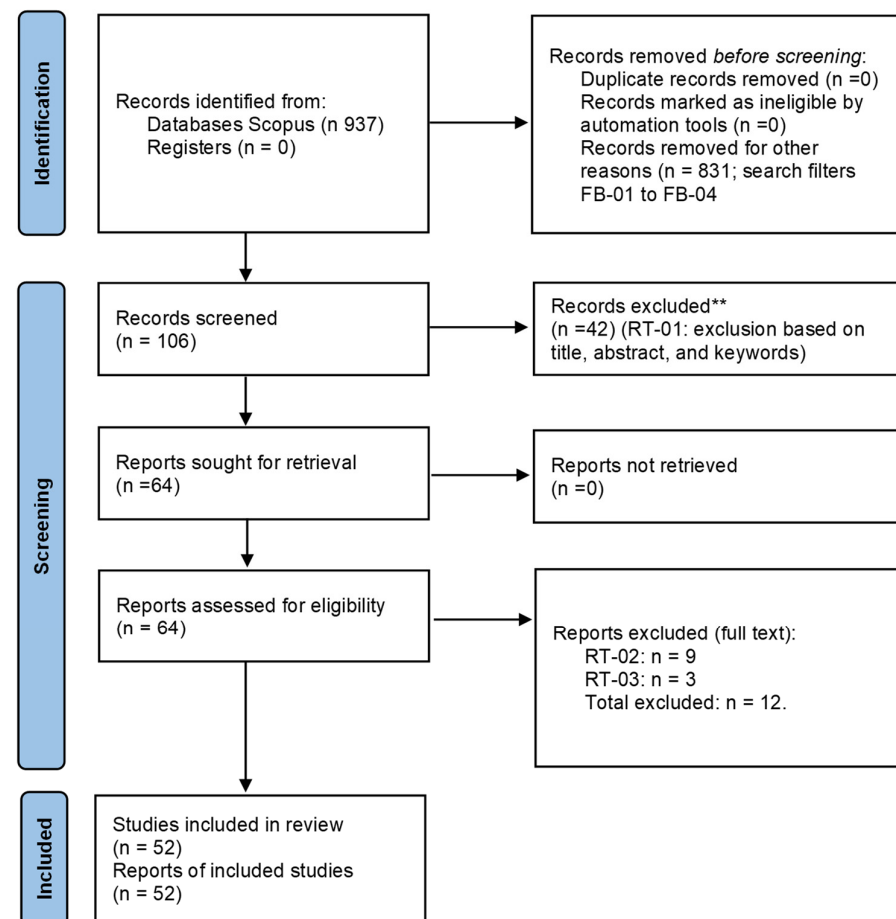


Figure 1. PRISMA Diagram.

During the identification phase, a systematic search of the Scopus database was conducted, resulting in the identification of 937 records. No additional records were retrieved from the study registries. Prior to selection, 831 records were removed using predefined search filters, and no duplicate records were identified.

In the selection phase, the remaining 106 records were selected based on their titles, abstracts, and keywords. As a result, 42 records were excluded for not meeting the established inclusion criteria. During the eligibility assessment, 64 full-text reports were retrieved, and

their eligibility was assessed. All reports were successfully accessed. Following the full-text assessment, 12 reports were excluded due to methodological or thematic incompatibility with the scope of the review.

Finally, 52 studies met all the inclusion criteria and were included in the systematic review. Each included study was represented by a single report; thus, the number of included studies and reports was identical ($n = 52$).

Within the framework of the analysis of the reviewed articles, critical factors were identified, establishing categories and subcategories to systematize the approaches discussed in relation to the research objective. The structuring process was developed inductively, based on the findings reported in the analyzed articles, and relied on classification approaches widely adopted in the construction management literature. In this context, the identified factors were grouped into three general categories: human, technical, and management-related factors, based on shared functional roles and conceptual affinity. This hierarchical organization allows for capturing the key dimensions that influence the implementation of Lean Construction and is consistent with the classification frameworks commonly used to structure complex and multidimensional phenomena in construction management research (Table 2).

Table 2. Categorization and subcategorization of factors of the selected articles.

Category	Description	Subcategory	Description
Human	Refers to the key role people play in the success or failure of the approach	Managerial	Performance of senior management and middle management in planning, leadership, decision-making and strategic alignment.
		Education	Lack of knowledge, skills, training and understanding of the staff.
Technical	Deals with knowledge, tools, processes, methodologies, and technological systems.	Technology	Obstacles related to the adoption, use, access or integration of technologies.
		Security	Weak security management, lack of a preventative culture, ineffective supervision, and poor risk control
Management-Related Factors	Consists of the efficient management of the economic and material resources necessary to sustain the project's execution	Financial	Budgetary constraints, low bids, and inefficiencies in cost control.
		Logistics	Lack of integration and coordination with suppliers and project stakeholders.

3. Results

Table 3 shows the distribution of scientific output by continent and country. The Americas account for 17% of total publications, with the United States as the main contributor (3 articles, 6%), followed by Peru (4%) and Colombia, Mexico, Chile, and Brazil, each with 2%. In Asia, the percentage rises to 35%, including contributions from Vietnam (2%), Indonesia (4%), India (3%), Pakistan (2%), China (8%), Jordan (2%), Palestine (2%), and Malaysia (6%). Europe is the second continent with the largest share, reaching 16%, represented by Spain (2%), Italy (4%), Finland (6%), Turkey (4%), Denmark (4%), Poland (2%), Russia (2%), and the United Kingdom (8%). Africa shows a 12% share, with contributions

from Egypt (6%), Uganda (2%), South Africa (2%), and Ethiopia (2%). Finally, publications were also recorded in Oceania, specifically in New Zealand (2%) and Australia (4%).

