Lean Construction and SDGs: Delivering value and performance in the built Environment

Alex Opoku, Ayomikun Solomon Adewumi, Ka Leung Lok (Lawrence) and Ellen Amoh

Introduction

Lean construction has been a novel idea since the middle of the 1990s, both in the field of construction management and in the actual practice of building. The lean construction philosophy, upon which lean construction is built, places a high emphasis on the generation of value in building and construction projects. Lean manufacturing involves designing production processes to produce goods with the least amount of material, labour, and time loss (Koskela, et al., 2002). Also known as lean production (Teixeira et al., 2021), it aims to reduce costs and eliminating activities that do not deliver value (Varela et al., 2019; Rodrigues et al., 2019). By removing waste, lean construction (LC) excels in overseeing the building process and achieving the project's objectives (Marhani, et al., 2013). The construction sector is currently faced with a significant challenge associated with increasing productivity. Although construction activities account for about 10% of GNP globally, it is unacceptable for any country's economy to be experiencing productivity growth that is substantially lower than that of manufacturing in many of those countries (Bertelsen, 2004). To prevent the production of defective goods, Sakichi Toyoda, the creator of Toyota Industries Corporation, created the first automatic loom, which introduced the idea of lean production. This loom automatically detects faults and halts production when they occur. Following research in the United States, his son Kiichiro Toyoda, the creator of Toyota Motor Corporation, developed the Just-in-Time (JIT) manufacturing strategy. Later in the 1950s, Toyota Engineer Taiichi Ohno and his associates gradually implemented the Lean Production system to decrease waste on the production lines of automakers and adopted a customer-centred approach to performance (Bayhan, et al., 2022). Global difficulties facing the built environment today include resource scarcity, population increase, anthropogenic climate change, decarbonizing heating and cooling as well as the building process. These difficulties have been made much more difficult by the Covid-19 issue, which has put the industry under hitherto unheard-of societal and economic pressure. This means that sustainability must be integrated into our daily practices rather than treated as an afterthought. Throughout the lifespan of our built environment, development, design, and construction experts must take whole-life costs into account. There is strong evidence that integrating lean and sustainable building methods can have a positive impact on the industry, and that the synergy that results from fusing the two methods can achieve the individual goals of each (Sarhan and Pretlove, 2021).

The Concept of Lean Philosophy

According to (Pinch, 2005), it is understandable that "lean" has become the newest buzzword to define anything from cuisine to corporate strategies in today's fast-paced society. This suggests a case for its possible potentials for the construction industry. The lean approach has been used to meet strict project goals, including those relating to timelines, quality, and budgets (Fang, et al., 2021). Most executives in the construction industry are aware that wasted spending, delays, and project inefficiency can occur in the sector. To increase performance, a variety of project management strategies have been developed, including value engineering, partnership, and design-build. According to the non-profit Lean Construction Institute (LCI), lean construction is a project delivery method based on production management that places a strong emphasis on the prompt and dependable delivery of value. For the benefit of all project stakeholders, the project must be built while maximizing value (Rodrigues et al., 2019), reducing waste (Brito et al., 2019), and pursuing excellence (Rosa et al., 2019). Any business, whether manufacturing- or service-focused, may ultimately rely on its capacity to consistently and methodically react to changes to increase the value of the output to survive. To attain this perfection, value-adding processes are therefore required. To this end, building a lean manufacturing system is now a key capability for any type of firm to thrive (Sundar, et al., 2014). In fact, there appear to be three conflicting perspectives on how lean management and the three pillars of sustainable company performance relate to each other. On the one hand, some studies concluded that lean management techniques might reduce waste, consume less energy, prevent pollution, and use fewer natural resources, all of which would considerably contribute to environmental sustainability. The implementation of lean methods, however, does not always lead to an improvement in environmental performance, according to other studies. In certain cases, a negative link is revealed in the literature (Mohaghegh, et al., 2021). Lastly, the impact of lean practices and tools on achieving environmental and social sustainability has not yet been clarified (Teixeira et al., 2021).

The Finnish academic, Koskela, was the first to put up the idea of lean construction (LC). Different definitions of LC have been offered by academics (Tommelein, 2015). This idea can be explained in two ways: One perspective claim that LC is the implementation of lean production techniques in the construction industry. Whereas, the opposing perspective asserts that lean production was first introduced as a theory to create a new model for the construction industry (Li, et al., 2020).

Lean construction is a useful method that tries to reduce different kinds of waste in the industry seven of which are directly related to the production process (Brito et al., 2019). Lean construction seeks to satisfy customers while consuming less of everything, including time, money, and resources (Radhika & Sukumar, 2017). Initiatives in lean and sustainable construction both seek to use less energy. Whilst Lean Construction (LC) concentrates on reducing energy consumption during the production stage (Verrier et al., 2014), sustainable construction (SC) focuses on optimizing energy performance of buildings throughout maintenance and operational stages to decrease the effects of climate change and global warming. Both practices support the argument that the design phase is crucial to attaining their goals. Both activities could be combined and integrated to use energy more effectively during a construction project (Garza-Reyes et al., 2017; Sarhan and Pretlove, 2021).

Implementing lean concepts means applying tools and procedures at various stages of a project. The transformation-flow-value viewpoint and additional components of complexity theory and management theory serve as a theoretical framework. However, it appears that implementing lean concepts necessitates a fundamental alteration of conventional systems in terms of both organization and behaviour (Johansen & Walter, 2007). Lean construction primarily tries to reduce waste brought associated with faults and defects, delays brought on by having to wait for earlier tasks to be completed before moving on to the next one, inappropriate processing, overproduction, keeping extra inventory, transport, and unnecessary human movement (Pinch, 2005; Verrier et al. 2014).

Lean project delivery system (LPDS) creation led to the development of lean construction. According to Howell and Ballard (1994), LPDS is composed of four primary domains: project definition, lean design, lean supply, and lean assembly. The similar goals of providing a competitive product in the shortest amount of time, with the most value and quality, and at a lower/reasonable cost are the essential characteristics or attributes when applying the lean manufacturing philosophy to construction practices (Madanayake, 2015).

By maximizing resource usage, enhancing worker safety, reducing waste through standardized processes, and other factors, the application of lean construction offers the construction sector a strategy to enhance sustainability. This is because, there would be a decrease in the volume of solid waste generated by construction dumped in landfills delivering environmental sustainability; a standardize work that can result in lower production expenses promoting economic sustainability; and an improvement in the safety and well-being of workers as a result of fewer hazardous activities achieving social sustainability (Solaimani and Sedighi, 2020; Nahmens & Ikuma, 2012).

Lean Business Models

Utilizing material and energy resources heavily exacerbates socioeconomic issues and hinders the pursuit of sustainable development. Particularly, the planet's resource capacity is being depleted and ecosystem integrity is being affected, which has a negative impact on humanity's socioeconomic position and poses a threat to the existence of future generations. To address global challenges attributed to civilization, modern economic trends are looking for ways to reduce the waste from production and consumption, which has been on the increase (Dmitriev and Zaytsev, 2021).

Lean as a comprehensive management philosophy, must be applied throughout the entire organization to deliver its full benefits, in contrast to lean construction, which is by definition a methodology to enhance project delivery practices to achieve better project outcomes (Howell et al. 2017). Lean implementation typically begins with a small group of people in construction firms who may be able to put some lean tools and practices, and occasionally even lean mindsets, into practice, and the outcomes can be good. However, these improvement efforts seem isolated inside the larger picture. This is because, the difficulty with implementing lean within the constraints of current business models is in not understanding it as a system, but rather in implementing it as a system. One of the primary reasons businesses desires to become leaner is that neither of the industry's two dominant business models is customer focused (Pekuri, et al., 2014). Scholars and business strategists interested in describing how businesses create value, operate, and gain a competitive edge are now beginning to pay more attention to the idea of a business model (Zott et al. 2011).

