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Review Article

Impact of Lean Construction on Productivity: A Systematic Review and Lessons for Colombia

Impacto de Lean Construction en la productividad: una revisión sistemática y lecciones para Colombia

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Abstract

Introduction: The construction industry faces low efficiency characterized by missed deadlines, unfinished projects, and low operational efficiency. This situation demands a rethinking of production methods and the incorporation of approaches aligned with the Sustainable Development Goals.
Objective: To analyze how the application of Lean Construction has contributed to improving productivity in construction projects internationally, through a systematic literature review, identifying the most widely used tools, their benefits in terms of efficiency, time, costs, and waste reduction, as well as the barriers and opportunities for their adoption in the Colombian context.
Methodology: A systematic literature review was conducted in the scientific database following the PRISMA guidelines, using the search equation "Lean Construction AND Construction AND Productivity AND Project". Inclusion and exclusion criteria were applied. The documents were analyzed using nonlinear regression to identify the growth trend and processed in a matrix with variables.
Results: 102 documents were identified that met the inclusion and exclusion criteria. The evidence shows improvements in productivity, time, costs, and waste reduction, with a predominance of tools such as LPS, VSM, 5S, Kanban, and their integration with BIM.
Conclusions: Lean Construction improves productivity and sustainability when implemented in an integrated and sustained manner; in Colombia, its adoption requires standardized training, pilot projects, and institutional frameworks that allow for progressive implementation and strengthen the competitiveness of the construction sector.

Keywords: Lean Construction, Productivity, Construction.

Resumen

Introducción: La industria de la construcción enfrenta baja eficiencia caracterizada por cronogramas incumplidos, obras inconclusas y baja eficiencia operativa. Esta situación exige replantear los métodos productivos e incorporar enfoques alineados con los Objetivos de Desarrollo Sostenible.
Objetivo: Analizar cómo la aplicación de Lean Construction ha contribuido a mejorar la productividad en proyectos de construcción a nivel internacional, a través de una revisión sistemática de literatura, identificando las herramientas más utilizadas, sus beneficios en términos de eficiencia, tiempos, costos y reducción de desperdicios, así como las barreras y oportunidades para su adopción en el contexto colombiano.
Metodología: Se realizó una revisión sistemática de literatura en la base de datos científicas bajo los lineamientos PRISMA, utilizando la ecuación de búsqueda "Lean Construction AND Construction AND Productivity AND Project". Se aplicaron criterios de inclusión y exclusión. Los documentos fueron analizados mediante regresión no lineal para identificar la tendencia de crecimiento y se procesaron en una matriz con variables.
Resultados: Se identificaron 102 documentos que cumplieron los criterios de inclusión y exclusión. La evidencia muestra mejoras en productividad, tiempos, costos y reducción de desperdicios, con predominio de herramientas como LPS, VSM, 5S, Kanban y su integración con BIM.
Conclusiones: Lean Construction mejora productividad y sostenibilidad cuando se implementa de forma integrada y sostenida; en Colombia su adopción requiere formación estandarizada, proyectos piloto e institucionalidad que permitan una implementación progresiva y fortalecer la competitividad del sector de la construcción.

Palabras clave: Lean Construction, Productividad, Construcción.

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Contribution to the Literature:

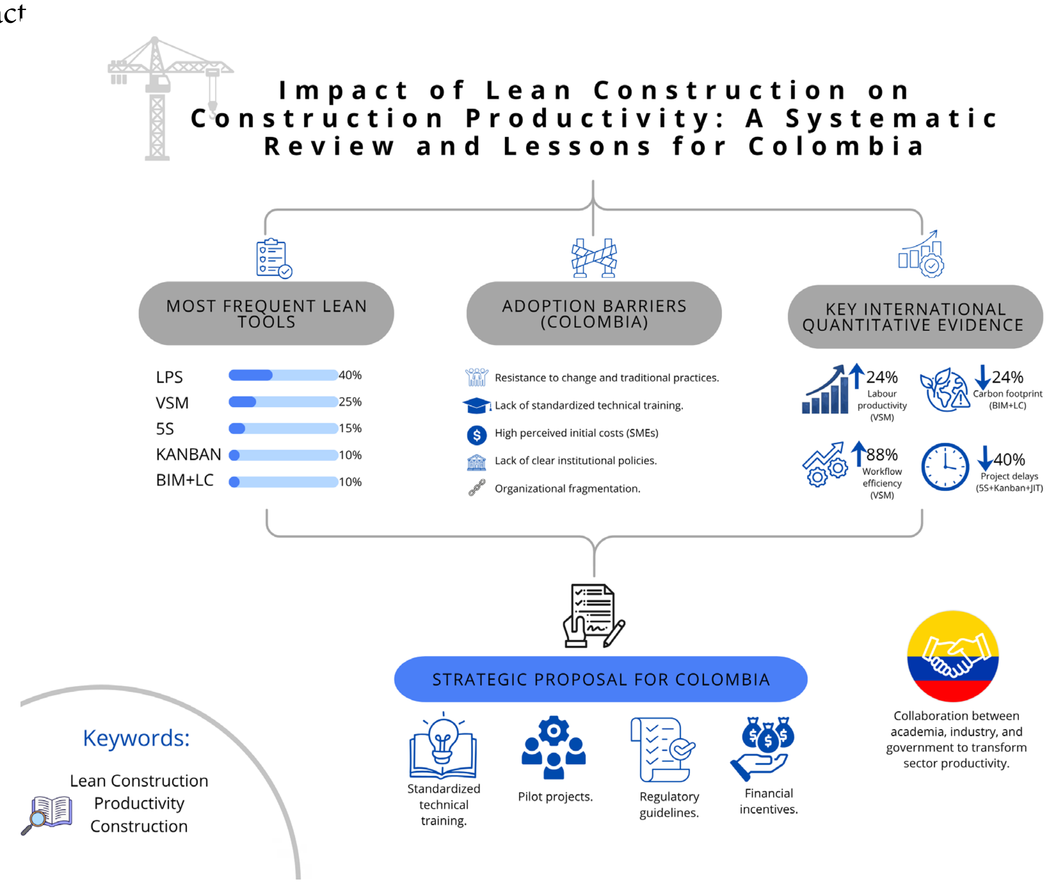
What were the key findings?