Table 3. Geographical distribution of research on lean construction critical factors.

Continent	Country	Total Continent	% Continent	Total Country	% Country
America	Colombia	9	17%	1	2%
	Mexico			1	2%
	Chili			1	2%
	Peru			2	4%
	USA			3	6%
	Brazil			1	2%
Asia	Vietnam	18	35%	1	2%
	Indonesia			4	8%
	India			3	6%
	Pakistan			1	2%
	China			4	8%
	Jordan			1	2%
	Palestine			1	2%
	Malaysia			3	6%
Europa	Spain	16	31%	1	2%
	Italy			2	4%
	Finland			3	6%
	Türkiye			2	4%
	Denmark			2	4%
	Poland			1	2%
	Russia			1	2%
	United Kingdom			4	8%
África	Egypt	6	12%	3	6%
	Uganda			1	2%
	South Africa			1	2%
	Ethiopia			1	2%
Oceania	New Zealand	3	6%	1	2%
	Australia			2	4%
Total		52	100%	52	100%

Table 4 presents the methodological approaches adopted by the researchers in the development of their studies. The qualitative approach represents 40.38%, followed by the quantitative approach with 30.77% and the mixed approach with 28.85%.

Table 4. Scientific production according to methodological approach.

Approach	Articles	%
Qualitative	21	40.38%
Quantitative	16	30.77%
Mixed	15	28.85%
Total	52	100.00%

Figure 2 shows the keyword co-occurrence network with a minimum of three occurrences in the selected articles. Four clusters can be seen: the green cluster, formed by the

words Lean Construction, lean production, construction, implementation, and success factors; the blue cluster, with the words project management, construction industry, lean tools, construction waste, and project performance; the red cluster, with the words construction management, construction projects, integrated project delivery, efficiency, barriers, and construction companies; and finally, the yellow cluster, with architectural design, BIM, information management, building information modeling, and sustainable development.

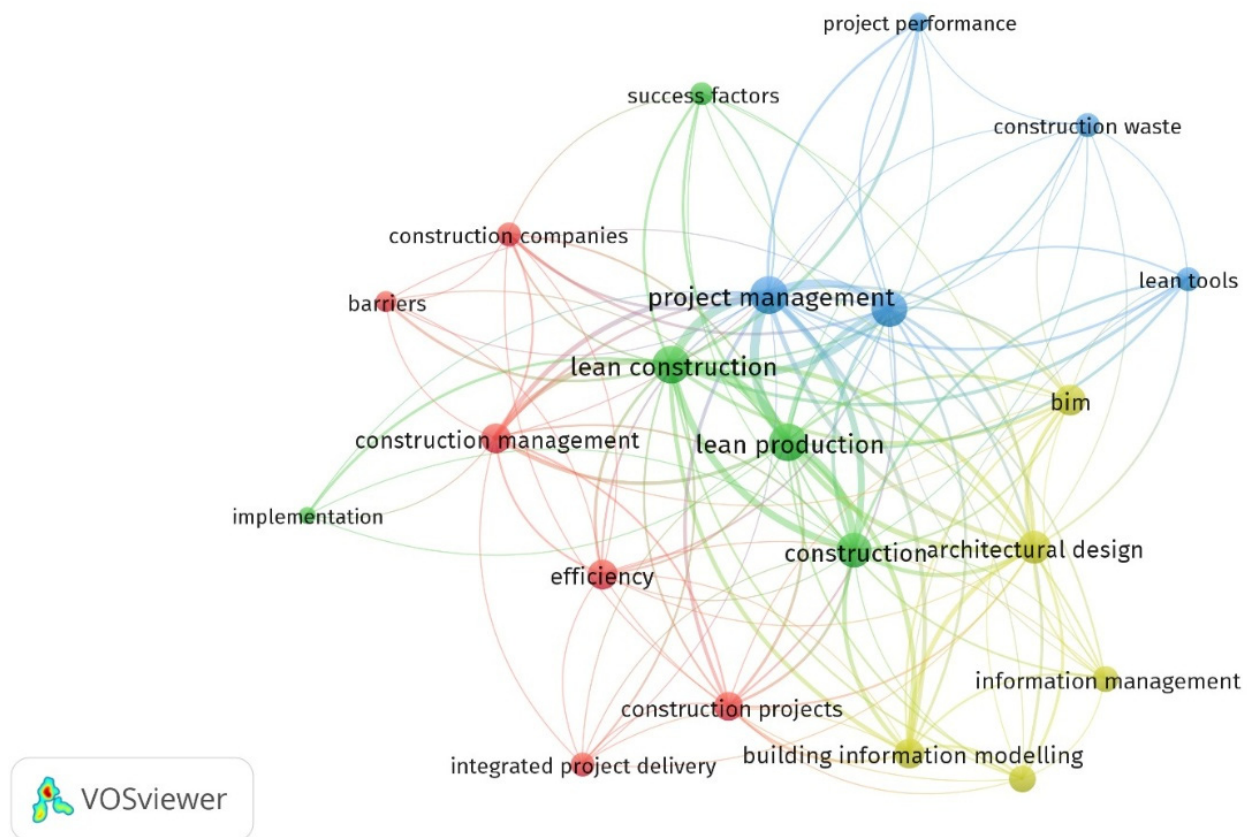


Figure 2. Visualization of the co-occurrence network by keywords (minimum 3 words).