Lean: The Culture of Continuous Improvement and Performance

Over the last 40 years, the global construction industry's productivity has been declining, and lean construction has been regarded as one method to address this from the sustainability perspective (Dues et al., 2013; Galeazzo et al., 2014). Lean construction is the result of applying a new type of production management to the construction industry resulting in lower production expenses (Teixeira et al., 2021). A clear set of delivery objectives aimed at maximizing performance for the customer at the project level, concurrent design, construction, and the application of project control throughout the project's life cycle from design to delivery are essential features of lean construction (Aziz and Hafez, 2013).

The lean construction approach alters the socio-technical system used to create processes that reduce all types of resource and process wastes through improved relationships and practices within the design and delivery process itself (Sandberg and Bildsten, 2011; Ghosh and Robson, 2015). This is significantly different from the sustainability agenda in construction which to some extent prioritizes environmental issues through reduced energy consumption and carbon emissions, reduced waste of building materials, reduced use of non-sustainable materials, and so on. In this instance, savings are primarily attained by applying metrics to evaluate performance and score work, which results in the credit points required to earn certain certifications and credentials (Sarhan and Pretlove, 2021).

The construction industry has also adopted lean construction as a means of improving supply chains (Ng et al., 2013; Ladhad and Parrish, 2013; Banawi and Bilec, 2014). Adopting innovative management practices, such as supply chain management and lean thinking, from the manufacturing context to the construction industry is not without difficulties (Ogunbiyi and Goulding, 2014). In addition, lean construction is a new approach to capital facility design and construction. It promotes the use of simultaneous engineering concepts to consider product and process development at the same time. This philosophy has challenged the notion that there is always a cost, time and quality trade-off (Mohammed and Tanamas, 2001). Lean tools have emerged and been successfully applied to both simple and complex construction projects which are generally: easier to manage, safer, completed faster, cost less, and are of higher quality (Aziz and Hafez, 2013).

Lean production aims to design and make things that are distinct from mass and craft forms of production in terms of objectives and technique using BIM in combination with simulation techniques (Ahuja et al., 2017; Yin et al., 2014), as well as to optimise production system performance against a standard of perfection to meet unique customer requirements (Andujar-Montoya et al., 2015; Aziz and Hafez, 2013). Lean construction management differs from typical contemporary practices in that it has a clear set of objectives for the delivery process such as the incorporation of modular design (Ghosh and Robson, 2015) whilst also maximizing performance for the customer at the project level through designs of products and processes concurrently. In addition, it employs production control throughout the lifecycle of the project.

To this end, lean implementation begins with commitment from leaders and is sustained by a culture of continuous improvement anchored on collaborative learning and experimentation (Ko and Chung, 2014). When the principles are properly applied, significant improvements in safety, quality, and efficiency can be obtained at the project level. Improvements at the process and enterprise levels are enablers that allow project-level improvements to be more successful and sustainable (Aziz and Hafez, 2013).

The Principles of Lean Construction

Lean Construction is to a large extent, an adaptation and implementation of Japanese manufacturing principles within the construction process. This it does by assuming that construction is a type of production, albeit a unique one (Bertelsen, 2016).

Koskela (1992) presented the 'TFV' theory of production, which conceptualised production in three complementary ways: as a Transformation (T) of raw materials into standing structures, as a Flow (F) of raw materials and information through various production processes, and as Value (V) generation and creation for owners through the elimination of value loss (realised outcome versus best possible). Lean Construction has directed attention and focus to some critical methods. The challenge is not to improve productivity in undertaking transformations, which takes only 30% of working time and thus account for only 10% of total construction costs, but to improve flow and focus on value generation. According to data presented by the Lean Construction Institute, 70% of projects are currently over budget and delivered late. The situation in the construction industry is deteriorating yearly. In fact, the results obtained in construction sector are far less efficient than those obtained in other sectors such as education, health and social care, transportation, and information (Cwik and Rosłon, 2017).

Improving flow may reduce not only the time spent waiting and on transportation, but it may also reduce the cost of the building materials themselves. According to studies, one-third of the cost of building materials is associated with packaging, storing, handling, transporting, and disposing of package and waste materials (Bertelsen, 2016). Lean thinking specifically places a lot of emphasis on the waste produced in a construction process in addition to the physical waste (Nikakhtar et al., 2015). Managers of projects might define waste as only tangible construction waste, which frequently includes material losses. Other forms of waste in a process, on the other hand, relate to the use of resources for pointless tasks that raise costs but do not improve the quality of the final product (Koskela, 1992) or result in any value (Rodrigues et al., 2019; Verrier et al., 2014; Santos et al., 2019).

The lean construction theory holds that there are significant opportunities for improvement in construction processes by eliminating or at least reducing all types of waste, particularly non-physical waste (Nikakhtar et al., 2015). In addition to the seven categories of waste identified by Verrier et al. (2014) Koskela (1992) enumerated defect, rework, design error, omission, change order, safety cost, and excess consumption of materials as other waste groups that occurred in construction processes. Table 1 presents the 2 categories of wates based on their frequency of being mentioned.

Table 1: **Categories of construction wastes**

Waste Categorization		
#	**Commonly Mentioned**	**Occasionally Mentioned**
1	Waste due to waiting periods	Over production
2	Defects	Equipment wear and tear
3	Waste due to design errors	Safety costs
4	Excess materials	Resting time
5	Transport/handling time	Clarification needs
6	Waste due to operations	
7	Activity delays	
8	Excessive space/stock	
9	Rework	

Source: Nikakhtar *et al.* (2015)

Although the term "construction and demolition waste" has been defined as any type of solid waste produced during construction processes, lean construction suggests a broader definition of waste that encompasses not only physical waste but also waste related to any inefficiency of equipment or worker performance generated in a construction process (such as waiting time and transportation time). These waste types according to (Nikakhtar *et al.*, 2015) are referred to as construction process waste.

By eliminating waste from the value stream, the principles of lean manufacturing have the potential to enable businesses to produce goods at a lower cost (Rodrigues et al., 2019). As a result, many sectors of the economy, including the construction sector, have adopted lean manufacturing production philosophies (process improvement) to address business challenges, leading to LC. The effectiveness of the construction industry may be impacted by the lean manufacturing philosophy, which has been well documented by Ansah et al. (2016) and Solaimani and Sedighi (2020). It is noteworthy to refer to five-step thought process of lean thinking and practice by Womack and Jones (1996) as presented in Figure 1.

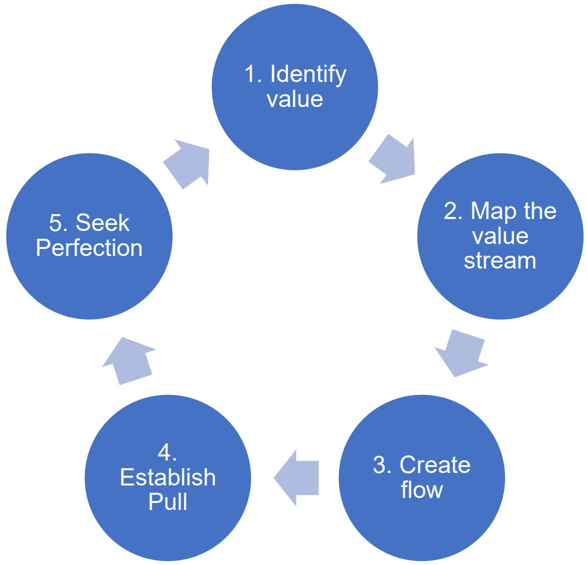

Figure 1: The five-step thought process adapted after Womack and Jones (1996)

According to the Lean Enterprise Institute (2023), first is to specify the value from the standpoint of the end customer; followed by this is the mapping of the value stream which involves also eliminating steps that do not create value; the third stage is create flow whilst ensuring that value-creating steps occur in tight sequence. The fourth stage is that as this flow is introduced, customer should pull value from the next upstream activity. This fifth stage is that of perfection after stages 1-4 are repeated until they become a culture.

