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A Review Study on Lean Implementation for Construction Waste Reduction

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ABSTRACT

The building sector has a significant impact on how economically and socially a country develops. It boosts economic growth and contributes to the advancement of infrastructure in countries. Despite the positive consequences of the construction field, it frequently comes with several challenges that may lead to material waste, delays, and budget excesses. However, the attempts to find solutions to the waste issues on construction sites have been meagre. Construction waste may be classified as a complicated and multidimensional problem because of its hazy, interconnected nature, which makes it difficult to address. Lean construction techniques are excellent at managing the construction process and could address inefficiencies and non-value-adding processes. The main topics of identifying lean construction principles and practices for eliminating waste in construction projects are explicitly discussed. The appropriate database was used to perform the literature studies. The challenges of labour, supply chain, leadership, and just-in-time (JIT) production were some of the obstacles to executing lean construction. By identifying the pertinent amounts of waste-generating variables and the best tools to use, industry stakeholders may create strategies to manage construction waste more successfully. This paper will make a significant contribution to the field's understanding of how businesses can better structure lean implementation procedures for long-term success. The education of lean tools deployment is necessary for the workforce, the engagement of stakeholders in utilising lean tools and the fostering of lean culture is required for continuous improvement. This study supports previous literature reviews and other case disciplines that have affirmed the tools of lean construction in boosting effectiveness through the elimination of waste and optimization of resources.

Keywords: Lean construction; lean construction principle; lean tools; waste elimination; review paper

INTRODUCTION

The construction industry has a crucial role (Foo et al. 2013) to play in boosting the Gross Domestic Product (GDP) of various countries through its significant contributions, such as creating employment opportunities and offering most of their fixed capital assets alongside substantial infrastructural development, so it enables other related industries to excel in their operations (Abo-Zaid and Othman 2018; Jiang 2013; Saka and Adegbembo 2022). However, the sector is held accountable for its unsustainable waste creation practices, which include overproduction, overprocessing, lead time, rework, inventory, and defects (Rahim et al. 2017; Ikau et al. 2016). Waste signifies considerable inefficiencies in both overall manufacturing systems and building projects (Kaneku-Orbegozo et al. 2019). Construction projects would perform more productively and sustainably if waste was identified and eliminated (Aziz and Hafez 2013). Both internal and external manufacturing processes experience waste. The non-added-value activity is alternatively known as internal production waste. A non-value-added activity is characterized by the utilization of time, space, resources, materials, and information without contributing value for either internal or external clients. Furthermore, construction waste may be transformed into other types of waste, such as operational malfunctions with problems with cost,

safety, and the environment. Waste and non-value-adding operations can cause each project's productivity and profit margin to drop, resulting in both cost and schedule overruns (Ansah et al. 2016). Therefore, the prime objective behind the thorough examination of lean construction application and perception is to curtail waste generation and non-value-adding activities at construction sites.

This study undertakes a preliminary review of lean construction techniques as applied within the context of construction organizations, and the research delves into aspects such as their effectiveness when it comes to reducing material waste, their applicability on work sites, the lean principle, and possible limitations that need to be addressed to maximize adoption (Sundar et al. 2014; Helmold et al. 2022; Howell 2014).

WASTES IN CONSTRUCTION

According to several studies, waste in construction projects is characterized as exceeding the essential minimum of labour, materials, supplies, and equipment utilized in the manufacturing process (Sapuay 2016; Al-Hajj and Hamani 2011; Rai Widhiawati et al. 2019). Waste in construction projects is viewed as being of utmost importance since it has an impact on both the environment and the economy (Tafesse et al. 2022; Ghaffar et al. 2020). The understanding of construction and destruction has begun to get the attention of researchers worldwide in the last few years. Researchers studied many waste management strategies to discover the best methods to minimize waste in the construction sector (Kaneku-Orbegozo et al. 2019; Lu 2022; Dwiyanti and Jati 2019; Stoyanov et al. 2020).

The primary objective of this research is to enhance waste management in the construction industry (Luangcharoenrat et al. 2019). Construction waste has become one of the most crucial factors to consider since it will ultimately increase the project's cost. Waste also has several other detrimental consequences for the ecosystem, for instance, the excessive use of lands and natural resources and a considerable rise in total expenses because of the amount of waste created.

Waste falls into eight areas, including excess production, excess processing, waiting, defects, wasteful transportation, superfluous motion, excess inventory, and talent misuse, which have an immediate influence on the construction industry (Kaneku-Orbegozo et al. 2019; Senaratne and Wijesiri 2008). In short, excess production refers to constructing a particular item earlier than necessary, having an excessive amount of it already produced, or constructing something faster than necessary. Excess processing describes the extra stages that are added to a process, such as changing or handling materials or supplies twice. Defects, overproduction, and excess inventory all tend to result in overprocessing being included in a process. Waiting, also referred to as delay, describes the times when nothing is being done (Leksic et al. 2020). Waiting is the term for tasks that cannot be installed because of the effects of other waste. On the other hand, defects in manufacturing sites are categorized as materials that are flawed or improperly produced (D'Aureliano et al. 2019). Defects include incomplete or inaccurate work that needs to be fixed.