Four thematic categories structure the scientific production on Lean Construction: definition and conceptual evolution, guiding principles, practical applications (LPS, VSM, 5S, Kanban, and BIM + Lean), and adoption challenges. The frequency of use of the main Lean Construction tools in the international literature is as follows: LPS (40%), VSM (25%), 5S (15%), Kanban (10%), and BIM + Lean (10%), confirming the global predominance of LPS. Tangible improvements in productivity were observed: increases of 24% in labor productivity and 88% in workflow through VSM, reductions of 30% in project duration, decreases of up to 31% in waste, and increases in product lifecycle efficiency (PCE) from 72% to 79%. In Latin America, reductions of 40.5% in delays and 52.8% in non-conforming materials were recorded (Peru), along with decreases of 18% to 24% in the environmental footprint (Colombia).

What do these findings contribute?

They offer an integrated and internationally comparative perspective that facilitates the transfer of lessons learned from industrialized economies to emerging contexts, consolidating Lean Construction as a systemic management framework. They provide a critical and diagnostic framework for the construction sector in Colombia, contrasting local barriers with successful international experiences and providing companies, trade associations, and academic institutions with evidence to guide adoption decisions. They support the formulation of public policies through an integrated national strategy (standardized training, pilot projects, financial incentives for SMEs and dissemination of success stories), aligned with SDGs 9 and 11. They constitute a call for academic training, by highlighting the curricular gap in Lean Construction within Civil Engineering programs in Colombia and by encouraging the incorporation of skills in LPS, VSM and Lean + BIM integration from the undergraduate level.

Graphical Abstract



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Introduction

The low efficiency in resource management at construction sites represents a significant problem in the industry worldwide, characterized by delays, cost overruns, and rework that compromise the final project outcomes (1). Despite technological advances and new management methodologies, the sector continues to lag behind others in terms of efficiency, a finding consistent with multiple recent reports showing that, globally, construction productivity has grown by only 1% annually over the past two decades—well below the 2.8% global average recorded in other industries (2).

In the specific case of Colombia, and according to figures from the National Administrative Department of Statistics (DANE), a comparison between the fourth quarter of 2023 and the official projection for the fourth quarter of 2024 shows a decrease in the area approved for social-interest housing (VIS) and non-VIS residential construction, with declines of 7.2% and 1.96%, respectively (3). This phenomenon can be attributed to the significant increase in the housing construction cost index, which stood at 6.87%, reflected in a rise in new housing prices of up to 4.9% by 2025 (3). This situation has led to significant changes in the industry's dynamics, particularly regarding productivity constraints and failures in time management and project completion, highlighting an urgent need to rethink traditional on-site construction methods.

In light of this challenge, various strategies focused on sustainable construction management have been proposed, with the aim of contributing to the Sustainable Development Goals (SDGs) such as Sustainable Cities and Communities (SDG 11) and Industry, Innovation, and Infrastructure (SDG 9). In this context, emphasis is placed on the industry's social and environmental responsibility, and strategic approaches such as Lean Construction are increasingly adopted, which has gained recognition as a viable alternative for transforming construction processes in the industry (4). This approach was inspired by the Toyota Production System, which focuses on generating continuous value for the customer through the systematic elimination of waste, the improvement of workflows, and collaborative planning, utilizing tools such as the Last Planner System (LPS), Value Stream Mapping (VSM), Kanban, the 5S Methodology, and Single-Minute Exchange of Die (SMED), among others. These tools enable work to be managed from a systemic perspective, adapting to both highly complex projects and small-scale construction sites (5). Recent studies (4) (6) show that the implementation of Lean Construction has been associated with significant improvements in construction efficiency, reduced project durations, and optimized resource utilization. However, in the Colombian context, problems with productivity and schedule adherence persist, highlighting the need to adapt and strengthen the implementation of Lean Construction to local conditions in the sector (7).

The global studies reviewed agree that the Lean Construction philosophy has the potential to significantly improve project management, particularly by optimizing resources, minimizing waste, increasing the reliability of planning, and improving process quality—especially by fostering a culture of performance evaluation, training staff in Lean Construction tools, and promoting their integration across all phases and levels of construction projects (8) (9).

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In this context, this article aims to analyze how Lean Construction has contributed to improving productivity on construction sites worldwide, through the synthesis of empirical and theoretical evidence, identifying key concepts, applied tools, relevant case studies, and actionable insights for decision-making.

Methodology

To conduct this review, a systematic analysis of information was performed using the Scopus database and following the PRISMA methodology (10). For this purpose, the search terms "Lean construction AND construction AND productivity AND Project" were used. For the analysis, a nonlinear regression curve was constructed to find the inflection point of the publication timeframe and to identify publication trends within the database (11).