This is applicable to the construction industry in the following ways. Construction must adopt a product-focused approach that allows a long-term dialogue to begin about the nature of value and how the product delivers it. The client requires a building that meets his needs while also being cost effective. Mapping raises the possibility of maximising performance during construction by bringing options to the surface. Maps are typically created at the project level and then decomposed to better understand how the design of planning, logistics, and operation systems interact to support customer value. Lean which strives to eliminate points where value-added work on material or information is disrupted, may imply repackaging work so that parts of the project can proceed without completing others and/or ensuring that resources are delivered in the order required and transported directly to the installation location to avoid double handling (Dulaimi and Tanamas, 2001). The perfection stage is a crucial strategic level because it outlines the requirement for this method of organising construction products and working to become a way of life with a built-in culture. Perfection requires constant reflection on what is being done, how it is being done, and leveraging the skills and knowledge of everyone involved in the processes to change and improve them.

Lean Construction Tool

The past decade has witnessed a growing number of effective lean production methods and tools that have been created to manage construction projects (Ansah et al., 2016). These tools come in a variety of forms, including conceptual, procedural, and programming-embedded. Additionally, while some of these tools are straightforward, others are complicated. When used by managers who are motivated by the conceptualization and management of lean projects, this unique set of tools is very effective.

Literature reviewed identified some appropriate lean tools for additional empirical research on the development of construction projects as presented in table 2.

Table 2: A list of some lean construction tools and description

No.	Reference	Tools	Description
1	Alireza and Sorooshian (2014), Abdul et al. (2012)	5S (Sort, Straighten, Shine, Standardize, and Sustain)	It removes waste from the workplace using visual controls
2	Aziz and Hafez (2013), Abdul et al. (2012)	Concurrent Engineering	Involves the various tasks parallelly executed in multi-disciplinary teams to optimize engineering cycles of products for efficiency, quality, and functionality
3	Abdul et al. (2012)	Check Sheet (also known as defect concentration diagram)	Adapted for a variety of purposes including observation and a collection of data on the frequency of patterns of problems, events, defects, causes, etc
4	Abdul et al. (2012)	Construction Process Analysis	Actualizes process charts and top-view flow charts common among process analysis methods
5	Alireza and Sorooshian (2014), Abdul et al. (2012)	Six Sigma	Improves quality through identification and removal of defects and reduction of variability in processes
6	Abdul et al. (2012)	Pareto Analysis	This is a bar graph that is used for analysing data about the frequency of the causes or problems in processes by visually depicting which situation are more important
7	Alireza and Sorooshian (2014), Abdul et al. (2012)	Check Points and Control Points	Regulates and determines the levels of improvement in the activities of managers occupying different levels of positions

8	Abdul et al. (2012)	Failure Mode and Effects Analysis (FMEA)	Through a step-by-step approach and ranking, it identifies potential failures in product or service, design, and manufacturing, etc
9	Alireza and Sorooshian (2014)	FIFO line (First in, First Out)	An approach for handling work requests in order of flow from first to the last
10	Abdul et al. (2012), Muhammad et al. (2013), Aziz and Hafez (2013)	The Last Planner	A person or group of people with the task to control the production unit responsible for necessitating control of workflow, verify supply stream, design, and installation in all the production units
11	Abdul et al. (2012), Muhammad et al. (2013)	First Run Studies	Trial execution of a process with a specific end goal to decide the best means, strategies, sequencing, among others to perform it
12	Abdul et al. (2012)	Bottleneck Analysis	Identification of the part of the process that presents a limitation on the overall productivity to improve the performance of that part
13	Alireza and Sorooshian (2014)	Total Productive Maintenance (TPM)	Holistic maintenance approach for equipment to maximize the operational time of the equipment
14	Abdul et al. (2012), Muhammad et al. (2013), Alireza and Sorooshian (2014)	Visual Management	An information communication technique employed to increase efficiency and clarity in processes through the use of visual signals
15	Alireza and Sorooshian (2014)	Synchronize/Line Balancing	Involves levelling of workload across all processes in a value stream to remove excess capacity and bottlenecks
16	Abdul et al. (2012)	Work Structuring	Useful for the development of process design and operation in alignment with the supply chain structure, allocation of resources, product design, and assembly design efforts with the objective of making the work process more reliable and quicker while delivering quality to the client
17	Alireza and Sorooshian (2014)	Multi-Process Handling	Involves assigning operators' tasks in multiple processes in an oriented layout of a product flow

18	Muhammad et al. (2013)	5 Whys	A quality management tool for problem-solving which attempts to establish the root cause of an issue
19	Salem et al. (2005), Muhammad et al. (2013)	Daily Huddle Meetings	A technique used for communicating and for the everyday meeting process of the project team to accomplish workers' involvement
20	Alireza and Sorooshian (2014)	Quality Function Development (QFD)	This refers to the use of customer's voice and different organization functions and units for final engineering specification of a product
21	Alireza and Sorooshian (2014)	Setup Reduction	A changeover technique used to speedily change tools and fixtures for multiple products to be run on the same machine
22	Muhammad et al. (2013), Alireza and Sorooshian (2014)	Work Standardization	Manufacturing documented procedures that capture best practices
23	Alireza and Sorooshian (2014)	Statistical Process Control	A quality control tool that monitors and controls processes to ensure that system output variables operate to their full potential through periodic measurement
24	Alireza and Sorooshian (2014)	Suggestion schemes	A formal mechanism which allows employees to contribute productive ideas for product and process improvements
25	Abdul et al. (2012), Muhammad et al. (2013), Aziz and Hafez (2013), Alireza and Sorooshian (2014)	Just-in-Time (JIT)	A technique aimed primarily at minimizing flow times within a production as well as response times from suppliers and to end users

Overview of the Top Three Effective Lean Tools

Last Planner System (LPS)

Last Planner System of Production Control as a tool was developed by Hermann Glenn Ballard in 1992 (Cwik and Rosłon, 2017). At the start, the specific attention has been paid to attaining better results in weekly work plans. After a while, the look ahead process has been added to control the workflow better. Eventually, the scope of the Last Planner System has been extended from construction to design suggesting the shift from improving productivity to enhancing the reliability of workflow. The LPS methodology is illustrated below in figure 2.

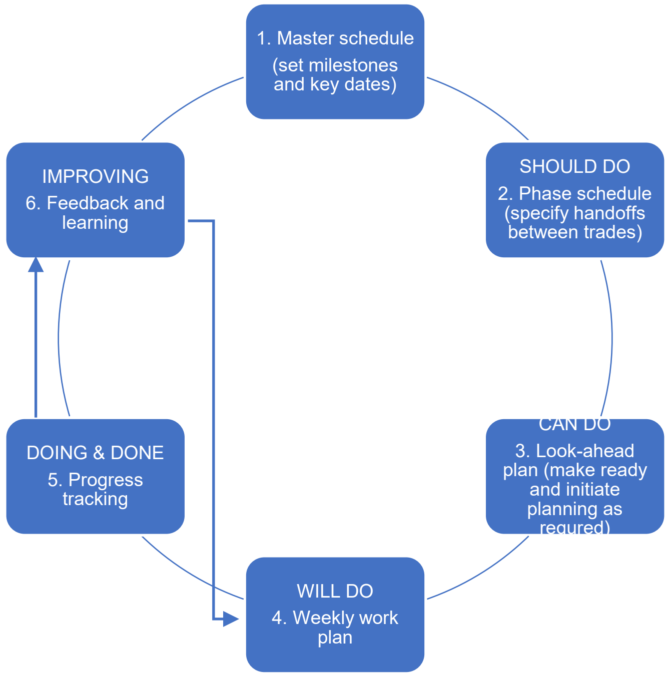

Figure 2: The Last Planner System adapted after DPS Group (2023).