Another area of waste is wasteful transportation, which is defined as unnecessary material or equipment movement, such as moving from one room, floor, or location where items are laid out to another before returning to the work area where they will be installed (Escuder et al. 2022). Although transportation waste cannot be eliminated, it is crucial to understand that it can increase project costs and time as well as cause damage while in transit. Motion is another waste area that involves craftsman movement. Even the smallest, non-value-added move could harm the project. Work is the movement and addition of value. Motion is defined as movement without adding value. The next waste area is excess inventory, where it is crucial to identify that waste occurs when there is excess due to overproduction (Kazancoglu and Ozkan-Ozen 2019). While keeping some inventory on hand could be necessary to keep the project moving forward, excessive inventory can rapidly accumulate, thereby immobilizing capital and resources (Zaky et al. 2023).

Talent misuse or inadequate application of employees' abilities, ingenuity, or knowledge on your job site is one of the waste areas. The greatest asset of every project is its workforce. Workers must concentrate on tasks that add value (Mandujano et al. 2016). These wastes are tied to the supply chain and various other industries. The concept of waste reduction involves tracking all activities, preserving only those that provide value, and removing those that add nothing. Another key component of the lean ideology is waste removal (Alieva and von Haartman 2020; Hamzeh and Albanna 2019).

Aspects of lean include designing, working in a continuous process flow, employing the appropriate method, and executing it correctly the first time. Lean focuses on eliminating waste (Tafesse et al. 2022). Waste is defined as any process that uses resources without

producing something of value. Such procedures and actions are considered a waste. Anything that is wasted from the viewpoint of the customer is useless. By meticulously identifying and removing process waste, lean seeks to produce a product that the consumer requires. In other words, lean prioritizes value over cost, aiming to enhance value-added operations while minimizing non-value-added ones. An overview of the eight categories of construction waste in the sector is shown in Table 1.

TABLE 1. The eight categories of waste in the construction sector

No.	Item Name	Information
1	Over Production	Flow of Materials
2	Correction	
3	Material Movement	
4	Processing	
5	Inventory	
6	Waiting	Human Action
7	Motion	
8	Making Do	Construction

CONSTRUCTION WASTE'S ROOT COURSE

In construction projects, waste can happen for several reasons. The primary cause of frequent waste in building projects is redesigning plans (Sasitharan Nagapan et al. 2011). As the customer makes a few last-minute changes to the project, it commonly happens. The inability of the team to comprehend the client's expectations and the ineffective communication among the multiple project participants are categorized as the root causes of this issue (Lau and Rowlinson 2009; Abdul Rahman and Wang 2017). Any project design changes will thus require time and money-consuming reconstruction and rewriting of the plans and specifications. Waste reduction during the design phase must receive a lot of attention if this source of waste is to be avoided (Abdul Rahman and Wang 2017). The improper handling or storage of resources is a common source of waste (Muhwezi, Chamuriho, and Lema 2012; Luangcharoenrat et al. 2019). The project's materials are mishandled during storage, which leads to cracks and other issues that need to be fixed. The method utilized to protect materials from varied weather conditions is, yet another problem associated with improper material storage. Another major external factor that is thought to contribute to waste in construction projects and cause delays is the weather (Sasitharan Nagapan, Ismail Abdul Rahman, and Ade Asmi 2011). Time is a crucial component of every project, but if project schedules need to be changed due to weather, this may cause delays and cost more than expected. However, by using the right decision-making criteria and having strong management and planning, the waste brought on by weather conditions may be avoided (Sasitharan Nagapan, et al. 2011).

Furthermore, inadequate planning can cause a range of waste in construction projects, ranging in magnitude. Effective management may have a substantial impact on the rate of waste if it is used across the whole project (Adewuyi and Odesola 2015). To assess the various project procedures and guarantee efficient operations, project managers must meticulously choose the management team and site supervisors (Fei and Khan 2015; Cline 2011; Rahman et al. 2020). Effective planning will also reduce the amount of waste in projects by being aware of all project processes and assigning supervisors to ensure no waste is created. Furthermore, mistakes by workers have typically produced problems in construction projects (E. C. et al. 2017). This is a result of bad management practices by senior engineers or supervisors, incorrect training, a lack of skills, a weak work ethic, and overload. To coordinate the activity at the site and guarantee the calibre of the labourers' work, engineers and supervisors must be always present while project-related activities are taking place (Abo-Zaid and Othman 2018; Sasitharan Nagapan et al. 2011).