Table 5 shows the percentage of incidence frequency of critical factors in the implementation of lean construction, grouped into categories and subcategories. Within the human category are the subcategories: managerial (22 articles; 42.3%) and education (11 articles; 21.2%). In the technical category, the subcategories are technology (12 articles; 23.1%) and safety (3 articles; 5.8%). In the management-related factors category, the subcategories are financial (1 article; 1.9%) and logistics (3 articles; 5.8%).

Table 5. Critical factor by category and subcategory according to the 52 selected articles.

Category	Subcategory	Articles	%
Human	Managerial	22	42.3%
	Education	11	21.2%
Technical	Technology	12	23.1%
	Safety	3	5.8%
Management-Related Factors	Financial	1	1.9%
	Logistics	3	5.8%
Total		52	100.0%

Table 6 presents the studies that constitute the eligible sample of the systematic review conducted, selected in accordance with the predefined inclusion criteria. The studies are organized by author, country, study objective, category, and subcategory, enabling a structured analysis of the available scientific evidence.

Table 6. Overview of Critical Factors by Category and Subcategory in the Eligible Sample.

Author	Country	Study Objective	Category	Subcategory
Al Balkhy et al. (2021) [3]	Jordan	Identify barriers to adopting Lean Construction practices using a case study from the Kingdom of Jordan.	Human	Managerial
Huaman-Orosco et al. (2022) [4]	Peru	Identify barriers to the implementation of the Lean philosophy in SMEs in Peru and analyze the relationships and correlations among factors influencing its adoption.	Human	Managerial
Marhani et al. (2021) [5]	Malaysia	Identify problems and evaluate the impact of Lean Construction (LC) implementation to propose improvements for its application in the MCI.	Human	Managerial
Meshref et al. (2022) [6]	Egypt	Identify and evaluate critical drivers for the sustainable implementation of Lean Construction oriented toward customer value.	Human	Managerial
Romo et al. (2024) [7]	Mexico	Identify and analyze the main obstacles to Lean Construction implementation, with emphasis on leadership, organizational culture, communication, training, and resources.	Human	Managerial
Pérez et al. (2024) [8]	Colombia	Analyze the influence of Lean tools and BIM uses on mitigating delay factors in residential projects.	Technical	Technology
Moradi y Sormunen (2024) [9]	Finland	Explore and compare challenges, facilitators, techniques, and benefits of integrating Lean Construction with BIM and sustainability in building construction projects.	Technical	Technology
Ismail et al. (2023) [10]	Malaysia	Explore the collaborative Lean–BIM approach to enhance sustainability in construction projects, identifying impacts and key capabilities of this integration.	Technical	Technology
Mehta et al. (2022) [11]	United States	Analyze efficient construction project management through the identification of inefficiency factors, perception gaps among occupations, and their interrelationships.	Human	Education
Viana et al. (2017) [12]	Brazil	Demonstrate the need to adopt an integrated conceptualization of product- and process-oriented modularity in industrialized building systems.	Technical	Technology
Zhang et al. (2017) [13]	China	Identify critical factors of workflow reliability and explore interrelationships among them.	Human	Managerial

Table 6. Cont.

Author	Country	Study Objective	Category	Subcategory
Aslam et al. (2024) [14]	Pakistan	Evaluate the effectiveness of Lean Construction practices in construction projects, identifying barriers and benefits in their implementation.	Human	Managerial
Kirby et al. (2025) [15]	New Zealand	Evaluate productivity in residential construction and quality management, with an emphasis on Lean Construction and ISO 9000.	Human	Managerial
Pham and Pham (2024) [16]	Vietnam	Evaluate the implementation of Lean Construction (LC) in the marble flooring finishing process to reduce waste through computational simulation.	Technical	Technology
Piras et al. (2024) [17]	Italy	Analyze a digital management methodology integrating DT, BIM, IoT, and AI to optimize construction production and address organizational and technological challenges.	Technical	Technology
Aziz et al. (2024) [18]	Egypt	Analyze Lean–BIM integration in the design phase to reduce waste and improve coordination and efficiency.	Human	Managerial
Santos Fonseca et al. (2024) [19]	Spain	Evaluate the implementation of an integrated Lean–BIM project management system to address organizational and technological challenges in construction.	Human	Managerial
Govindasamy and Bekker (2024) [20]	South Africa	Evaluate the impact of the Last Planner System (LPS) on planning reliability and performance in mining infrastructure projects, identifying critical success factors and implementation challenges.	Human	Managerial
Lindhard and Wandahl (2015) [21]	Denmark	Identify practices that hinder proper implementation of the Last Planner System.	Human	Education
Bohnstedt and Wandahl (2019) [22]	Denmark	Create knowledge that contributes to more effective and efficient collaboration among parties involved in a typical construction project.	Human	Managerial
Berawi et al. (2023) [23]	Indonesia	Implement Lean Construction in a highway project to identify non-value-added activities and assess impacts on time and cost.	Human	Managerial
Rashidian et al. (2024) [24]	Australia	Develop an integrated maturity model (BIL MM) to assess the combined implementation of BIM, IPD, and LC in construction organizations, identifying maturity levels and key attributes for continuous improvement.	Human	Managerial
Thaloor Ramesh and Nattanmai Swaminathan (2024) [25]	India	Analyze the synergistic integration of Lean Construction practices, sustainable construction, and alliance contracts to improve operational performance in construction projects.	Human	Managerial