This Last Planner System as a tool allows for the abandoning of the traditional approach to building project realisation by introducing a new way of thinking. However, to achieve a satisfactory result, the Last Planner System measures must be implemented correctly.

Concurrent Engineering

According to Aziz and Hafez (2013), concurrent engineering is defined as the parallel execution of various tasks by multidisciplinary teams with the goal of producing the best products in terms of functionality, quality, and productivity. It allows for design and development of products in which different stages run at the same rather than consecutively. Many enhancements can be accomplished by using concurrent engineering allowing other opportunities to be realised by overlapping activities, splitting activities, and shortening the transition time between activities. Lead time, quantity, and risk under ambiguity are important planning parameters for scheduling concurrent activities. This method lays emphasis on teamwork; communication; and information sharing as the essentials for discovering new ideas. While collaborating with subcontractors and suppliers can be beneficial in terms of concurrent engineering, the success of lean production is dependent on the early involvement of all participants. The concurrent engineering methodology is presented in figure 3.

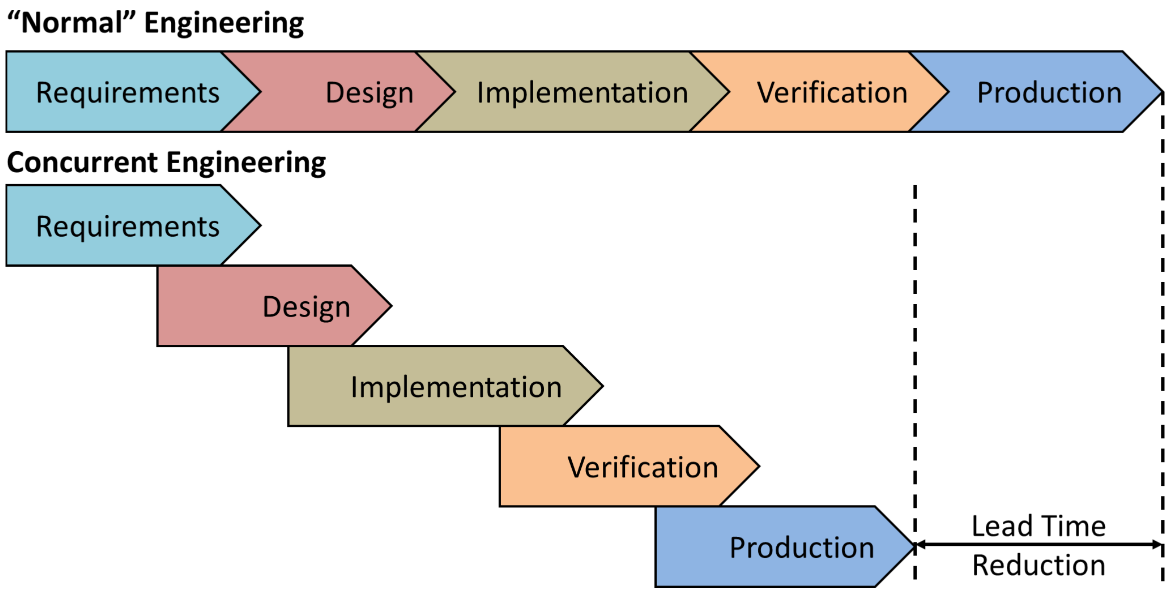

Figure 3: Illustration of the concurrent engineering
Source: Christoph Roser (2020) at AllAboutLean.com under the free CC-BY-SA 4.0 license

Daily Huddle Meetings

Daily huddle meetings provide a forum for team members to share their perspectives and accomplishments while also discussing problems encountered during the production process (Aziz and Hafez, 2013). Increasing participant involvement and enhancing interactions is one way to improve project performance. One such tool that increases participant interaction is the Formal Daily Huddle Meeting (FDHM). Workers are also given the opportunity to express their thoughts and concerns about the day's work (Ghosh, 2014).

The huddle is not a meeting. Rather, it is a continuous process. A group agrees to huddle at set times, which in the case of construction projects is daily for about fifteen to twenty minutes per session. The number of daily huddles can be increased to more than one. The main distinction between a huddle and a meeting is the absence of a formal agenda in the former. As a result, the minutes of the daily huddle are not recorded. The superintendent (of the general contractor) introduces the scope of work for that day to all workers (assigned to work on site that day), discusses related safety issues and imminent hazards, and shares information related to scheduling and deliverables that all the project participants need to know (*ibid*).

Workers are also given the opportunity to express their thoughts and concerns about the day's work. If there is more than one scheduled huddle per day, the subsequent huddle reinforces the previous huddle's discussions and inquiries about updates from the participants or provides information to the participants about any changed conditions or upcoming tasks. This collaborative process's success is dependent on two-way open communication, respect, trust, and accountability (Ghosh, 2014). Figure 4 presents an example of a daily huddle meeting.

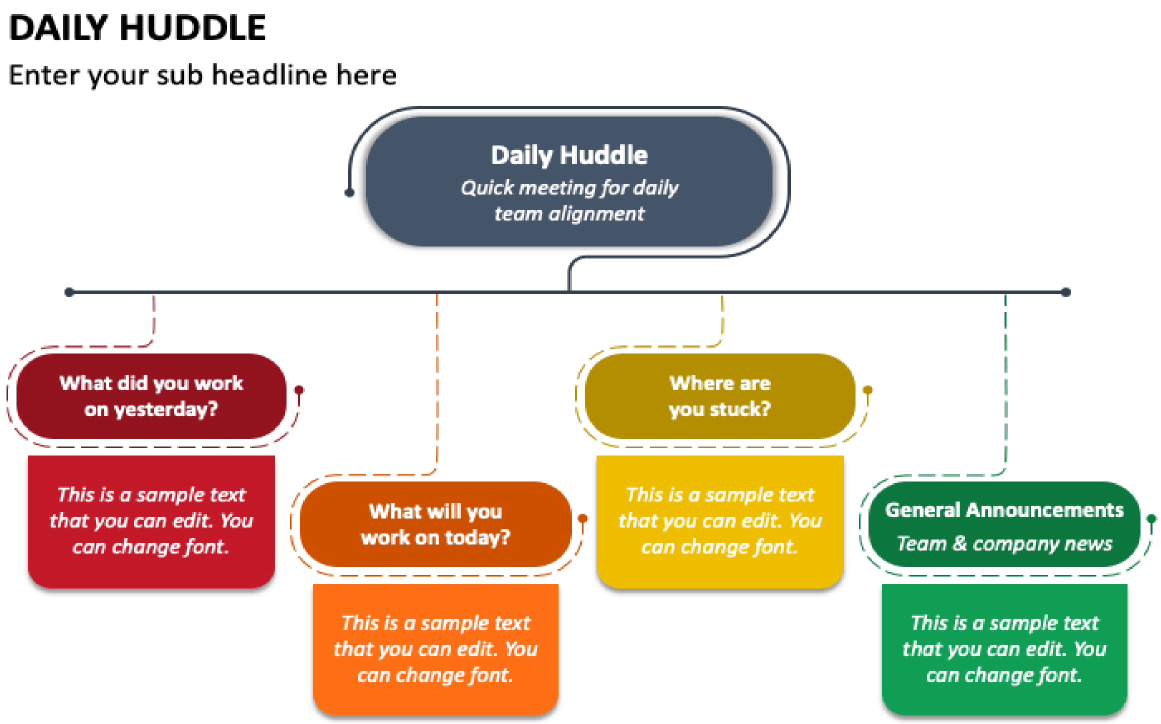

Figure 3: A typical structure of a daily huddle meeting
Source: SketchBubble (2023)