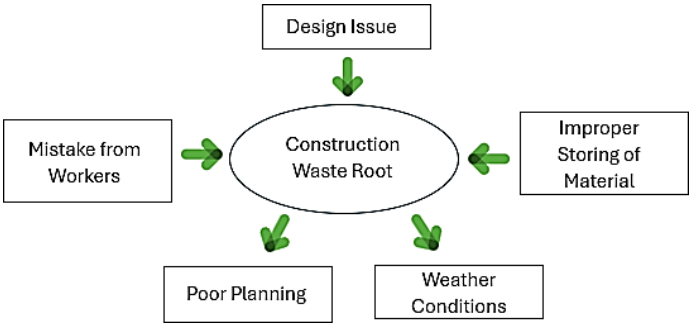

FIGURE 1. Waste in Construction

WASTE'S EFFECT ON THE CONSTRUCTION INDUSTRY

The negative effects of waste on the construction sector include those that harm the environment, such as the use of non-renewable resources like energy and water that are polluted. When it comes to waste's social impact, it is crucial to consider how it impacts both worker health and community safety since waste has a variety of negative consequences, including the loss of valuable resources like lost materials that cause cost overruns and time-related delays (Nagapan, et al. 2012). Many construction projects encountered time delays, subpar performance, expense overruns, and the creation of enormous volumes of trash. Most construction projects had to deal with this significant increase in construction (Sarhan et al. 2017). Many countries, including Japan, Sweden, Bangladesh, India, the United Kingdom, and many more (Cline 2011; Rahman et al. 2020), identify the advantages of adopting lean construction methodologies because of applying the principles behind them to their construction practices, so the utilization of lean construction practices will allow construction firms to reduce waste while increasing productivity, thereby making more profits (Ogunbiyi and Goulding 2013). The objective is to finalize a project that satisfies customer requirements while minimizing waste. Considering holistic methods such as lean principles (El Sawalhi et al. 2018), additionally, emphasizes how crucial every phase of the construction process is to its success. At every level of the procedure, lean construction assists building managers in making well-informed choices regarding projects and lowers the direct costs associated with effective project execution management (Sarhan et al. 2017).

LEAN CONSTRUCTION

Lean refers to a set of instruments that assist in identifying and gradually removing extraneous components (Jimenez et al. 2021). The elimination of waste leads to greater quality, shorter manufacturing times, and lower costs. When it comes to management strategies, lean manufacturing concepts are not very inventive. Lean production is important because it aims to reduce waste in all its forms, including extra time spent on tasks that don't add value, empty storage space, and unused or underused machinery (Marhani et al. 2013).

The phrase lean appeared and started from the Toyota Production System (TPS), which was created in 1990 (Yamamoto, Milstead, and Lloyd 2019). It outlines the plan of action this company took to increase the effectiveness of the services and products it produces for vehicles. Frederick Winslow laid the groundwork for the lean concept. Henry Ford's invention of the conveyor belt, which allowed for mass production in the 19th century, served as the foundation for Taylor's theory of repeating tasks and its best historical implementation (Selimović et al. 2020). Then, in 1949, a dramatic shift in manufacturing philosophy occurred in Japan because of a drop in Toyota sales, forcing the corporation to fire many employees after discovering that Taylor's mass production was insufficient and required revision and improvement. Lean manufacturing was formed in the 1990s because of the introduction of the Toyota Manufacturing System (TPS). The Toyota Production System (TPS) and Total Quality Control (TQC) were used in tandem to reduce waste and provide solutions for the underlying reasons for production failures (Deros et al., 2012). In the West, the same concept has been described using the term "lean thinking." Additionally, the names "lean construction" and "lean manufacturing" were borrowed from the manufacturing and construction sectors, respectively (Sarhan et al. 2017).

Lean construction employs methodologies to optimize manufacturing processes, hence minimizing waste related to materials, time, and labour, to achieve the most economical outcomes (Lim et al. 2009)(Nordin et al., 2012). A comprehensive endeavour for concurrent and ongoing enhancements in design, construction, maintenance, salvage, and recycling pertains to building projects (D' Aakanksha et al. 2015). The term "lean construction" was developed by the International Group for Lean Construction at its first meeting in 1993. Lean construction practices include setting milestones, identifying lengthy lead times in the plan, defining handoffs, identifying operational conflicts, organizing work availability to guarantee readiness for installation and adjusting plans as required. In contrast to aiming to proactively mitigate the negative impacts of loss, this strategy promotes understanding the fundamentals of identifying waste sources, eliminating them using appropriate tools and methods, and advocating for waste prevention (Sarhan et al. 2017).

Emerging from lessons learned through developing the Toyota Production System (TPS) so that it might deliver maximum value and minimum waste in response to clients' requirements, keystones of its wider corporate philosophy process engineering methodology, now commonly referred

to as ‘lean production’, are widely implemented across industry sectors worldwide (Shaqour 2022; Pranav Y. Dav 2020).

LEAN CONSTRUCTION PRINCIPLES AND BENEFIT

Compliance with five key criteria is necessary to execute the lean thinking idea and benefit from waste management on the building site. The first crucial thing is specifying the client’s value by having a thorough understanding of their specific wants (Salem et al. 2005). Understanding specific requests made by clients can avoid any unnecessary activities (Salem et al. 2005). Besides, having a solid understanding of value stream function by producing products or services in logical services and resulting in significant value to customers while at the same time being able to eliminate wasteful and non-value-adding activity (Gupta et al. 2016). Other than that, facilitating a smooth transition in the flow of work in between successive value-adding or supporting activities. A smooth flow significantly increases the processing speed and efforts should be focused on eliminating any obstacles or bottlenecks that impede the flow (Olesen et al. 2015). Another lean construction principle is implementing the pull approach in response to customer demand. Work is pushed and produces unnecessary outputs in non-lean organizations. By pulling through the system, the majority of lean services respond to client demand. Additionally, an excellent organization should continually increase its effort and understanding of the lean principle and come up with new proposals for additional improvements that can be made. Every stage of a methodical process adds significantly more value, increasing the likelihood of a successful outcome, the planned output, being adequate, adaptable, and connected by a constant stream. If one of these principles is broken, waste will eventually be created.