Table 6. *Cont.*

Author	Country	Study Objective	Category	Subcategory
Bigwanto et al. (2024) [26]	Indonesia	Develop SMART-based KPIs to assess the effectiveness of Lean Construction implementation in government projects, focusing on waste reduction and productivity.	Human	Managerial
Aguome et al. (2024) [27]	Uganda	Evaluate the effectiveness of Lean Construction practices in improving construction project delivery in a rural context, identifying benefits, tools used, and implementation challenges.	Human	Managerial
Garcés y Peña-Ramírez (2023) [28]	Chile	Analyze the creation of effective production systems that optimize, reduce, or eliminate flows to improve delivery times.	Human	Managerial
Shaqour (2022) [29]	Egypt	Analyze the causes of construction waste and its control through Lean tools.	Human	Managerial
Limenih et al. (2021) [30]	Ethiopia	Analyze road project management in Addis Ababa and propose a framework for implementing the Last Planner System.	Human	Managerial
Velezmoro-Abanto et al. (2024) [31]	United Kingdom	Analyze the application of AI techniques in Lean Construction to improve efficiency in construction project management, focusing on tools such as BIM and the Last Planner System (LPS).	Technical	Technology
Sari et al. (2023) [32]	Indonesia	Analyze the effect of early stakeholder involvement on construction project performance.	Human	Managerial
Bigwanto et al. (2024) [33]	Indonesia	Analyze the implementation of Lean Construction in Design–Build (DB) projects to improve productivity and reduce waste, identifying key factors influencing its application.	Human	Managerial
Ratajczak et al. (2019) [34]	Poland	Analyze data exchange between BIM software and the Unity environment, as well as the integration of LBMS into BIM software and the AR4C application.	Technical	Technology
Petäjäniemi (2023) [35]	Finland	Analyze the contribution of IPD models and accurate budgeting to stakeholder commitment and the introduction of Lean principles in public projects in Finland.	Human	Education
Ahmed y Wong (2018) [36]	Malaysia	Evaluate Lean construction techniques and assess their viability in terms of applicability to selected construction sites in the Klang Valley, Malaysia.	Human	Education
Besklubova and Zhang (2019) [37]	China	Determine optimal and beneficial solutions to eliminate interruptions in order to improve productivity.	Human	Education

Table 6. Cont.

Author	Country	Study Objective	Category	Subcategory
Abbaszadegan et al. (2022) [38]	United States	Evaluate workflow and the effectiveness of near-real-time monitoring to document, stabilize, and improve operations of individual production units.	Human	Education
Aslam et al. (2022) [39]	United States	Develop an easy-to-follow LC implementation framework based on a robust analysis of contextual relationships among factors for successful Lean projects.	Human	Education
Bayhan et al. (2023) [40]	Turkey	Analyze the synergy between Lean and BIM through different components reflecting this synergy and present it within an integrated model.	Technical	Technology
Lehtovaara et al. (2019) [41]	Finland	Understand how learning and methods can be standardized and accelerated in a design management unit by leveraging feedback from the production team.	Human	Education
Cairampoma-Caro et al. (2022) [42]	Peru	Present an applied toolkit to improve processes related to social housing construction projects using Lean Construction.	Human	Education
Hettiaarachchige et al. (2022) [43]	United Kingdom	Develop a framework for implementing LIPD (Lean and IPD) in the IC.	Human	Education
Erol et al. (2017) [44]	Turkey	Uncover practical applications of Lean Construction and reveal its benefits.	Human	Education
Kulakov et al. (2023) [45]	Russia	Evaluate the impact of Lean Construction tools and digital technologies (Lean 4.0) on labor productivity in construction projects, focusing on reducing idle time and improving processes.	Technical	Technology
Ma et al. (2018) [46]	China	Explore and explain how BIM-based Integrated Data Management (IDM) facilitates efficiency achievement in construction projects.	Technical	Technology
Dallasega et al. (2018) [47]	Italy	Develop a Lean approach to plan and monitor Engineer-to-Order (ETO) construction projects in real time, in order to identify budget deviations and undertake improvement actions.	Technical	Technology
Mahfuth et al. (2019) [48]	Palestine	Identify and classify safety factors in construction project implementation and their contribution to waste minimization.	Technical	Security
Moaveni et al. (2019) [49]	Australia	Analyze Lean Construction theory from a safety perspective.	Technical	Security
Renuka y Umarani (2019) [50]	India	Identify critical risk factors and propose a model to determine the probability of cost overruns in medium-sized construction projects.	Technical	Security

Table 6. *Cont.*

Author	Country	Study Objective	Category	Subcategory
Yang et al. (2024) [51]	China	Propose a methodological approach for cost management in construction projects, based on alternative models and S-curve analysis, aimed at improving adaptability and flexibility in implementation.	Management-Related Factors	Financial
Meng (2019) [52]	United Kingdom	Analyze the level of Lean Construction implementation across different project types, its integration with supply chain management, and its impact on project performance.	Management-Related Factors	Logistics
Subramani y Prabhu (2018) [53]	India	Analyze problems related to material procurement in construction projects.	Management-Related Factors	Logistics
Tezel et al. (2018) [54]	United Kingdom	Identify parameters defining the current state of Lean Construction (LC) implementation and how it can be further promoted from the perspective of Small and Medium Enterprises (SMEs).	Management-Related Factors	Logistics

The results show a clear predominance of studies classified within the Human category, particularly in the Managerial subcategory, indicating that the literature mainly focuses on organizational aspects such as leadership, culture, change management, collaboration, and project performance. Secondly, studies in the Technical category (especially within the Technology subcategory) stand out, as they address the integration of Lean Construction with BIM, artificial intelligence, and digital technologies to enhance productivity and process efficiency.