Drivers and Barriers to Lean Construction

Barriers facing the implementation of Lean Construction are identified as a very important focus area, and extremely relevant for future success and further development of Lean Construction in pursuance of an efficient construction process. According to Huaman-Orosco et al. (2022), the competition in the construction industry is driving companies to implement the Lean philosophy to improve project management and prepare for the adoption of Lean Construction. However, further identified lack of collaborative work between academia and the construction industry, high cost of implementation, and contracts not requiring the use of Lean are major issues that have direct impact on the implementation of Lean strategies and approaches.

Salontis and Tsinopoulos (2016) categorised the barriers to the uptake of the lean construction under four strands. One has to do with the financial aspect because of necessity of high investments and costs. Two is top management barrier because of inadequate knowledge of the LC concept and inconsistent commitment. Three is the workforce related barrier associated with undesirable commitment from employees due to fear of job loss, inadequate communication with the top management. The fourth covers other barriers such as distraction, multiple production sites, and difficulty in quantifying the upfront benefits. These could also include company's willingness to increase market shares, organizations strive for continuous improvements, the desire to employ world best practice.

Wandahl (2014) identified that although the success of lean construction is obvious, implementation challenges remain. These include: culture, training, and the right leadership. According to some reports, the major implementation challenges are related to misconception of lean construction tools, and case studies have revealed that lean construction is frequently applied partially or incorrectly. Table 3 presents some of the barriers for the implementation of lean construction as reported by several scholars.

Table 3: Barriers for the implementation of lean construction methodology

#	Some scientific papers addressing implementation challenges of applying lean construction practice	
	Authors	**Implementation Challenges**
1	Friblick et al. (2009)	Change in production and planning methodologies Requires more knowledge than available
2	Brady et al. (2009)	Minimum involvement of construction workers Inadequate preparations and training Lack of role definition Inadequate information Time constraints due to deadlines Non-integrated production supply chain.
3	Polesie et al. (2009)	Discusses the challenges of standardised activities and processes to reduce waste and increase efficiency. Based on interviews with eight site managers in three medium-sized Swedish construction firms, the indications are that processes should be developed slowly with a bottom-up approach
4	Viana et al. (2010)	Culture Personal qualifications Lack of communication
5	Porwal et al. (2010)	Inadequate training Resistance to change. Lack of leadership and management support. Requires additional resources. Partial implementation.
6	Nesensohn et al. (2012)	Requires change in organisational culture and structure. Requires a rigorous analysis of the organisation's capability to adopt lean construction.
7	Ahiakwo et al. (2013)	Lack of commitment to change and innovation Late introduction of the concept to the project e.g., starting off the implementation half way into the start of the project.
8	Barbosa et al. (2013)	Inadequate understanding of the new philosophy of planning and production of field employees, such as foramen and crew leaders.

9	Cerveró-Romero et al. (2013)	Language and culture Resistance towards change of senior craftsmen Incorrect interpretation of the cencept Lack of training for contractors and subcontractors.
10	Sarhan and Fox (2013)	Lack of adequate awareness and understanding Culture and human attitude issues Lack of top management commitment Resistance to change Financial issues

The relationship between Lean and sustainability

Academics and professionals in the fields of architecture, engineering, and construction (AEC) are becoming more and more interested in sustainability and how it can be applied in construction projects (Koranda et al. 2012; Nahmens and Ikuma, 2012; Rosenbaum et al., 2013). This is in line with the modern society's growing awareness of the gradual degradation of the natural environment brought on by human activity as well as the effects that this degradation has on the environment, economy, and society from the perspective of the construction industry (United Nations Environment, 2018). Lean construction and sustainable construction are thought to be two separate ideologies with different objectives suggesting a need for clarity of the relationships between the two concepts (Dey et al., 2020). Lean construction is focused on the process-related aspects of building that improve flow, boost production, get rid of waste, and shorten delays (Santos et al., 2019). While doing so, sustainable construction pays careful attention to the project's economic and social implications as well as its negative effects on the environment. However, it has been discovered that both paradigms share the same goals of encouraging resource efficiency and reducing waste (Francis & Thomas, 2019).

Many sustainability strategies are implemented in the early stages of conceptualization and design and are focused on reducing resource consumption as well as increasing the efficiency of the product or infrastructure during the phase of use and occupation because most impacts associated with the construction industry occur during the phases of use and occupation (Carvajal-Arango, et al., 2019). Sustainable construction is defined as the application of sustainable practices and sustainable development principles to the activities of the construction industry. A new production philosophy called lean construction has the potential to bring about revolutionary innovations in the building sector. Lean construction practices emphasize reducing material and process waste, which helps to enhance health and safety, reduce energy use, and other aspects of sustainable construction (Ogunbiyi and Goulding, 2014).

The construction sector plays an important role in the progress of a society. It has a significant impact on economic activity, employment, and growth rates, as well as the natural environment and human health. As a result of the foregoing, sustainable development is an important factor to consider in improving living conditions worldwide (Mavridou and Tsigkas, 2018). Sustainability is gaining popularity in the construction industry because of the industry's growing concern about the serious negative environmental impacts of construction activities. Construction waste management is critical to achieving sustainable development through environmentally friendly practices such as green building. Lean construction, on the other hand, can be used to overcome the environmental challenges of sustainable development (Wijerathne et al., 2019).

Lean thinking benefits the environment, the economy, and society (Murmura et al., 2021). The goal of sustainability in construction is to use resources efficiently in the design, construction, and use of buildings, with a focus on resources related to the environment and user health. As a result, the focus of sustainability in the construction industry is on energy use, natural waste, environmental impacts, and the creation of a healthy and productive work environment. As a result, according to Mavridou and Tsigkas (2018), it is critical that a framework be put in place that will fully adopt the production line requirements, adhere to sustainability aspects, respect the environment, and allow for flexible usage. Jum’a et al. (2022) concludes that in manufacturing firms, lean practices significantly improve environmental, economic, and social sustainability. Furthermore, sustainability-oriented innovation has a partial mediation between lean practices and sustainability dimensions. In other words, the presence of sustainability-oriented innovation enhances the significant contribution of lean practices to sustainability.

Several scholars have alluded to this argument that the adoption of the lean construction methodology could be helpful to deliver sustainability targets as presented in table 4.