This technique was chosen over traditional linear models because the growth in Lean Construction publications does not follow a strictly linear pattern, but rather exhibits phases of acceleration and stabilization. The nonlinear fit allowed for a more accurate representation of the temporal evolution and strengthened the validity of the bibliometric analysis.

The following inclusion criteria were applied:

- Articles published between 2015 and 2025.
- Publications indexed in the Scopus database.
- Studies on the practical application of Lean Construction in construction projects.
- Studies that report productivity metrics (cost, time, efficiency, among others)

The following were considered as exclusion criteria:

- Documents with no practical application (conceptual or theoretical only)
- Publications without full-text access or duplicates.
- Studies outside the established time frame.
- Articles without productivity metrics reports.
- Studies with insufficient data for comparative analysis.

The selected articles were then organized into a data extraction matrix, where they were classified according to: project type, Lean Construction tools applied (LPS, VSM, 5S, Kanban, among others), productivity metrics evaluated (time, costs, efficiency, waste, environmental footprint), and region of application.

Finally, the processed data were analyzed comparatively to identify common patterns in productivity improvements, as well as barriers and opportunities for implementation. This process made it possible to establish a clear link between the application of Lean Construction and its effects on productivity.

Although the methodological approach of this review is global in scope, some sections of the manuscript include national examples—such as the case of Colombia—in order to contextualize the

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international findings and demonstrate their applicability in specific settings. These illustrative cases help to enhance understanding and facilitate the practical application of the findings obtained at the global level.

In total, 102 articles that met the inclusion criteria were identified and analyzed; of these, 61 studies are explicitly cited in the text due to their theoretical or empirical relevance, while the remaining articles were considered exclusively for the quantitative analysis and to inform the development of thematic categories.

Recent literature includes several systematic reviews on Lean Construction that have helped to consolidate its theoretical and practical foundation in project management, such as (12), which conducted a comprehensive review of the Lean philosophy and its relationship to the project delivery system, highlighting the historical evolution of the approach and its integration with Building Information Modeling (BIM) and Integrated Project Delivery (IPD).

In addition, (13) conducted an analysis of 80 indexed publications from 2017 to 2021, highlighting the positive impact of adopting Lean Construction on reducing costs and waste, particularly in Latin America. For its part, (14) conducted a systematic review of articles published between 2019 and 2023, highlighting the growing synergy between Lean Construction and BIM globally, as well as cultural and regional differences in their implementation.

Unlike previous studies, this review incorporates a broader time frame, considering sources published up to 2025, and applies a bibliometric analysis based on the PRISMA methodology, supplemented by nonlinear regression techniques, which allows for a more precise identification of trends in scientific output on the subject. In addition, an international comparative approach is adopted that seeks to draw lessons from the global literature to guide future applications of Lean Construction in emerging contexts.

Results

Based on the information retrieved from the Scopus database, 536 published documents related to Lean Construction were identified between 2015 and 2025; after applying the inclusion and exclusion criteria, 102 published documents were identified. This overview reflects the importance of this strategy within this industrial sector, as well as its implementation within the framework of a more sustainable world. Therefore, as shown in Figure 1, it is evident that publications on Lean Construction have been increasing significantly, particularly in response to international policies such as the Millennium Development Goals (MDGs) and now, the commitments established in the SDGs., which replaced the Millennium Development Goals (MDGs) in 2015. Furthermore, research trends related to Lean Construction have focused on changes in the construction sector, its application to reduce environmental impacts caused by the industry's development, and the adoption of its principles to achieve standardization of procedures and their definition within a conceptual framework that can be applied to the dynamics of the construction sector.

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This trend aligns with the global patterns identified by (12) and (14), who report sustained growth in publications on Lean Construction linked to the sector's digitalization and sustainability.

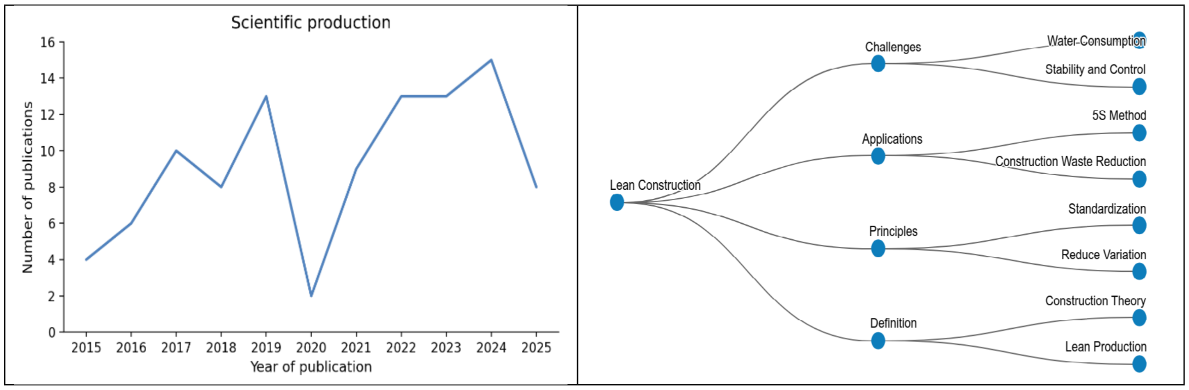

Figure 1. Analysis of documents published in the Scopus database. Source: Scopus

In line with current trends, the main components of the Lean Construction philosophy are clearly outlined, organized into four sections: definition, principles, applications, and challenges. In the first section, to guide process optimization and eliminate activities that do not add value, the theory of construction is linked to lean production.