Additionally, although less represented, studies related to Management-Related Factors (Financial and Logistics) examine issues associated with cost management, supply chain integration, and planning reliability. The Education and Security subcategories reflect emerging research streams focused on training, organizational learning, and safety as key enablers for the sustainable implementation of Lean Construction. Overall, the results highlight a growing shift toward integrated approaches that combine human, technological, and managerial dimensions in Lean Construction research.

4. Discussion

The results presented in Tables 3–5 and Figure 2 provide a comprehensive overview of the geographical distribution, methodological approaches, and critical factors influencing Lean Construction (LC) implementation. Beyond their descriptive value, these findings reveal important temporal, contextual, and causal patterns that help explain how and why certain barriers persist across different regions and research traditions.

Table 3 shows that research on LC critical factors has been predominantly concentrated in Asia and Europe, with a growing but still limited contribution from Africa and the Americas. This geographical distribution reflects the temporal diffusion of Lean Construction practices, which were initially consolidated in developed construction markets and have progressively expanded into emerging economies over the past decade. The increasing participation of Asian countries aligns with rapid urbanization, large-scale infrastructure development, and recent efforts to integrate Lean principles with digital construction strategies. However, the uneven regional distribution also suggests that contextual factors (such

as institutional maturity, resource availability, and industry structure) may shape both the adoption of LC and the types of barriers emphasized in the literature.

From a methodological perspective, Table 4 indicates a balanced use of qualitative, quantitative, and mixed approaches. The predominance of qualitative studies highlights the exploratory nature of much of the existing research, particularly in identifying human and organizational barriers that are difficult to capture through purely quantitative measures. At the same time, the growing use of mixed methods reflects a gradual methodological maturation of the field, enabling more robust analyses that link perceptions, practices, and performance outcomes. This evolution supports the need for integrative frameworks capable of accommodating multidimensional and interrelated factors.

Figure 2 presents the keyword co-occurrence network generated with VOSviewer (versión 1.6.20), revealing four interrelated thematic clusters in Lean Construction research. The green cluster, focused on lean construction and lean production, constitutes the conceptual core of the field and is closely linked to success factors. The blue cluster highlights the role of project management as a driving force for improving project performance and reducing waste through lean tools. The red cluster groups organizational and implementation aspects, including barriers, efficiency, and integrated delivery models. Finally, the yellow cluster reflects the increasing integration of digital technologies, such as BIM and information management, in project design and management. Beyond cluster identification, the spatial proximity among nodes provides additional insights into the current research trajectory. The close positioning of lean-related and project management terms indicates a well-established managerial foundation of the field. In contrast, the moderate distance between technology-oriented nodes (e.g., BIM, information management) and core lean concepts suggests that digital technologies are increasingly associated with Lean Construction but remain partially decoupled from lean cultural and human-centered dimensions. This pattern indicates that much of the existing literature approaches digitalization from a tool- and process-oriented perspective, rather than as an integrated socio-technical transformation. Taken together, the figure demonstrates the multidimensional and systemic nature of Lean Construction, in which human, technical, and managerial factors interact interdependently to influence implementation outcomes. At the same time, it highlights an emerging research opportunity to strengthen the conceptual integration between digital technologies and lean culture, reinforcing the need for holistic frameworks that bridge technical innovation with organizational and human factors.

Table 5 synthesizes the critical factors identified across the reviewed studies and reveals that human-related factors (especially managerial issues) remain the most frequently reported barriers to LC implementation. This persistent dominance over an 11-year period suggests that, despite technological advancements and methodological innovations, leadership, decision-making, and organizational culture continue to play a central role in shaping implementation outcomes. In contrast, technical and management-related factors show lower frequencies, which does not necessarily imply lesser importance but rather points to their role as enabling or constraining conditions that often operate indirectly.

In aggregate, these findings indicate that the challenges of Lean Construction implementation cannot be fully understood through static or isolated observations. Instead, they reflect a dynamic interaction between geographical context, methodological orientation, and evolving industry priorities over time.

In the following subsections, each category and its corresponding subcategories are discussed in detail, allowing for a deeper examination of their specific characteristics, empirical evidence, and implications for Lean Construction implementation.

4.1. Human Category

The analysis of the 52 selected articles published between 2015 and 2025 consistently demonstrates that human factors constitute the most decisive dimension in the implementation of Lean Construction (LC). This category, according to the classification used in this review, encompasses aspects related to management, leadership, resistance to change, communication, organizational culture, and staff training, all of which directly or indirectly influence the adoption of lean methodology in construction projects. In percentage terms, human factors account for 63.5% of the findings reported in the analyzed literature, significantly exceeding technical (28.9%) and management-related factors (7.6%).

4.1.1. Managerial Subcategory

One of the most recurring conditions identified in the literature is related to leadership and commitment from senior management. Several studies demonstrate that the absence of clear and committed leadership translates into planning failures, inefficient resource allocation, unclear objectives, and low motivation in work teams [14–17]. In this context, leadership is understood not only as the ability to direct, but also as the skill to align organizational strategy with lean principles, ensuring that continuous improvement practices translate into measurable results [18,19].