Table 4: Potential effects of lean construction on sustainable construction as documented in existing literatures

No.	Authors	Publication Title
1	Azevedo et al. (2012)	Influence of Green and Lean Upstream Supply Chain Management Practices on Business Sustainability
2	Bergmiller and McCright (2009a)	Are Lean and Green Programs Synergistic?
3	Bergmiller and McCright (2009b)	Parallel Models for Lean and Green Operations
4	Carvalho et al. (2011)	Lean, agile, resilient, and green: divergencies and synergies
5	Duarte and Cruz-Machado (2015)	Investigating lean and green supply chain linkages through a balanced scorecard framework
6	Dües et al. (2013)	Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain

7	Fahimnia et al. (2015)	A trade-off model for green supply chain planning: A leanness-versus-greenness analysis
8	Faulkner and Badurdeen (2014)	Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance
9	Figge and Hahn (2012)	Is green and profitable sustainable? Assessing the trade-off between economic and environmental aspects
10	Florida (1996)	Lean and Green: The Move to Environmentally Conscious Manufacturing
11	Galeazzo et al. (2014)	Lean and green in action: interdependencies and performance of pollution prevention projects
12	Hajmohammad et al. (2013)	Lean management and supply management: their role in green practices and performance
13	Jabbour et al. (2013)	Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing
14	King and Lenox (2001)	Lean and green? An empirical examination of the relationship between Lean Production and Environmental Performance
15	Herrmann et al. (2008)	An environmental perspective on Lean Production
16	Kuriger and Chen (2010)	Lean and Green: A Current State View
17	Larson and Greenwood (2004)	Perfect complements: Synergies between lean production and eco-sustainability initiatives
18	Mollenkopf et al. (2010)	Green, lean, and global supply chains
19	Ng et al., (2015)	Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric
20	Piercy and Rich (2015)	The relationship between lean operation and sustainable operations
21	Rothenberg et al. (2001)	Lean, Green, and the Quest for Superior Environmental Performance
22	Verrier et al. (2016)	Lean and Green strategy: The Lean and Green House and maturity deployment model

23	Simons and Mason (2003)	Lean and green: 'doing more with less'
24	Simpson and Power (2005)	Use the supply relationship to develop lean and green suppliers
25	Vinodh et al. (2011)	Tools and techniques for enabling sustainability through lean initiatives
26	Yang et al. (2011)	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms

Overall, the adoption of lean construction methodology could help address the various dimensions of sustainable construction as documented in Solaimani and Sedighi (2020) addressing the needs of the supplier, developer, and the end-user. For the supplier, lean construction principles could deliver economic, environmental, and social sustainability targets in areas relating to extraction and processing; and logistics and distribution (Barathwaj et al., 2017; Zhang et al., 2017); whilst achieving similar targets for the developer in the areas of design and planning, and project delivery (Zaeri et al., 2017; Ghosh and Robson, 2015). The sustainability aspirations of the end users could also be delivered through co-creation such as participatory design which the concept advocates for (Sandberg and Bildsten, 2011).

Lean Construction as Catalyst for the SDGs

A mutual co-existence is required to generate and sustain the environmental, social, and economic conditions that allow people to live with nature today and in the future. Sustainable goals are considered in the construction industry at every stage of the building's life cycle (Rosenbaum et al., 2013). Whilst Wijerathne et al. (2019) attempted to map lean construction principles that could address economic, environmental, and social sustainability challenges, this paper attempts to further identify the sustainable developments goals (SDGs) that each of these principle could help to achieve as presented in table 5.

Table 5: Sustainability challenges, associated lean principles and targeted SDGs

Economic sustainability challenges, associated lean principles and SDGs			
#	**Challenges for Economic Sustainability**	**Lean Principles**	**Associated SDG**
1	Poor knowledge of sustainable design	Identifying the value stream Specifying value Perfection	SDG11 (Sustainable cities and communities) SDG4 (Quality education)
2	Fear of increase in cost / price fluctuations	Pull driven system Identifying the value stream Continuous flow	SDG8 (Decent work and economic growth) SDG12 (Responsible consumption and production)

3	Poor workmanship during construction	Continuous flow Perfection Pull driven system Specifying value	SDG8 (Decent work and economic growth) SDG11(Sustainable cities and communities)
4	Mode of funding the project / Financing the project	Identifying the value stream Perfection Specifying value Pull driven system	SDG9 (Industry, innovation, and infrastructure) SDG11 (Sustainable cities and communities
5	Unrealistic project duration	Continuous flow Pull driven system Identifying the value stream	SDG9 (Industry, innovation, and infrastructure) SDG11 (Sustainable cities and communities) SDG1 (No poverty)
6	Budget constraints	Specifying value Identifying the value stream Continuous flow	SDG1 (No poverty) SDG8 (Decent work and economic growth)
7	Lack of technical expertise in sustainable construction	Identifying the value stream Perfection Continuous flow	SDG4 (Quality education) SDG9 (Industry, innovation Infrastructure) SDG11 (Sustainable cities and communities)
8	Greenhouse gases	Identifying the value stream Perfection Specifying value	SDG13 (Climate action) SDG15 (Life on land) SDG14 (Life below water) SDG11 (Sustainable cities and communities)
9	Migration to cities	Perfection Pull driven system Specifying value	SDG11 (Sustainable cities and communities) SDG8 (Decent work and economic growth) SDG1 (No poverty) SDG13 (Climate action)
10	Lack of skilled workers	Specifying value Identifying the value stream Pull driven system	SDG1 (Quality education) SDG9 (Industry, innovation and infrastructure) SDG10 (Reduce inequalities)
11	Income inequality Population	Perfection Pull driven system Continuous flow Identifying	SDG10 (Reduce inequalities) SDG1 (No poverty) SDG5 (Gender equality) SDG8 (Decent work and economic growth)
12	Population growth	Identifying the value stream Perfection Specifying value	SDG4 (Quality education) SDG11 (Sustainable cities and communities) SDG2 (Zero hunger)

Environmental sustainability challenges, associated lean principles and SDGs			
#	**Challenges of Environmental Sustainability**	**Lean Principles**	**Associated SDG**
1	Lack of knowledge and non- availability of alternative sustainable materials	Lean principles Identifying the value stream Specifying value Continuous flow	SDG4 (Quality education) SDG9 (Industry innovation and infrastructure)
2	Poor working conditions in relation to safety	Pull driven system Identifying the value stream Continuous flow	SDG8 (Decent work and economic growth) SDG12 (Responsible consumption and production) SDG16 (Peace justice and strong institution)
3	Poor construction methods	Identifying the value stream Pull driven system Continuous flow	SDG4 (Quality education) SDG9 (Industry innovation and Infrastructure) SDG11 (Sustainable cities and communities, Climate change
4	Lack of demand for sustainability in construction from the clients	Specifying value Perfection Identifying the value stream	SDG13 (Climate action) SDG11 (Sustainable cities and communities) SDG4 (Quality education) SDG15 (Life on land) SDG1 (No poverty)
5	Use of toxic materials	Specifying value Perfection Identifying the value stream	SDG3 (Good health and well-being) SDG15 (Life on land) SDG14 (Life below water) SDG13 (Climate action) SDG11 (Sustainable cities and communities)
6	Contaminated sites	Specifying value Identifying the value stream Perfection	SDG13 (Climate action) SDG1 (Zero hunger) SDG15 (Life on land) SDG3 (Good health and well-being) SDG 11 (Sustainable cities and communities)
7	Industrial emissions	Specifying value Identifying the value stream Perfection	SDG13 (Climate action SDG15 (Life on land) SDG14 (Life below water) SD3 (Good health and well-being) SDG11 (Sustainable cities and communities)