The 102 studies analyzed were classified into four main thematic categories:

Definition: Includes works that describe the conceptual evolution of Lean Construction and its relationship to lean manufacturing (15) (16) (12) (17).

Principles: Encompasses studies that highlight the essential principles for ensuring project efficiency and stability, such as process standardization, continuous improvement, workflow, and waste elimination (4) (18) (19) (20).

Applications: Compiles case studies on the implementation of Lean tools, including LPS (20) (21) (22), VSM (5) (23) (24), the 5S Methodology (25) (26), and Lean + BIM (12) (27).

Challenges: Includes studies addressing cultural, training, and financial barriers that hinder the adoption of Lean Construction (7) (8) (28) (29) (30)

These results are consistent with the findings of (25) and (26), who document improvements in operational efficiency, on-site environmental control, and VSM-based training to reduce cycle times and waste in construction projects. These findings are consistent with the evidence presented by (18) and (31), who highlight the importance of environmental control and process documentation for Lean Construction productivity.

Overall, this perspective reflects a research trend that positions Lean Construction as a key step toward more efficient, cleaner, and sustainable construction through the implementation of strategies designed to optimize material use and reduce waste, thereby lowering environmental impact and aligning with global policies on responsible production and energy efficiency.

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By integrating Lean Construction, the goal is to achieve safer projects with greater competitiveness and added value; it also establishes itself as a strategic tool for linking the Sustainable Development Goals (SDGs) with the sector's productivity.

The Origins and Evolution of Lean Construction

The Lean Construction philosophy emerged as an adaptation of Lean Manufacturing principles to construction processes, aimed at maximizing value for the client and reducing waste at every stage of the project. As a result, this approach has established itself as a key strategy for efficiency and effectiveness in the construction industry, drawing on theories such as those outlined by (15) and further developed by (16), which articulate the principles of efficient construction—primarily based on the elimination of non-value-added activities, continuous improvement, the reduction of variability, and workflow management. Likewise, studies conducted by (12) on the Lean Construction approach highlight the evolution toward a systemic approach to project management that promotes collaborative planning, the integration of digital technologies such as BIM, and the alignment of teams around common goals of productivity and quality. In addition, studies such as those by (4) and (6) have demonstrated that the systematic application of these fundamentals significantly improves on-site productivity indicators.

In this regard, the most recent studies agree that the Lean Construction philosophy has been effective in addressing the industry's traditional problems, particularly those related to delays, cost overruns, and low productivity. Consequently, a recent study (57) confirm emerging trends in Lean Construction, noting that the leading research countries include the United States, Australia, China, and Chile; it also emphasizes that its implementation helps improve operational efficiency through process simplification, task standardization, and the efficient use of resources. For this reason, research on Lean Construction, digital tools, and their integration with the BIM methodology has been conducted using research methods such as case studies, surveys, interviews, and experimentation.

However, within the framework of Lean Construction, a model has been proposed that integrates sustainability principles and seeks to improve efficiency in this industry by adopting efficient methods and practices. This model aims to achieve just-in-time manufacturing and inventory control, as well as ongoing collaboration with people and partners—recognizing their importance to the model's success—while emphasizing teamwork, training, and the creation of a culture of continuous learning (Figure 2).

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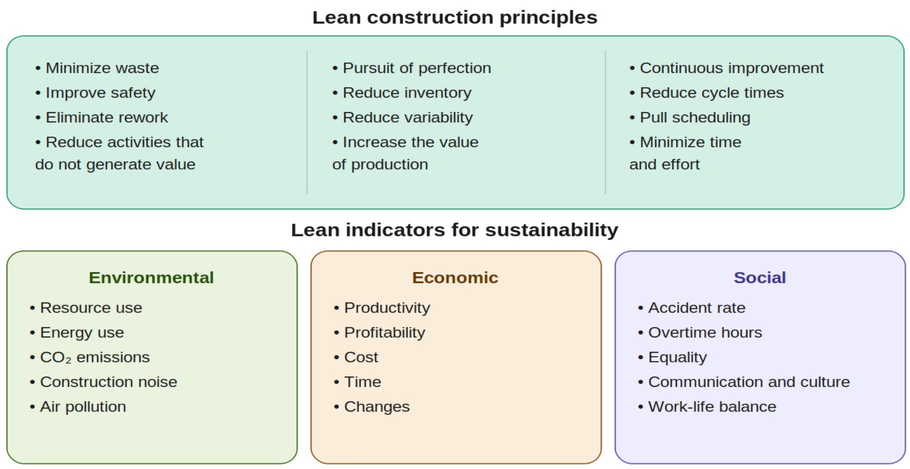

Figure 2. Elements of Lean Construction for the sustainable industry. Source: Author.

As a result, analyses conducted from this perspective have led to contributions such as a deep understanding of the principles and foundations of Lean Construction, the development of tools and techniques that promote the adoption of this approach, empirical evidence of the positive impact achieved through Lean Construction, the development of awareness-raising strategies to adopt Lean Construction within the framework of sustainable construction, and the consolidation of theoretical and conceptual frameworks that underpin the approach (18)

In this regard, the theoretical foundation has also been strengthened by the incorporation of advanced concepts in the planning and control of activities intrinsic to the industry, as proposed by (33), who recognizes the importance of adopting a three-pronged approach to the construction industry—based on transformation, flow, and value creation—that allows for a more comprehensive understanding of the construction process, as it has become a key focus for the development of tools such as LPS, whose application has expanded into residential, infrastructure, and maintenance projects.