By removing waste from the value chain, the lean construction philosophy may make it possible for construction firms to build projects for less money (Karaz 2020). As a result, the sector has adopted lean philosophies to address waste and difficulties that may substantially affect the efficiency of the construction sector such as decreasing waste by 80%, construction costs by 50%, decreasing manufacturing cycle time by 50% and reducing labour by 50% while maintaining or increasing throughput (Abo-Zaid and Othman 2018). Surprisingly, implementing the lean principle can improve quality and increase profits, increasing system responsiveness to shifting demands and enhancing cash flow through higher shipment and billing frequencies (Gupta et al. 2016).

FIGURE 2. Lean principles

LEAN CONSTRUCTION PRINCIPLE

Lean construction is an ongoing process of concentrating on the value chain, reducing waste, exceeding all client requirements, and focusing on perfection in the way construction projects are carried out. To satisfy consumer needs and improve via the removal of waste, the lean concept asks for a nonstop progress effort that is determined by the value stream (Gupta et al. 2016). To develop a lean workplace in the construction sector, several lean ideas and best practices, including waste reduction, customer focus, and continuous improvement, may be helpful. Though the lean perception has been introduced to the various construction industries in several nations, including Australia, Brazil, Denmark, Finland, Peru, the UK, the United States, and Venezuela, surveys conducted in the UK revealed that the overall adoption of the lean approach in the construction sector has been delayed (Abo-Zaid and Othman 2018).

To adopt the lean concept in one industry, the entire organization must participate, and it takes time (Zvidzayi 2021). There are not just a few principles or methods that make up the lean concept. The concept should be viewed as a common system of beliefs and actions that permeate the whole value chain. A thorough dedication to long-term development is necessary because it equates to a shift in the company's culture (Zvidzayi 2021; Kalyan et al. 2018). Lean concepts need to be studied and understood through knowledge of a complex, interconnected, and variable construction industry. Despite the many advantages of the lean construction concept paradigm, its effectiveness depends on the organizational setting and culture that have been created (Sahwan et al., 2012). Social constructivist-based techniques and methodologies are necessary for the successful development of lean construction.

LEAN TECHNIQUES TO REDUCE WASTE

To improve the issue of waste in construction projects, it is necessary to emphasize the value of applying process analysis, the pull technique, and mistake-proofing techniques. The construction process is examined using a process analysis method to find wasteful areas and eradicate them. The pull technique is employed to regulate the flow of information and materials during construction, whereas mistake proofing is employed to stop mistakes and flaws from arising. The use of these lean tools and approaches by construction organizations may decrease waste, boost productivity, and boost profitability (Abhishek Dixit et al. 2015).

By providing systematic configurations that are based on customer needs, implementing lean tools may achieve a lot of things, like enhancing processes continuously, focusing on process completion, boosting output value, minimizing process variability, reducing the number of stages and parts, increasing output flexibility, and more (Leksic et al. 2020). Construction organizations may decrease waste, boost efficiency, and boost profitability by putting these concepts into practice.

PREVIOUS ANALYSIS OF LEAN CONSTRUCTION TOOLS

Using lean tools in construction projects can assist in finding and removing waste that doesn't provide value and increase performance. Table 2 is a review of the advantages of the implementation of lean tools that have been carried over from lean manufacturing by previous researchers.

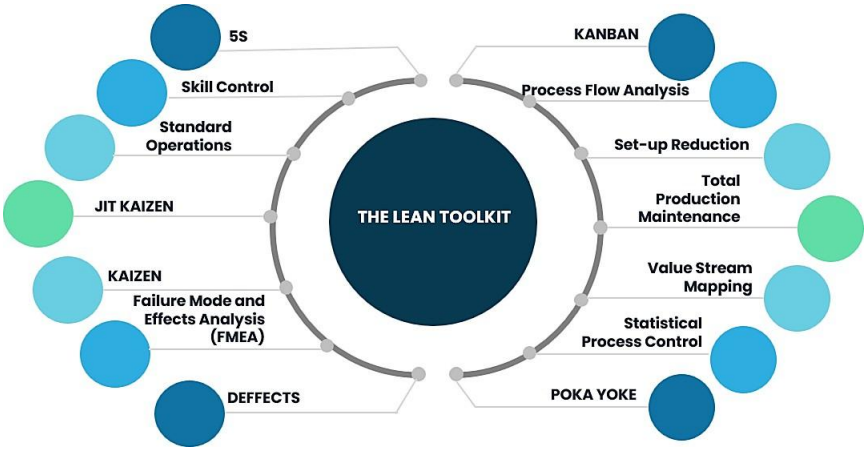

FIGURE 3. Lean Tools (Odeyinka et al. 2018)

In previous research, Bao Chao et al. (2022) and Chao et al. (2022) developed value stream mapping and the lean manufacturing concept for sand casting workshops. The concept uses eliminate, reorganize, combine, simplify, and increase theories in conjunction with Kanban management to address issues related to manufacturing processes. The model's use results in significant improvements, such as a 50% increase in production capacity, a 60.3% reduction in production lead time, a 44.7% rise in line of balance, and a reduction in equipment idle time.