8	Contaminated water/ Contaminated water at the site	Identifying the value stream Perfection Specifying value	SDG13 (Climate action) SDG14 (Life below water) SDG2 (Zero hunger)
9	Dung and wood burning/ Increased pollution	Specifying value Identifying the value stream Perfection Pull	SDG15 (Life on land) SDG13 (Climate action) SDG3 (Good health and well-being)
10	Ecosystem destruction caused by development	Pull driven system Perfection Specifying value	SDG11 (Sustainable cities and communities) SDG9 (Industry innovation and infrastructure) SDG13 (Climate action) SDG4 (Quality education) SDG15 (Life on land) SDG14 (Life below water)
11	Insufficient reuse and recycling of resources	Specifying value Identifying the value stream Perfection	SDG13 (Climate action) SDG12 (Responsible consumption and production)
12	Over exploitation of renewable resources	Perfection Identifying the value stream Pull driven system	SDG13 (Climate action) SDG12 (Responsible consumption and production)
13	Deforestation	Identifying the value stream Pull driven system Perfection	SDG13 (Climate action) SGD12 (Responsible consumption and production) SDG15 (Life on land)
14	Overgrazing	Specifying value Identifying the value stream Perfection	SDG13 (Climate action) SDG15 (Life on land) SDG2 (Zero hunger)
15	Soil loss	Identifying the value stream Pull driven system Specifying value	SDG2 (Zero hunger) SDG13 (Climate action) SDG15 (Life on land)

Social sustainability challenges, associated lean principles and SDGs			
#	**Challenges of Environmental Sustainability**	**Lean Principles**	**Associated SDG**
1	Inadequate awareness and knowledge of the concept of sustainability and its benefits	Specifying value Perfection Continuous flow	SDG13 (Climate action) SDG4 (Quality education)
2	Poor understanding of project objectives and requirements.	Specifying value Continuous flow Pull driven system	SDG4 (Quality education) SDG9 (Industry, innovation Infrastructure)

			SDG11 (Sustainable cities and communities
3	Lack of related legislation and government support	Specifying value Continuous flow Pull driven system	SDG16 (Peace justice and strong institution)
4	Incompetence of contractors/subcontr actors	Pull driven system Continuous flow Specifying value	SDG11 (Sustainable cities and communities) SDG16 (Peace justice and strong institution) SDG4 (Quality education)
5	Unwillingness to adopt new construction methods	Specifying value Identifying the value stream Continuous flow Pull driven system Perfection	SDG13 (Climate action) SDG11 (Sustainable cities and communities) SDG16 (Peace justice and strong institution) SDG4 (Quality education)
6	Economic, physical and social environment of the educational building project	Pull driven system Perfection Specifying value	SDG4 (Quality education) SDG9 (Industry, innovation and infrastructure) SDG11 (Sustainable cities and communities) SDG3 (Good health and well-being)
7	Non availability of sewage treatment	Identifying the value stream Perfection Continuous flow Specifying value Pull driven system	SDG3 (Good health and well-being) SDG13 (Climate action)
8	Absence of sanitation	Continuous flow Pull driven system Perfection	SDG13 (Climate action) SDG3 (Good health and well-being) SDG11 (Sustainable cities and communities)
9	Scarcity of materials	Identifying the value stream Perfection Specifying value	SDG17 (Partnership for the goals)
10	Overuse of water for irrigation	Identifying the value stream Pull driven system Perfection	SDG13 (Climate action) SDG14 (Life below water) SDG4 (Quality education)
11	Urban and minority unemployment	Pull driven system Specifying value Identifying the value stream	SDG1 (No poverty) SDG8 (Decent work and economic growth) SDG10 (Reduce inequalities)

12	Low status of women	Perfection Specifying value Identifying the value stream	SDG 5 (Gender equity) SDG4 (Quality education) SDG10 (Reduce inequalities) SDG 16 (Peace justice and strong institution)

Summary and conclusion

Sustainability is gaining popularity in the construction industry because of the industry's growing concern about the serious negative environmental impacts of construction activities. Construction waste management is critical to achieving sustainable development through environmentally friendly practices. Lean construction, on the other hand, can be used to overcome the environmental challenges of sustainable development. The construction industry has an impact on society, the economy, and the environment, whereas the industrial sector is one of the largest energy consumers. There is compelling evidence that combining lean and sustainable building techniques can benefit the sector and that the resulting synergy can help each technique accomplish its own aims. To conclude, there is need for significant adjustments in the operations of the construction industry to successfully address the global issues of the twenty-first century, particularly the need for sustainable development and the impact of climate change. Lean Construction will go a long way to solve these challenges facing the globe.

References

Abdul, R. H., Wang, C. & Yen, W. L. I., 2012. Waste Processing Framework for Non-Value: Adding Activities Using Lean Construction. Journal of Frontiers in Construction Engineering, 1(1), pp. 8-13.

Ahiakwo, O., Oloke, D., Suresh, S. & Khatib, J., 2013. A Case Study of Last Planner System Implementation in Nigeria. Fortaleza, s.n., pp. 699-707.

Ahuja, R., Sawhey, A. & Arif, M., 2017. Driving lean and green projects outcomes using BIM: a qualitative comparative analysis. International Journal of Sustainable Built Environment, pp. 69-80.

Alireza, A. & Sorooshian, S., 2014. Lean ManufacturingTools. Kuantan, Malaysia: UMP.

Andújar-Montoya, M. D., Gilart-Iglesias, V., Montoyo, A. & Marcos-Jorquera, D., 2017. A construction management framework for mass customisation in traditional construction. Sustainability, 7(5), pp. 5182-5210.

Ansah, R. H., Sorooshian, S. & Mustafa, S. B., 2016. Lean construction: An effective approach for project management. ARPN Journal of Engineering and Applied Sciences, 11(3), pp. 1607-1612.

Azevedo, S. G., Carvalho, H., Duarte, S. & Cruz-Machado, V., 2012. Influence of Green and Lean Upstream Supply Chain Management Practices on Business Sustainability. IEEE Transactions on Engineering Management, 59(4), pp. 753-765.

Aziz, R. F. & Hafez, S. M., 2013. Applying lean thinking in construction and performance improvement. Alexandria Engineering Journal, 52(4), pp. 679-695.

Banawi, A. & Bilec, M. M., 2014. A framework to improve construction processes: integrating lean, green and six sigma. International Journal of Construction Management, 14(1), pp. 45-55.

Barathwaj, R., Singh, R. V. & Gunarani, G. I., 2017. Lean construction: value stream mapping for residentials construction. International Journal of Civil Engineering and Technology, 8(5), pp. 1072-1086.

Barbosa, G., Andrade, F., Biotto, C. & Mota, B., 2013. Implementing Lean Construction Effectively in a Year in a Construction Project. s.l., s.n.

Bayhan, H. G., Demiirkesen, S., Zhang, C. & Tezel, A., 2022. A lean construction and BIM interaction model for the construction industry. Production Planning & Control.

Bergmiller, C. G. & McCright, P., 2009b. Parallel Models for Lean and Green Operations, s.l.: s.n.

Bergmiller, G. G. & McCright, P. R., 2009a. Are Lean and Green Programs Synergistic?. s.l., s.n., pp. 1155-1160.

Bertelsen, S., 2016. Lean construction: Where are we and how to proceed?. Lean Construction Journal, 1(1), pp. 46-69.

Bertelsen, S., 2016. Lean construction: Where are we and how to proceed?. Lean Construction Journal, 1(1), pp. 46-69.

Brady, D., Tzortzopoulos, P. & and Rooke, J., 2009. An Examination of the Barriers to Last Planner Implementation. s.l., s.n.

Brito, M., Ramos, A. L., Carneiro, P. & Gonclaves, M., 2019. The eight waste: non-utilized talent. In: Lean manufacturing: Implementation, opportunities and challenges. New York: Nova Science Publishers, pp. 151-164.

Carvajal-Arango, D. et al., 2019. Relationships between lean and sustainable construction: Positive impacts of lean practices over sustainability during construction phase. Journal of Cleaner Production, pp. 1322-1337.