Similarly, positive results have been demonstrated through the implementation of Lean Construction in various contexts, as noted in (34), which documents improvements in the planning and performance of railway maintenance in Sweden through the application of Lean Construction principles, while studies conducted in Asia have shown significant reductions in costs and execution times, as well as greater predictability in the delivery of activities, which is attributed to visual management, continuous improvement, and early collaboration among the stakeholders involved in the project.

In addition to its technical foundations, Lean Construction also involves organizational transformations, as it involves fundamental changes in project culture, engaging and involving senior management, and developing competencies within work teams, where the analysis of construction trends, ongoing research and experimentation, and organizational learning becomes a cornerstone for sustaining implementation over time and achieving real impacts on productivity and the quality of the final product (17).

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Lean Construction has evolved from a focus on continuous improvement to becoming a comprehensive project management system. By combining principles, technical tools, and processes that engage all stakeholders within the organization, it has had a positive impact on the construction industry and has emerged as a viable and effective alternative to traditional methods, serving as a key driver of productivity transformation on construction sites.

Productivity on the Construction Site

In the construction industry, productivity is viewed from various perspectives, providing insight into the balance that must exist between the resources used and the results achieved. One of the main approaches to productivity is the technical approach, whose primary objective is to increase output while using as few resources as possible (35). In the context of construction, this involves optimizing processes such as improved planning, resource management, and quality control during the project's execution phases. Consistent with the theory, productivity increases when advanced technologies are implemented and human, physical, and material resources are efficiently coordinated (1). To achieve this, the construction industry has turned its attention to the use of technological tools, such as construction management systems and Building Information Modeling (BIM), which aim to facilitate time optimization and reduce operating costs, thereby achieving greater efficiency and profitability in construction projects, as outlined by (2) (35)(36)(31), who address productivity metrics from a technical and multidimensional perspective.

Given this trend, on-site productivity has focused on the ability to make efficient use of available resources—particularly labor, materials, equipment, and budget—thereby ensuring that projects are fully executed without compromising product quality. Based on this premise, productivity is measured by the ratio of the volume of completed work (output) to the resources invested in time, effort, and materials (input), which facilitates the identification of key indicators for analyzing the operational performance of construction projects (31).

Consequently, this approach has been used to conduct analyses at different levels depending on the measurement objective; for example, studies have been carried out that detail the evaluation of specific activities during the course of construction work (3), these approaches allow project managers to identify bottlenecks, verify progress against the schedule, and make timely corrective decisions in pursuit of economic and environmental objectives (37).

One of the biggest challenges in measuring productivity is the lack of standardized criteria and integrated data collection tools (4), as many organizations still rely on manual records, which limits accuracy and makes it difficult to compare different projects or companies. Added to this are factors specific to the construction site, such as variable on-site conditions, logistical problems, and weather-related interruptions, which cause fluctuations in performance and make it difficult to obtain an objective assessment (31).

Accordingly, it is important to understand that on-site productivity does not depend solely on technical execution, but rather on various organizational and human factors, including, notably, staff experience, the clarity of technical specifications, the existence and quality of planning, the timely

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delivery of materials, constant on-site supervision, and effective coordination among the project stakeholders (23). It is important to note that the absence of these elements can lead to increased downtime, rework, and unnecessary delays on the job site, and, as a result, negatively impact overall performance.

In the construction industry, the most commonly used metrics include the square meters of walls built, the volume of concrete poured by a crew in a single workday, and the percentage of planned activities that have been completed. Research such as that cited in (37) indicates that the effectiveness of the aforementioned metrics as a control tool is not absolute, since it depends on factors such as the type of project, the complexity of construction activities, and the level of technology employed in the project. Likewise, (38) and (37) use these indicators as operational control parameters in evaluating project efficiency. For this reason, to address these challenges, various tools have been proposed that can be integrated with one another, such as VSM, Percent Plan Completed (PPC), LPS, and BIM-based digital tracking systems (27). These tools enable real-time monitoring of progress, thereby allowing for timely adjustments during project execution (39). Consequently, productivity in construction projects is a technical and multidimensional phenomenon that is heavily influenced by contextual conditions; effective management of productivity requires the use of reliable measurement tools, trained personnel, and collaborative methodologies that enable the anticipation of potential constraints, the minimization of waste, and the alignment of the workflow with production objectives (5).

Lean Construction and Its Tools for Productivity

Various studies, such as those cited in (19) and (20), have shown that the application of Lean Construction has a direct and positive impact on on-site productivity, as its implementation helps reduce waste, improve workflow, and increase the reliability of work planning (6). Thus, by focusing on value creation and the elimination of activities that do not contribute to the final product, the Lean Construction philosophy introduces substantial changes to production management on the construction site, particularly in terms of optimizing resource use and maximizing operational efficiency, while fostering a culture of continuous improvement. In this regard, (19)(40)(20)(41) demonstrate increases in productivity through the implementation of LPS and other Lean tools, which reaffirms the effectiveness of this approach in various types of construction projects.

One of the most important tools in Lean Construction is LPS, which has proven effective in improving short-term planning by establishing realistic commitments among those responsible for carrying out the activities. According to (20), the increase in PPC is directly linked to improved productivity on-site, achieved through the proper implementation of LPS. This tool helps reduce downtime or waiting times, improve workflow, and decrease uncertainty during the execution of activities. Along the same lines, (21) indicates that these effects translate into better utilization of available resources. These results are consistent with those reported by (20) and (21), who documented increases in PPC and improvements in planning reliability through the implementation of LPS and linked-data-based tracking systems.