Similarly, Cabrera et al. (2023) developed a management model based on lean techniques like TPM, 5S, and Kanban to avoid non-contributory time (NCT) in construction services. The pilot research and assimilation processes' assessment of the result's appropriateness. A 10% increase in equipment availability and a 51% decrease in downtime due to material shortages were a positive outcome of the strategy. On the other hand, according to Dhruv Shah et al. (2018) and Shah and Patel (2018), the Indian industrial sector uses lean manufacturing techniques to increase output and reduce waste. There are other approaches used, including TPM, TQM, and Six Sigma. By using these lean tools, waste can be eliminated, and lead times, stock levels, cycle times, and value-added activities can be analyzed for total lead time. The objective of this study is to pinpoint small-scale industries' potential and suggest appropriate ways to boost production to raise customer satisfaction.

As supported by Luay Jum'a et al. (2023) the impact of TPM and lean manufacturing techniques on environmental sustainability in Jordanian SMEs was investigated. The report highlights the significance of these practices in SMEs, which provide insightful information to decision-makers.

Patrycja Habek et al. (2023) assert that lean manufacturing approaches when bolstered by competent management, yield significant benefits in the areas of employee motivation, process quality, and product quality. Key tools for implementing lean manufacturing include Poka Yoke, Visual Management, Kaizen, and the 5S technique. Continuous improvement and training are required to enhance knowledge and skills in lean manufacturing.

In addition, Leksic et al. (2020) highlight the magnitude of lean tools in illustrating the lean concept's philosophy, way of life, and culture. The focus of this study is on how lean manufacturing tools affect waste reduction in the West's manufacturing sector. This study also emphasizes the dominance of 5S and Kaizen at the beginning of the lean transition because of its obvious and immediate impact on the shop floor environment. Lean tools like Poka-Yoke, Kanban, Kaizen, and TPM were recommended as the foundational tools for each lean manufacturing project. These tools were shown to be the best models for raising the improvement level of waste reduction and to have a strong beneficial impact on waste reduction. Research carried out in Croatia demonstrated the effectiveness of lean tools in cutting waste in the industrial sector.

To maximize consumption performance, lean construction technologies require careful examination of organizational processes. Armenia Androniceanu et al. (2023) support it by stating that it uses the Kaizen technique to access and enhance energy efficiency inside production organizations. Technical improvements made in line with the Kaizen concept result in increased energy efficiency of up to 7.5% in the production line, 3.5% in the extruder stage, and 20% in the injection stage of the manufacturing process.

On the other hand, Enshassi, Saleh, and Mohamed (2019) asserted that the implementation of lean construction tools will guide experts and construction organizations in mitigating the factors leading to accidents and enhancing safety at building sites. Therefore, safety enhances the standard of excellence and diminishes the economic expenses associated with productivity declines, as well as the societal costs related to the emotional and psychological effects on families (Enshassi et al.2019).

S. Singh and K. Kumar (2020), examine the growth of the Lean Toyota Production System in the manufacturing business and its application in the construction industry. The concept of lean rationality revolves around achieving a consistent and efficient workflow on a construction site by optimizing the whole supply chain responsible for constructing facilities, to maximize value and minimize waste. Given the extensive scope of this field, it is widely accepted that the tools employed in Lean Manufacturing and Lean Production, refined by Toyota and other companies, have been adapted to align with the principles of Lean development (Singh, S., & Kumar, K. 2020).

These analyses and reviews of the application of lean tools showed that they significantly and multifariously contributed to improvements in time, cost, and quality across a range of industries. Clearly, lean is more of a mindset, and an organization can only apply lean if the top leadership embraces it and it permeates every aspect of the company's lifestyle related to product and service development. It proves that understanding lean construction significantly raises construction quality and productivity (Idrissi Gartoumi et al. 2023).

TABLE 2. Listing the lean techniques and tool that support the use of lean construction

Lean Tools/ Techniques	Benefits	Authors												
		Olenka Cabrera et al. (2023) & Cabrera et al. (2023)	Subhav Singh et al. (2020) & S. Singh and Kumar (2020)	Adnan Enshassi and Nour Saleh (2019) &Enshassi, Saleh, and Mohamed (2019)	Bao Chao at al. (2022) & Chao et al. (2022)	Subhav Singh et al. (2018) & S. Singh et al. (2018)	I. Leksic et al. (2020) & Leksic, Stefanic, and Veza (2020)	Armenia Androniceanu et al. (2023) & Androniceanu et al. (2023)	Patrycja Habek et al. (2023) & Hąbek, Lavios, and Grzywa (2023)	S. Nallusamy and Adil Ahamed M.A (2017) & Nallusamy and Adil Ahamed (2017)	D. Shah and P. Patel (2018) & Shah and Patel (2018)	David Romero et al. (2019) & Romero et al. (2019)	Luay Jum'a et al. (2023) & Jum'a et al. (2023)	Esmatullah Noorzai (2022) & Noorzai 2023)
Value Stream Mapping	Known as the flow of materials and information, it makes process chain mapping and analysis possible.				√					√	√			
The 5S Process	Aim to design an efficient and organized workplace by eliminating clutter, optimizing layouts, maintaining cleanliness, establishing standards, and ensuring continuous improvement.	√	√	√		√	√		√	√				√
Total Quality Management	To increase both quality and performance by integrating all processes.											√	√	
Just in Time (JIT)	A management tactic called an inventory system reduces stock and boosts productivity.												√	√