Romo et al. [7] reinforce this idea by showing, through a Partial Least Squares–Structural Equation Modeling (PLS-SEM) statistical model, that management commitment significantly influences the probability of success in implementing Lean planning. Along the same lines, Govindasamy and Bekker [20] identify that a lack of leadership in mining projects in South Africa limited the effectiveness of Lean methodologies, as was the case with the Last Planner System (LPS), generating recurring delays. This finding is consistent with previous research, such as that by Lindhard and Wandahl [21] and Bohnstedt and Wandahl [22], which highlights that leadership in scheduling is a critical factor in ensuring the correct application of Lean tools in complex projects. Likewise, Berawi et al. [23] and Rashidian et al. [24] emphasize that leadership maturity determines the effective integration of Lean, Building Information Modeling (BIM), and Integrated Project Delivery (IPD) methodologies into the project lifecycle.

Transformational leadership has been identified as a particularly favorable style for implementing LC, as it promotes innovation, active staff participation, and the internalization of a culture of continuous improvement [10,25]. This type of leadership contrasts with more authoritarian or passive styles, which tend to reinforce resistance to change rather than mitigate it [15].

Resistance to change is another critical human factor. According to Bigwanto et al. [26], in the Indonesian context, this resistance manifests as a lack of willingness among staff to modify traditional work routines, even when these routines prove inefficient. This situation was also observed in Egypt by Meshref et al. [6], who demonstrated that a lack of awareness and adherence to conventional practices hinder the adoption of lean systems, even when formal institutional support exists.

Aguome et al. [27], in a case study in Uganda, emphasize that cultural resistance is not limited to the operational level but is rooted in the widespread perception that LC represents an “additional cost” rather than an “investment in the future.” This cultural view, according to the authors, constitutes a profound barrier that cannot be overcome solely with technical training but requires comprehensive organizational change [28,29]. The literature also identifies that resistance is linked to individual fears related to job loss, an overload of responsibilities, and insecurity regarding new technologies [3–5]. Therefore, it is not just a cultural issue in a broad sense, but a multifaceted phenomenon that combines personal insecurities, collective attitudes, and rigid organizational structures [30].

Poor communication is another of the most visible structural causes of human problems in the implementation of the LC. Pham V. and Pham T. [16] highlight that the lack of clear communication channels between designers, contractors, and suppliers leads to misalignment of objectives, duplication of tasks, and increased waste. These findings are consistent with studies such as that of Zhang et al. [13], who identified that low workflow reliability is closely related to internal communication problems.

Interorganizational collaboration is also highlighted as a key dimension of communication. Velezmoro-Abanto et al. [31] suggest that the use of artificial intelligence techniques can facilitate coordination among different actors in the value chain, improving real-time communication. However, they emphasize that this technology alone does not guarantee collaboration if it is not accompanied by a culture of openness and trust among project stakeholders [24,32].

The results presented in Table 5 show that the “Human” category has the highest number of cited articles. Within this category, the managerial (42.3%) and education (21.2%) subcategories stand out. This finding is consistent with previous research on the implementation of Lean Construction [6,10,13,14,16,17,21,33]. Likewise, in this review, aspects such as poor contract management, lack of clarity in objectives, inadequate allocation of personnel, and low team involvement are also represented [7,20,27,34], which were included within the cited subcategories given their lower incidence.

4.1.2. Education Subcategory

Insufficient staff training is another barrier identified in 21.2% of the reviewed articles. Workers, middle managers, and executives require training that not only covers technical aspects but also addresses soft skills such as change management and conflict resolution [10,11,35]. In this regard, comprehensive training strengthens staff commitment to organizational goals and reduces errors stemming from a lack of coordination between teams [36].

Marhani et al. [5] highlight that, in Malaysia, the lack of robust educational programs in continuous improvement has delayed its consolidation, while in Peru, Huaman-Orosco et al. [4] demonstrate that small and medium-sized enterprises lack the resources to invest in training, perpetuating the knowledge gap. Similarly, Besklubova and Zhang [37] emphasize that the absence of comprehensive training programs limits productivity and hinders the adoption of continuous improvement models.

In this context, the literature suggests that training should be continuous and adaptive, enabling workers to stay up to date with new technologies and methodologies [38,39]. Furthermore, it proposes integrating university academic programs with on-the-job training, which would help reduce the disconnect between theory and practice [40,41]. This integration between academia and industry fosters the generation of applied knowledge and the effective transfer of innovation to the construction site [42,43].

Similarly, Erol et al. [44] argue that organizational maturity in implementing Lean Planning depends directly on the level of training and the degree to which staff internalize Lean principles. Along the same lines, Lindhard and Wandahl [21] demonstrate that efficient project scheduling under the Lean Last Planner System requires skilled leadership and teams trained in identifying and eliminating waste.

The accumulated evidence suggests that the human factor is not only the most cited but also the most pervasive, as it directly influences technical aspects (technological training), administrative aspects (cost perception), and cultural aspects (resistance to change) [15,23]. Without transformational leadership, an open organizational culture, clear communication, and continuous training, the implementation of Lean Construction is limited, regardless of any technical or financial progress that may be achieved [24].

Thus, the literature not only identifies the human factor as the most critical, but also as the core element that connects the other factors, suggesting that implementation strategies should be based on this axis to ensure sustainability [28]. This also suggests that the managerial and educational subcategories are not the only ones within the “Human” category, but they constitute a necessary framework for understanding the organizational, behavioral, and educational challenges in the effective implementation of Lean Construction [18,19,23].

4.2. Technical Category

The analysis of technical factors is a key dimension in the implementation of Lean Construction, as it is directly related to technological resources and safety practices. Although its presence in the reviewed literature (28.9%) is proportionally lower than that of the human factor (63.5%), several authors highlight its importance and consider it the basis on which improvements in productivity, quality, and waste reduction are structured [16,17,45].