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Furthermore, VSM is one of the key tools of Lean Construction for identifying waste in various operational processes, as it facilitates the visualization of current and target-state workflows, enabling the detection of bottlenecks and coordination issues (58). Its implementation in projects has proven effective through specific adaptations, such as organizing the installation of metal structures, optimizing the logistics of material delivery, and streamlining recurring activities in medium-scale projects; all of this contributes to more agile and coordinated work (59)

In addition, the application of Lean Construction in infrastructure projects has promoted practices such as visual site planning, collaborative production meetings, and controlled documentation of constraints. These strategies have led to improved team performance, adherence to established deadlines, and reduced material waste (42). Furthermore, there has been evidence of a positive impact on team motivation and on-site decision-making capacity, factors that contribute to reducing downtime (43).

As a result, a key factor in achieving improvements in labor productivity is the implementation of Lean Construction, which allows for its integration with technologies such as BIM. This integration enables the anticipation of errors during execution, optimizes the sequence of activities, and creates more efficient and safer work sites (32). This combination generates a comprehensive impact on project management, improving operational efficiency and increasing the likelihood of meeting cost, time, and quality objectives through more organized and precise processes.

The implementation of VSM in the construction sector has proven to be highly effective, as demonstrated in (5) and (23), across various application contexts including both laboratory and field studies, resulting in a 24% increase in labor productivity, an 88% improvement in workflow efficiency, and fostering more active worker participation, which was the key factor in achieving these benefits (60). Another application case involves a structural steel project, which reduced the project duration by 13 days, equivalent to 30% of the total scheduled time (24).

Similarly, the application of Lean tools such as 5S, Kanban, and JIT has a positive impact on operational productivity by reducing waste and improving workflow. The 5S technique organizes the workplace through five steps: sort, set in order, shine, standardize, and sustain; Kanban visually manages material and task flow, regulating inventories according to demand; and JIT supplies materials exactly when needed to prevent stockpiling. Albertini et al. (25) document improvements in productive efficiency through the systematic control of construction site processes, while Wang et al. (26) demonstrate that VSM-based training in virtual reality environments reduces cycle times and waste, validating the potential of these tools to improve construction productivity.

In addition, practices such as Kaizen, Total Productive Maintenance (TPM), and Poka-Yoke enhance workplace safety and quality, thereby increasing the efficiency of project execution. Kaizen focuses on continuous improvement, with a particular emphasis on making small, consistent improvements to processes. TPM establishes preventive equipment maintenance, involving all staff in the care and upkeep of the machinery used. Poka-Yoke focuses on preventing errors during processes, ensuring quality, and reducing risks (44) (45).

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Therefore, the combined impact of various Lean Construction tools and/or principles leads to improved on-site results, such as operational efficiency, enhanced worksites, and reduced downtime—achieved through the individual contributions of each.

International Case Studies on Lean Construction and Productivity

The application of Lean Construction in different regions of the world has generated significant improvements in on-site productivity, as demonstrated by (43) in China, particularly by optimizing processes, reducing waste, and meeting deadlines. From a methodological standpoint, studies in Asia and North Africa have documented the implementation of tools such as VSM and the Ishikawa diagram for identifying root causes on a construction site (45). These analyses have shown that Process Cycle Efficiency (PCE) increased from 72% to 79%, while waste associated with unnecessary inventory, overproduction, and defects was reduced by up to 31% (45).

Furthermore, (43) developed a method based on digitalization and machine learning to evaluate process improvements in offsite construction, integrating RFID sensor data with BIM models to increase production efficiency and support real-time data-driven decision-making.

Likewise, in Sweden (46), Lean Construction principles were applied to a railway maintenance project, resulting in improvements in planning and the achievement of contractual goals; however, significant barriers were identified related to the limited technical training of operational staff, which limited the full impact of the Lean Construction tools.

In the specific case of Latin America, empirical evidence also shows encouraging results, as seen in Chile, where (47) analyzed the use of collaborative contracts from a Lean Construction perspective, identifying improvements in cooperation, organizational efficiency, and the alignment of objectives among project stakeholders. (48) documented how the harmonization of repetitive construction processes through learning-based production rates improves coordination and reduces variability in construction projects. In the same line, (49) identified differences between "ideal" planning and "real" execution when applying LPS, revealing that efforts in eliminating constraints directly influence final productivity.

Meanwhile, in Peru (26), tools such as JIT, Kanban, and 5S were implemented in medium-sized companies in the urban construction sector, resulting in a 40.5% reduction in delays, a 47.2% improvement in the accuracy of estimates, and a 52.8% decrease in non-conforming materials. Thus, under the conditions of the COVID-19 pandemic, (50) noted that the adoption of Lean Construction improved planning and communication in residential projects, despite conditions of high uncertainty and operational constraints.

In Ecuador (51), Lean Construction was applied to a social-interest housing project, successfully reducing time and costs without affecting design adaptability, despite regulatory and financial constraints, while in Colombia (52), two construction projects with similar characteristics were compared: one using the traditional approach and the other applying Lean Construction practices through life cycle analysis with OpenLCA, resulting in an 18% to 24% reduction in the environmental footprint, reflecting better material utilization and more efficient processes, while (52) integrated

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BIM with a value model for sustainability assessment in a bridge infrastructure project, demonstrating that the integration of Lean and digital tools enables optimized design decisions and reduced environmental impact of the construction process.