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The Last Planner (LPS)	By encouraging everyone on the project team to contribute to the effort, LPS hopes to establish a dependable workflow.			√		√								√
Kaizen	Progressively increasing productivity and streamlining the workplace are the main goals of this Japanese business philosophy.					√			√	√	√			
Daily Huddle Meetings	Gives each team member a platform to rapidly go over all that needs to be done.					√								√
Pull 'kanban' system	To control workflow, construction managers are looking for techniques to facilitate communication between workers and constructors.	√							√			√	√	√
Error Proofing (Poka-yoke)	A precaution that holds back a procedure until all requirements are satisfied before moving on to the next stage.					√			√		√			

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Total Productive Maintenance (TPM)	A comprehensive strategy for maintaining machinery to achieve flawless output.	√		√			
Six Sigma	A collection of techniques and instruments aimed at raising overall quality and efficiency, decreasing variance, and decreasing errors in corporate processes						√
The Five Why's	To identify the underlying source of an issue and get past its apparent symptoms, the 5 Whys method involves asking why multiple times as it arises.		√		√		
First Run Studies	To gather information on a process to make it safer and faster,		√				√

LEAN CONSTRUCTION BARRIERS

Even though using lean construction in building projects has greatly benefited many nations, there are still several barriers and limitations that prevent lean construction from being widely used. The challenges that countries throughout the world that have implemented lean construction have to deal with can be categorized into four categories: labour, materials, just-in-time (JIT) procurement, leadership, and total quality management (TQM) as shown in Table 3.

Sandra Cano et al. (2015) state that cultural issues are the most significant and influential barrier and that developing and choosing the proper individuals according to the results of the MIC-MAC evaluation is the most significant critical success factor (CSF). According to Lodgaard et al. (2016), in a single case study survey conducted in Norway, the following factors hinder lean implementation: insufficient leadership, minimal management commitment, lack of daily focus on lean principles, ambiguous responsibilities, diminished motivation, lean tools and practices deviating from best practices, and lean tools and practices failing to provide adequate value. The major challenges to the implementation of lean include, according to Huaman-Orosco and Erazo Rondinel (2021), the absence of government regulations, the lack of academic-business collaboration, the elevated expense of implementation and the lack of awareness among university-educated or industrial experts concerning lean principles.

TABLE 3. Barriers to lean construction

Lean Concept	Barriers to lean construction	Authors
Barriers related to TQM and leadership	Change management resistance	William Nwaki et al. (2021); Wassim Albalkhy et al. (2020); Arpit Singh et al. (2023); Nwaki, Eze, and Awodele (2021); Albalkhy and Sweis (2021); A. Singh et al. (2023)
	Lack of stakeholder and management commitment	William Nwaki et al. (2021); Cristian Huaman-Orosco et al. (2021); Nwaki, Eze, and Awodele (2021); Huaman-Orosco and Erazo Rondinel (2021); (Mamat et al., 2015)
	Lack of proper risk assessment & management	William Nwaki et al. (2021); Nwaki, Eze, and Awodele (2021); (Yin et al., 2023)
	Lack of client and consultant engagement	
	Lack of commitment to teamwork	Aline Patricia Mano et al. (2022); Mano et al. (2023)
	Lack of leadership abilities	
	Absence of laws encouraging the application of lean	
	Exorbitant implementation costs	
	Lack of cooperation between academic institutions and the building sector.	Cristian Huaman Orosco et al. (2021) ; Huaman-Orosco and Erazo Rondinel (2021)
	Decision-making is delayed in the organization by lowering the empowered capability of its members.	
	Insufficient knowledge, and unawareness of the core goal and reasoning for the application of Lean.	Cristian Huaman-Orosco et al. (2021), Falah Abu et al. (2019); Marvin I. Norona and Althea C. Mendoza (2020); Huaman-Orosco and Erazo Rondinel (2021); Abu et al. (2019); Norona and Mendoza (2020)
	Lean may lead to higher expenses or implementation costs.	Falah Abu et al. (2019) ; Abu et al. (2019)
	Insufficient client orientation and inadequate understanding of customer requirements.	Arpit Singh et al. (2023); Huaman-Orosco and Erazo Rondinel (2021); A. Singh et al. (2023); Huaman-Orosco and Erazo Rondinel (2021)
	Absence of long-term thinking and planning.	