4.2.1. Technology Subcategory

Recent literature highlights the importance of digital transformation for consolidating Lean Construction. Tools such as Building Information Modelling (BIM) and Artificial Intelligence (AI) are considered key to mitigating delays in construction projects [8,31]. Along these lines, Ismail et al. [10] point out that the Lean-BIM approach has high potential to transform sustainable management in the sector. Complementarily, Piras et al. [17] emphasize the need to incorporate technologies such as Digital Twin and AI algorithms to generate dynamic simulations that allow for predicting deviations and reducing waste. According to Bayhan et al. [40], Ma et al. [46] and Ratajczak et al. [34] argue that combining Lean and BIM optimizes production, standardizes processes, and improves information accuracy, while technologies such as augmented reality and location-based systems facilitate real-time monitoring and tracking on construction sites. Dallasega et al. [47] propose a lean approach supported by digital technologies such as BIM and Industry 4.0 principles, aimed at improving planning, real-time control, and responsiveness to unforeseen events through strategies such as pitching and immediate feedback. Moradi and Sormunen [9] offer a broader perspective, highlighting not only the importance of BIM for achieving Lean Construction objectives but also its integration with sustainability, emphasizing the importance of the human factor in achieving this integration. Similarly, the literature review shows that technology not only drives digital technology, but also promotes the industrialization of the sector, highlighting the use of modularity as a way to facilitate mass customization, process standardization and the reduction in complexity [12].

According to the reviewed literature, the technology subcategory, with a 23.1% adoption rate, is highly relevant to a certain segment of researchers seeking to maximize productivity and optimize available resources. This could indicate a trend and direction for the construction sector in the coming years. However, the literature also highlights barriers to technology adoption: a lack of financial resources, insufficient training in digital tools, and cultural resistance to the use of collaborative platforms [45]. These limitations suggest that, while technology represents an opportunity, it can also become a source of competitive inequality between large and small companies within the construction sector.

4.2.2. Security Subcategory

The safety component appears as a technical subcategory that, although a minority at 5.8% of the reviewed articles, has a strategic impact on the sustainability of Lean construction. Authors such as Mahfuth et al. [48] and Moaveni et al. [49] point out that integrating safety into Lean principles contributes not only to reducing accidents but also to eliminating waste associated with interruptions due to workplace incidents. However, this subcategory is not only associated with accident reduction but also with analyzing the

critical risk factors that influence cost deviations in a project [50]. This limited attention it has received in academic research could be attributed to a lack of appreciation by the scientific community or a shortage of specialists dedicated to this specific area. Consequently, a significant opportunity is identified for future studies that delve deeper into the relationship between safety and Lean construction.

4.3. Management-Related Factors Category

Although the management-related factors category represents only 7.7% of the findings in the reviewed literature, it should not be underestimated, as this research includes the financial and logistical subcategories, which are fundamental to the implementation of Lean Construction. These subcategories encompass aspects such as cost management and both internal and external logistics. While not recurrent in the analyzed studies, their proper management could be key to the success of Lean approaches in construction.

4.3.1. Financial Subcategory

The literature review reveals that the financial subcategory is the least explored, with an incidence of only 1.9%. Despite this, some authors highlight its relevance, such as Yang et al. [51], who propose a comprehensive methodological approach for managing costs in engineering and construction projects. This approach allows for the adaptation of economic and financial flows through the use of three S-curves, corresponding to direct costs, indirect costs, and project reserves. However, Aguome et al. [27], in their study in Uganda, emphasize that many organizations perceive the implementation of Lean tools, such as the Last Planner System (LPS) or Value Stream Mapping (VSM), as an economic burden that does not necessarily translate into immediate benefits. This dissonance could limit the sustainable adoption of Lean Construction, as companies tend to prioritize visible cost reductions over long-term benefits, such as waste reduction and productivity improvements. This finding highlights a gap in research regarding the need to understand the impact of the financial aspect on construction projects.

4.3.2. Logistics Subcategory

One under-explored but highly relevant area is logistics and supply chain management within the framework of Lean Construction (LC). Meng [52] argues that efficiency in construction depends not only on internal processes but also on coordination with suppliers, subcontractors, and other actors in the supply chain. Subramani and Prabhu [53] identify recurring problems in material procurement: delivery delays, a lack of purchasing planning, and poor integration of suppliers into lean planning systems. These problems create bottlenecks that affect workflow reliability, contradicting LC's fundamental principle of maintaining stable and continuous operations.

Similarly, authors such as Tezel et al. [54] identify problems such as short-term relationships, lack of standardization, and insufficient training. They propose improvements in project delivery, training, and governance, with future actions highly valued by the supply chain. These authors detail, from their perspectives, the importance of considering logistics in construction projects; however, this review identified limited attention to this topic in the literature, highlighting the need for further research.

Finally, from an integrated perspective of the interrelationships among the identified categories, management-related factors limitations (particularly financial and logistical ones) can restrict the availability of resources for training and the development of organizational capabilities, thus intensifying human barriers such as insufficient education and limited management capacity. In turn, these weaknesses in the human factor hinder the adoption, integration, and effective use of technological solutions, leading to additional technical challenges. This causal sequence highlights the systemic nature of Lean Construc-

tion implementation, in which barriers do not act in isolation but rather interdependently. Consequently, addressing individual factors in a fragmented manner is unlikely to generate sustainable improvements, reinforcing the need for coordinated, comprehensive, and long-term approaches.