These studies demonstrate that Lean Construction generates tangible improvements in on-site productivity, in both industrialized and emerging contexts, as the observed benefits—such as waste reduction, improved workflow, more reliable planning, and greater logistical efficiency—validate the transformative potential of this philosophy in the construction sector, especially in Latin America, where there is growing interest in sustainable and high-performance practices.

To facilitate understanding of the findings, Table 1 summarizes the most frequently used Lean Construction tools in the analyzed cases, along with their main benefits. Additionally, Figure 3 graphically shows their percentage distribution, highlighting the predominance of LPS over other methodologies.

Table 1. The most commonly cited Lean Construction tools in international studies and their associated benefits

Lean Construction Tool	% Incidence rate	Key findings	Featured Countries
Last Planner System (LPS)	40%	Improvement in PPC, planning reliability	Chile, Colombia, Brazil
Value Stream Mapping (VSM)	25%	Reduction of waste and time	Asia, Morocco, international contexts
5S	15%	On-site order and cleanliness, reduction of losses	Asia, Latin America
Kanban	10%	Continuous flow of materials and tasks	Diverse international contexts
BIM + Lean	10%	Digital integration, greater control	United Kingdom, Colombia

Source: Author.

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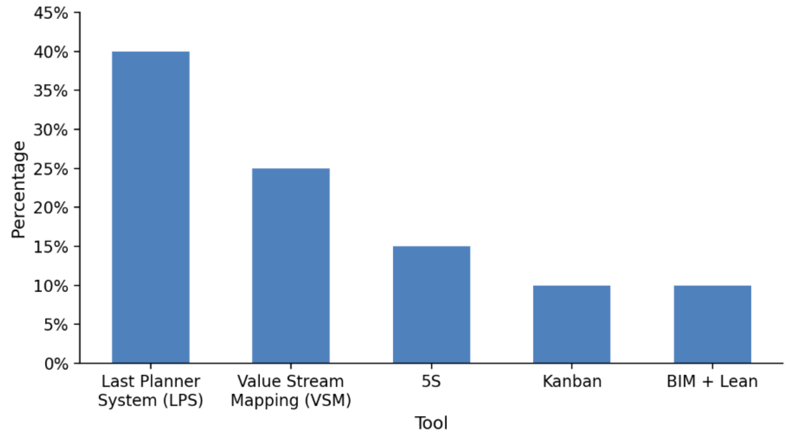

Figure 3. Frequency of Use of Lean Construction Tools. Source: Author.

The frequency percentages were derived from an analysis of the articles included in the systematic review, based on the Lean Construction tool applied, and their occurrence in the reviewed publications was recorded. The results reflect the relative proportion of each tool within the total number of empirical studies analyzed.

Last Planner System (LPS): mentioned in 40% of the articles, including (20), (21), (22), (49), and (47).

Value Stream Mapping (VSM): identified in 25% of the articles, such as (5), (23), (24), and (45).

5S: applied in 15% of the studies, including (25), (26), and (44).

Kanban: appears in 10% of the publications, mainly in continuous flow studies such as those in (26), (46), and (51).

BIM + Lean Integration: documented in 10% of the articles, notably (12), (27), and (52).

Global limitations in the implementation of Lean Construction

Globally, the implementation of Lean Construction faces challenges at the structural, organizational, and cultural levels, which limit its effective adaptation to the construction sector. Various studies, such as those in (28) and (29), have identified the following as the main constraints: resistance to change within the sector, which relies on traditional practices, coupled with the widespread perception that Lean implementation requires significant financial investment; and the lack of clear policies promoting the integration of this philosophy into various projects, both public and private.

Another limitation identified in various regions around the world is the lack of technical training that involves all stakeholders in the sector—both professionals and workers—which hinders the adoption of key tools such as LPS, VSM, and collaborative planning (29) (30). This situation is exacerbated by the lack of standardized educational programs and formal training in Lean Construction, which contributes to a slower learning curve, thereby delaying the effective implementation of these methodologies on construction sites.

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In various Latin American contexts, studies such as those in (53) show that the adoption of Lean Construction and industrialized construction (IC) is still in its early stages, as these studies note that, although there is business interest in applying Lean Construction principles, these efforts remain isolated and have not been institutionalized or incorporated into a comprehensive business strategy, while supply chain fragmentation and organizational silos also represent significant barriers to the effective integration of Lean Construction in the sector.

Internationally, another recurring challenge is financial constraints, as there is a widespread perception that implementing Lean Construction entails high upfront costs—in terms of training, digital tools, and process reorganization—which hinders adoption, especially among small and medium-sized enterprises (28) (30), given that companies often lack the necessary resources to sustain a phased implementation plan or to hire specialized consultants in the field.

In addition, the lack of transparency and an efficient flow of information within organizations is also identified as a significant limitation; in some cases, key stakeholders in the construction process withhold critical information, or there is a lack of effective communication between organizational levels. This, in turn, reveals a lack of internal collaboration and trust, hindering joint planning and visual control—fundamental aspects of Lean Construction (30)

Finally, no standardized strategic plan or practical guidelines exist at the national level to promote the implementation of Lean Construction in the Colombian industry; at the institutional and trade association levels, this highlights the absence of implementable and scalable protocols, which hinders current initiatives by rendering them isolated cases lacking replicability or continuity (28) (29).