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Barriers related to labour	Hierarchical or inappropriate organizational structures.	Arpit Singh et al. (2023); A. Singh et al. (2023)
	Lack of quality planning	
	Lack of training for employees	Wassim Albalkhy et al. (2020); Falah Abu et al. (2019); Arpit Singh et al. (2023); Albalkhy and Sweis (2021)
	Resistance to change among employees	Falah Abu et al. (2019); Abu et al. (2019)
	Additional labour cost	Arpit Singh et al. (2023); Moyo and Chigara (2021), Al Balkhy et al. (2021); A. Singh et al. (2023); Moyo and Chigara (2023); Albalkhy and Sweis (2021)
Barriers related to materials	Lack of government support	Wassim Albalkhy et al. (2020); Albalkhy and Sweis (2021)
	Absence of lasting relationships with suppliers	Arpit Singh et al. (2023); Moyo and Chigara (2021), Al Balkhy et al. (2021); A. Singh et al. (2023); Moyo and Chigara 2023); Albalkhy and Sweis (2021)
	Limited use of design-build procurement	
	Subpar delivery performance and delayed material delivery	Arpit Singh et al. (2023); A. Singh et al. 2023)
Barriers to JIT	Stringent procurement stipulation and authorization	Arpit Singh et al. (2023); A. Singh et al. (2023)
	Uncertainty in the supply chain	
	Inadequate infrastructure in transportation and communications	Ivina, D. and Olsson, N.O. (2020); Ivina and Olsson (2020)

APPLICATION OF LEAN THINKING IN VARIOUS SECTORS

To use lean methodologies, organizations across multiple sectors must adopt the principle of lean thinking, which focuses on generating value with reduced resources and minimal waste. Ongoing experimentation is necessary to attain optimal value with minimal waste.

Table 4 displays a compilation of lean initiatives across several sectors. Womack and Jones (2003) claimed that efficient operating procedures in specific industries necessitate a thorough implementation of lean principles.

TABLE 4. Application of lean thinking in various sectors

Sectors	Lean Concept	Lean Drivers	References
Finance	Enterprise-wide system Four interdependent roles of finance functions, including the control role, compete role, collaborate role, and adhocracy role. Assessed through survey items that capture the degree of understanding of customers' needs, continuous improvement, problem-solving, and standardized work.	Improve efficiency and flexibility in response to customer demands. Involve monitoring performance, financial reporting, and supporting decision-making processes. Avoid prioritizing exploitation to the detriment of exploration, or vice versa.	Henrik Nielsen and Thomas Borup Kristensen (2020); Mary Margaret Crowdle (2023); Nielsen and Kristensen (2020); Crowdle, McDermott, and Trubetskaya (2023)

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Health	Focus on coordination, integration, and the creation of an integrated healthcare system founded on a lean and safety-oriented framework. Hospital managers and patients. Manage risk and waste. Training and empowering workers.	Enhance the efficiency, effectiveness, safety, and continuity of care for vulnerable patients in primary care and chronic care pathways. Have long-term sustainable effects, including reducing patient care times, optimizing resource utilization, improving work habits, and impacting patient satisfaction.	Anna Tiso and Chiara Verbano (2021); Poonam Singh (2018); Higor Leite (2022); Tiso and Verbano (2021); P. Singh (2019); Leite (2023)
Construction	Prefabricated or modular construction, VSM, improvement culture (Kaizen/ Kaikaku), Poka Yoke, IPD, Six Sigma, BIM, 5S Method, LPS, Kanban, Concurrent Engineering, and Visual Management	Minimizing environmental, economic, and societal impacts during construction while enhancing the project's sustainability standards.	David Carvajal-Arango et al. (2019); Jamil Ghazi Sarhan (2018); Mohammad Omar Aburumman at al. (2023) ; Carvajal Arango et al. (2019) ; Sarhan et al. 2017); Aburumman, Sweis, and Sweis (2023)
Aerospace	5S methodology, process optimization, layout configuration, storing tools, dead inventory, low-cost solution	Increase customer value with minimum waste, dramatic improvement in product efficiency, reduced cycle times, improved productivity, responsiveness to change,	Parthasarathy Garre et al. (2017); J. Azevedo et al. (2019); Garre et al. (2017); Azevedo et al. (2019)

SUMMARY OF RESEARCH ISSUE

JUSTIFICATION OF LEAN CONSTRUCTION

To enhance cost savings for both industry and society, eliminating the generation of waste is a critical issue, as the building sector significantly impacts every nation's economy. The importance of the adoption of lean construction in the construction field has been highlighted. It is crucial to highlight the value of them. Lean construction achieves this by coordinating and merging the efforts of all project stakeholders.

Maximizing customer satisfaction is the goal of concurrent engineering, which integrates many processes carried out concurrently by varied teams to improve product engineering cycles for effectiveness and functionality. Lean construction also only seeks to condense the benefits of the Master Builder concept. Lean construction understands that reachable means will influence goals that are realized and that intended outcomes will influence these outcomes. In the supply chain process, strong alignment throughout the whole supply chain is essential to ensure a reliable and predictable production system flow at project locations. Tools and methods for lean manufacturing or production have gained popularity and have proven particularly successful in reducing waste in supply chain delivery that the client is receiving for the project's provision and completion.

The client, architect/engineer, facility managers, and end users, among others, must all work together early in the project to create the production system that will enable the achievement of the specified goals. Construction contractors and facility managers may go above their contractual obligations for design, construction, or constructability evaluation when they just respond to designs rather than contributing to and influencing.