From this systemic perspective, recent dataset-based studies further illustrate how Lean Construction principles can be operationalized through digital and data-driven approaches across different project phases. For instance, text-based datasets for fire door defect classification enable early detection and systematic categorization of quality issues during the construction stage, supporting core Lean objectives such as waste reduction, prevention of rework, and built-in quality through rapid feedback loops [55]. Similarly, real operational datasets from Air Handling Units (AHUs) facilitate automated fault detection and diagnosis during the operation and maintenance phase, enhancing process transparency, reliability, and continuous improvement [56]. In both contexts, the integration of structured data, automation, and machine learning acts as a technical enabler of Lean Construction, reinforcing the role of digital technologies in improving quality control, maintenance efficiency, and value delivery throughout the building lifecycle.

5. Conclusions

The studies analyzed show a strong, predominantly human-factor approach, followed by technical factors and, to a lesser extent, management-related factors. Within the human-factor sphere, managerial leadership and human capital development emerge as the most influential elements. The review of fifty-two articles published between 2015 and 2025 suggests that the success of Lean Transformation (LT) may depend largely on organizations' ability to manage and/or mitigate the critical factors mentioned. Along these lines, the absence of adaptive leadership or the lack of progressively implemented strategies tailored to the organizational context appear to limit the effectiveness of Lean practices, even in environments with adequate financial or technological resources.

Regarding the technical aspect, there is a consolidated trend toward digitalization and the adoption of technological tools such as Building Information Modelling (BIM), digital twins, and process simulation systems, which have shown potential for improving planning, traceability, and real-time decision-making. However, challenges persist related to limited technical training and resistance to technological change, which could restrict their full adoption. Similarly, the safety dimension, despite its close relationship with technical efficiency, is presumably still underrepresented in the literature, suggesting a research gap in risk prevention and safety management under Lean principles.

Regarding the management-related factors, the reviewed results seem to indicate that insufficient attention to financial and logistical aspects may hinder the consolidation of Lean as a sustainable practice. Factors such as cost management, budget constraints, and a lack of logistical integration among value chain actors are obstacles highlighted by the researchers. These limitations partly prevent Lean benefits from being sustained in the long term and generate an excessive dependence on the initiative of project leaders. In this context, the limited exploration is concerning, as few authors in this review emphasize the importance of financial and logistical models for driving continuous improvement through the implementation of methodologies such as the Lean philosophy, which are geared towards evaluating comprehensive benefits for the organization, as well as indirect impacts such as waste reduction, increased productivity, and supply chain optimization.

Taken together, the reviewed findings suggest that Lean should be implemented as a comprehensive system that integrates human, technical, and management-related factors. Its effective implementation would require a sustained cultural shift, the gradual adoption of compatible technologies, and the consolidation of collaborative management models

where leadership, communication, and joint planning serve as fundamental pillars. The available evidence also suggests that the implementation of Lean methodologies should be contextualized, adapting to the specific cultural, organizational, and geographical characteristics of each environment, in order to ensure more stable and lasting results.

On the other hand, it is acknowledged that this review has methodological and geographical limitations. A key methodological limitation is the reliance on a single bibliographic database (Scopus) for the literature search. Although Scopus offers broad multidisciplinary coverage and is widely used in construction management research, the exclusive use of one database may have resulted in the omission of relevant studies indexed in other major sources, such as Web of Science. Consequently, the findings should be interpreted with caution regarding their completeness and generalizability.

Another methodological limitation of this study is the restriction of the literature search to open-access publications. While this criterion was intentionally adopted to ensure transparency, reproducibility, and unrestricted access to the evidence base, it may have resulted in the exclusion of relevant and potentially influential studies published in subscription-based journals. Consequently, the findings may not fully capture the entire body of knowledge on Lean Construction critical factors, which could affect the completeness and generalizability of the proposed taxonomy. Future research should therefore expand the search strategy to include non-open-access sources and additional bibliographic databases in order to validate, refine, and extend the results presented in this review.

In addition, the concentration of studies in Europe and Asia reduces the ability to extrapolate the results to other contexts, such as Latin America or Africa. Methodological heterogeneity among the reviewed studies and the limited number of longitudinal investigations further restricts the understanding of the sustained impact of Lean Construction (LC) over time. Therefore, the results obtained should be interpreted considering geographical particularities, organizational conditions, and the level of maturity of each environment in which LC is intended to be applied. Moreover, it is recognized that many of the reviewed studies do not explicitly identify critical factors, their interrelationships, or the specific impacts generated by LC implementation.

Finally, future research could benefit from expanding the search strategy to multiple bibliographic databases to enhance the robustness and coverage of the evidence base, as well as from exploring less-examined dimensions such as workplace safety, logistics management, and financial aspects. The use of mixed methodologies integrating quantitative and qualitative approaches, together with comparative analyses across regions and project types, could provide greater theoretical and practical robustness to Lean Construction implementation frameworks. Ultimately, the adoption of LC should be viewed as a continuous process of learning and improvement, in which people, technology, and resources converge. Only through a collaborative, adaptive, and long-term approach can the global construction industry advance toward consolidated Lean maturity.

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Abbreviations

The following abbreviations are used in this manuscript:

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
LC	Lean Construction
PLS-SEM	Partial Least Squares–Structural Equation Modeling
LPS	Last Planner System
BIM	Building Information Modeling
IPD	Integrated Project Delivery
AI	Artificial Intelligence
LT	Lean Transformation

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