Discussion of results

International evidence, such as that from (20) and (43), and local studies by (21) and (22), show that Lean Construction has significant potential to boost productivity on construction sites, but its implementation in Colombia requires overcoming specific challenges. The academic literature highlights that the isolated and fragmented use of Lean Construction tools, without a solid institutional strategy, limits the achievement of lasting and measurable benefits (29) (53). In medium and large companies, Lean Construction initiatives are often driven by middle managers or one-off projects, without being integrated into the organization's culture or strategic planning processes (53)

This situation is illustrated by studies conducted in Colombia (52), which demonstrate the benefits of Lean Construction tools for project planning, and (22), which documents that the implementation of LPS in civil engineering projects in Medellín resulted in significant improvements in activity control and coordination among crews. However, both studies also agree that the lack of standardization and the low level of institutional maturity limit the sustainability of these advances, reflecting a common trend in Latin American contexts where Lean initiatives are implemented in a fragmented manner and without a solid organizational strategy.

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Although the results presented are based on international trends, comparing them with the Colombian context reveals institutional and cultural gaps that explain the limited adoption of Lean Construction in the country.

Furthermore, there is a lack of structured training and certification in Lean Construction as applied to the construction industry. While in countries such as Chile, Brazil, and Peru, universities and chambers of commerce promote Lean Construction events and training, in Colombia, academic adoption is still in its infancy, and there is no standardized curriculum that integrates these practices into undergraduate programs (29)(54). This educational and technical shortfall contrasts with the high potential benefits associated with the systematic implementation of LPS, VSM, and collaborative visual planning.

From a financial standpoint, the perception of high initial costs limits adoption among small and medium-sized enterprises (SMEs), which make up the majority of the national construction sector (28). The lack of government incentives or subsidies for innovative practices hinders more ambitious initiatives. In contrast, in countries with active modernization policies, regulatory support has been observed to accelerate the adoption of Lean Construction.

Studies such as those cited in (30) show that trust and transparency within organizations are limited, which undermines the shared planning and visual control required to implement Lean Construction effectively. Without formal communication channels between hierarchical levels, the early identification and resolution of constraints becomes difficult, thereby reducing the capacity for continuous improvement and workflow optimization.

Despite these barriers, academic literature and some pilot projects have demonstrated that a systematic application of Lean Construction can improve strategic planning and financial resource management in Colombian companies. (55) describes a case where Lean Construction contributed to the competitiveness and administrative efficiency of a local construction firm by optimizing financial and strategic processes from a Lean Construction perspective.

All of this suggests that Colombia requires integrated technological strategies to modernize its construction sector (56), taking advantage of the fact that it has fertile ground for advancing Lean Construction. To achieve this, a national strategy is required that includes: standardized technical training, pilot projects with institutional support, regulatory guidelines, and the dissemination of success stories. Associations such as Lean Construction Colombia, together with universities and trade associations like Camacol, play a key role in leading this effort. Only in this way can the sector’s productivity be transformed through a sustainable Lean implementation adapted to the local context.

Conclusions

The review demonstrates that Lean Construction has established itself as a solid alternative for transforming project management in the construction industry, not only because of the technical benefits it offers, but also because of the cultural and organizational change it drives within

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companies. Its potential goes beyond waste reduction and workflow improvement, as it proposes a systemic vision where collaborative planning, standardization, and continuous improvement become cornerstones for generating value throughout the entire project delivery chain. This study is grounded in a global perspective, drawing on empirical and theoretical evidence reported from different regions of the world. This approach allowed us to identify common patterns in the relationship between Lean Construction and productivity, beyond regional particularities, providing a comprehensive view of its impact on efficiency, sustainability, and project management. From this global perspective, the findings constitute a useful knowledge base to guide the adoption of Lean Construction in emerging contexts such as Colombia's.

International analysis confirms, in line with the findings of (12), (48), and (47), that the true effectiveness of this approach lies in its strategic integration, rather than in the isolated use of tools. When Lean Construction is institutionalized, the impacts extend to both productivity and sustainability, fostering more resilient and competitive organizations in the face of global challenges. This perspective highlights the need for Colombia to move toward structural change that involves specialized training, coordination among stakeholders, and greater openness to innovation, moving beyond reliance on traditional practices that have limited the sector's efficiency.

In this regard, the experience of other countries demonstrates that the transition to a Lean Construction model depends not only on technical capabilities but also on a willingness for organizational learning, transparency in management, and commitment at all hierarchical levels. Colombia is well positioned to capitalize on these lessons, provided it consolidates policies, institutional partnerships, and business strategies that enable a progressive and sustainable adoption of the Lean Construction philosophy.

The specific contribution of this article to the construction sector in Colombia is to identify, through a systematic review, the main barriers limiting the implementation of Lean Construction in the country (cultural resistance, lack of technical training, initial costs, and organizational fragmentation), and to contrast them with successful international experiences. In this way, a critical framework is provided that not only describes the current state of affairs in Colombia but also proposes concrete guidelines for moving toward a progressive and sustainable adoption of Lean Construction, contributing to the improvement of production processes, organizational management, and policy formulation in the sector.

As a future agenda for Colombia, the study proposes strengthening academic and training programs in Lean Construction, developing national guidelines to standardize its application across different types of projects, and implementing financial incentives to encourage companies to adopt this philosophy. Collectively, these actions would accelerate the transition toward a more productive, innovative, and sustainable sector.

CreditT Authorship Contribution Statement

Conceptualization - Ideas: Álvaro José Quintero Rojas . Data Curation: Álvaro José Quintero Rojas . Formal Analysis: Álvaro José Quintero Rojas. Research: Álvaro José Quintero Rojas . Methodology:

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