TABLE 5. Contributions to lean construction

Dimension	LC Impacts
Increased Revenue	By implementing the ideas of lean construction into their business practices, firms may enhance productivity and financial rewards by removing waste and streamlining workflows (Ansah, Sorooshian, and Mustafa 2016; Zaky et al. 2023; Camuffo and Poletto 2023).
Waste Reduction	Reduce modification, overrun, staff waiting times, extra inventory, processing delays, and motion waste. The adoption of lean construction principles in construction organizations has greatly decreased various forms of waste (Gupta, Sharma, and Sunder M 2016; Ortiz-Porras et al. 2023).
Customer Satisfaction	To meet the expectations of consumers for high-quality outputs in a timely and economical way, procedures must be optimized as part of lean project delivery (Hatoum et al. 2018; Abualfaraa et al. 2023)(Bilgin Turna 2023).

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Minimizing Environmental Impact	Construction companies and project owners frequently give the environmental impact of a project top consideration. The reduction of environmental effects can be achieved through the implementation of lean principles and circular economy initiatives (Sweis et al. 2021; Lizarelli et al. 2023; Machingura, Adetunji, and Maware 2023).
Quality Improvement	Since Lean places a strong emphasis on ongoing process enhancement, superfluous processes are eliminated in favour of higher-quality outputs as well as quality control systems. (Ahmed, Hossain, and Haq 2021; Kumar et al. 2023).

The construction sector is a crucial component that directly improves the state of the economy and lowers construction waste. Lean construction is a technique for proposing fabrication processes that provide the most value for the client. It's an innovative idea with the power to completely transform the building industry and bring about significant benefits. Waste organization and the application of lean ideas have both been thoroughly investigated in this study. This study has shown that, in addition to improving the construction process economically, lean construction may also assist in addressing social and environmental issues. The application of lean philosophy establishes a conceptual framework for achieving waste control in building sites. To measure the impact of lean building practices on sustainable construction, more empirical research should be done in the future.

CONCLUSION

The construction sector is considered one of the global industries. Reaching the national and international targets for sustainable development is crucial. On the other hand, the detrimental effects on the environment are attributed to the construction field. One of the most crucial concerns is the waste that construction projects produce, including material waste, schedule overruns, and budget overruns. This article also discusses the history and progress of lean construction, the concepts and advantages of lean methodology, and the impact of waste in the construction sector. Applying the lean principle in construction sites, the lean technique to reduce waste and improve performance results in significant cost investments for industry and society. The practical implications include a better comprehension of waste and how it relates to lean concepts and techniques, which will help reduce waste and increase production. Theoretically, this will lead to a better understanding for academics and industry, which they can then apply and develop to offer fresh perspectives on current information and pinpoint the precise sources of waste in the construction sector. It is expected that the fundamental information presented in this article will contribute to the body of knowledge and experience with delay control or waste reduction and serve as a benchmark for permanent development in the future construction sector. The following conclusions can be derived:

1. Lean can be identified as a strong tool as it is a low-cost solution and enhances productivity. This study has found that adopting lean construction techniques and principles has the potential to lower non-value-adding activities during the construction process and has developed the ability to mitigate environmental, economic and social consequences throughout this period. According to literature studies, adopting lean tools able to increase efficiency and increase utilization by organizing the work area. The study's evidence may motivate other organizations to comprehend the implementation of lean principles.

2. The lean mindset seeks to achieve several objectives, including fostering collaboration among organizational stakeholders, increasing customer value, minimizing costs, and strengthening quality. Nonetheless, the application of lean faces numerous barriers. For instance, augmenting client value may be impeded by a lack of understanding of the value itself or insufficient quality planning. Likewise, collaboration among stakeholders may face their hesitance to share risk or opposition to altering conventional methods.

3. Transforming to LC practices necessitates alterations to the organizational structure and culture, along with a commitment from senior management. Organizations must promote awareness and understanding of LC and urge their workforce to participate in LC training to facilitate a shift in thinking. For the successful implementation of LC, all stakeholders, including top management, customers, and employees, must participate to effectuate changes in the behavioural characteristics and practices of the organizations.

FUTURE STUDIES

This review study contributes to the literature on LC, its practical use, and its influence on building construction. The status of the LC research domain was examined; nevertheless, certain aspects of LC were not thoroughly assessed or adequately addressed in previous studies.

Future research trends and assessments of LC must be intensified to ensure the ongoing enhancement of LC performance across all industries. The majority of contemporary research in the content distribution of LC theory and its application pertains to LC technology that underpins both theory and application. Nevertheless, emerging research tendencies ought to merge LC theory with alternative theories to enhance understanding. The integration of LC with Artificial Intelligence (AI) and the Internet of Things (IoT) necessitates additional investigation and inquiry. Research trends in LC typically focus on sustainability, safety management, supply chain management, and associated domains. The forthcoming research trend ought to enhance the examination of green construction from a stakeholder standpoint. Furthermore, future research should build a model to analyze the proportion of obstacles within individual organizations or enterprises, examining the interrelationship among various categories of barriers, including input barriers and external barriers. The objective of examining the inter-relationship barrier is to comprehend the potential for improving LC inside each business. Comprehensive empirical research is necessary to evaluate and substantiate the proposed model.

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DECLARATION OF COMPETING INTEREST

None

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