Carvalho, H., Duarte, S. & Machado, V. C., 2011. Lean, agile, resilient and green: divergencies and synergies. International Journal of Lean Six Sigma, 2(2), pp. 151-179.

Cerveró-Romero, F., Napolitano, P., Reyes, E. & Teran, L., 2013. Last Planner System and lean approach process: Experiences from implementation in Mexico. s.l., s.n., pp. 709-718.

Cwik, K. & Rosłon, J., 2017. Last planner system in construction. s.l., s.n., pp. 1-4.

David, S. & Robert, M., 2003. Lean and green: 'doing more with less'. International Commerce Review : ECR Journal, 3(1), pp. 84-91.

Dey, P, K; Malesios, C; De, D; Chowdhury, S. & Abdelaziz, F, B . 2019. The Impact of Lean Management Practices and Sustainably-Oriented Innovation on Sustainability Performance of

Small and Medium-Sized Enterprises: Empirical Evidence from the UK. British Journal of Management, 31(1), pp. 141-161.

Dmitriev, N. & Zaytsev, A., 2021. Effectiveness of Lean Business Model in Circular Manufacturing. Kidmore End, s.n.

Duarte, S. & Cruz-Machado, V., 2015. Investigating lean and green supply chain linkages through a balanced scorecard framework. International Journal of Management Science and Engineering Management, pp. 20-29.

Dues, C. M., Tan, K. H. & Lim, M., 2013. Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. Journal of Cleaner Production, Volume 40, pp. 93-100.

Dulaimi, M. F. & Tanamas, C., 2001. The Principles and Applications of Lean Construction in Singapore. s.l., s.n.

Fahimnia, B., Sarkis, J. & Eshragh, A., 2015. A tradeoff model for green supply chain planning:A leanness-versus-greenness analysis. Omega, Volume 54, pp. 173-190.

Fang, Y., Daniel, E. I. & Lia, S., 2021. Conceptual framework for lean construction ambidexterity in project-based organizations. Construction Management and Economics, p. 824–838.

Faulkner, W. & Badurdeen, F., 2014. Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. Journal of Cleaner Production, Volume 85, pp. 8-18.

Figge, F. & Hahn, T., 2012. Is green and profitable sustainable? Assessing the trade-off between economic and environmental aspects. International Journal of Production Economics, 140(1), pp. 92-102.

Florida, R., 1996. Lean and Green: The move to environmentally conscious manufacturing. California Management Review, 39(1).

Friblick, F., Olsson, V. & Reslow, J., 2009. Prospects of Implementing Last Planner in the Construction Industry. s.l., s.n.

Galeazzo, A., Furlan, A. & Vinelli, A., 2014. Lean and green in action: interdependencies and performance of pollution prevention projects. Journal of Cleaner Production, Volume 85, pp. 191-200.

Garza-Reyes, J. A., Kumar, V., Chen, F. & Wang, Y.-C., 2017. Editorial. International Journal of Lean Six Sigma, 8(1), pp. 2-6.

Ghosh, S., 2014. Does Formal Daily Huddle Meetings Improve Safety Awareness?. International Journal of Construction Education and Research, 10(4), pp. 285-299.

Ghosh, S. & Robson, K. F., 2015. Analyzing the Empire State Building Project from the Perspective of Lean Delivery System—A Descriptive Case Study. International Journal of Construction Education and Research, 11(4), pp. 257-267.

Hajmohammad, S., Vachon, S. K. R. D. & Gavronski, L., 2013. Lean management and supply management: their role in green practices and performance. Journal of Cleaner Production, Volume 39, pp. 312-320.

Herrmann, C., Thiede, S., Stehr, J. & Bergmann, L., 2008. An environmental perspective on Lean Production. Manufacturing Systems and Technologies for the New Frontier, pp. 83-88.

Howell, G. A., Ballard, G. & Demirkesen, S., 2017. Why lean projects are safer?. Heraklion, s.n.

Howell, G. & Ballard, G., 1994. Lean production theory: Moving beyond Can-Do. s.l., s.n.

Huaman-Orosco, C., Erazo-Rondinel, A. A. & Herrera, R. F., 2022. Barriers to Adopting Lean Construction in Small and Medium-Sized Enterprises—The Case of Peru. Buildings, 12(10).

Jabbour, C. J. C. et al., 2013. Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing. Journal of Cleaner Production, Volume 47, pp. 129-140.

Johansen, E. & Walter, L., 2007. Lean Construction: Prospects for the German Industry. Lean Construction Journal, 3(1), pp. 9-32.

Jum'a, L., Zimon, D., Ikram, M. & Madzík, P., 2022. Towards a sustainability paradigm; the nexus between lean green practices, sustainability-oriented innovation and Triple Bottom Line. International Journal of Production Economics, Volume 245.

King, A. A. & Lenox, M. J., 2009. Lean and Green: An empirical examination of the relationship between lean production and environmental performance. Production and Operations Management, 10(3), pp. 244-256.

Ko, C.-H. & Chung, N.-F., 2014. Lean design process. Journal of construction engineering and management, 140(6), pp. 01-11.

Koranda, C; Chong, W, K; Kim, C; Chou, J.-S. & Kim, C. 2012. An investigation of the applicability of sustainability and lean concepts to small construction projects. KSCE Journal of Civil Engineering, Volume 16, pp. 699-707.

Koskela, L., 1992. Application of the new production philosophy to construction, Standford: Center for Integrated Facility Engineering.

Koskela, L., Howell, G., Ballard, G. & Tommelein, I., 2002. The foundations of lean construction. In: Design and Construction: Building in Value. s.l.:Routledge, pp. 211-226.

Kuriger, G. W. & Chen, F. F., 2010. Lean and Green: A Current State View. In: Proceedings of the 2010 Industrial Engineering Research Conference. Norcross: s.n., pp. 1-6.

Ladhad, A. & Parrish, K., 2013. Phoenix's first net-zero energy office retrofit: a green and lean case study. Journal of Green Building, 8(4), pp. 3-16.

Larson, T. & Greenwood, R., 2004. Perfect complements: Synergies between lean production and eco-sustainability initiatives. Environmental Quality Management, 13(4), pp. 27-36.

Lean Enterprise Institute, 2023. Lean Thinking and Practice. [Online]

Available at: https://www.lean.org/lexicon-terms/lean-thinking-and-practice/

[Accessed 17 February 2023].

Li, S., Fang, Y. & Wu, X., 2020. A systematic review of lean construction in Mainland China. Journal of Cleaner Production, Volume 257.

Madanayake, U. H., 2015. Application of lean construction principles and practices to enhance the construction performance and flow. Colombo, Ceylon Institute of Builders, pp. 109-126.

Marhani, M. A., Jaapar, A., Nor, A. A. & Zawawi, M., 2013. Sustainability through lean construction approach: A literature review. Procedia- Social and Behavioural Science, Volume 101, pp. 90-99.

Mavridou, T. & Tsigkas, A., 2018. Design of industrial buildings: when lean meets sustainability. International Journal of Development and Sustainability, 7(4), pp. 1462-1473.

Mohaghegh, M., Blasi, S. & Grobler, A., 2021. Dynamic capabilities linking lean practices and sustainable buisness performance. Journal of cleaner production, 322(1).

Mollenkopf, D., Stolze, H., Tate, W. L. & Ueltschy, M., 2010. Green, lean, and global supply chains. International Journal of Physical Distribution & Logistics Management, 40(1/2), pp. 14-41.

Muhammad, W. M. N., Ismail, Z. & Hashim, A. E., 2013. Exploring lean construction components for Malaysian construction. Langkawi, Malaysia, s.n.

Murmura, F., Bravi, L. & Santos, G., 2021. Sustainable process and product innovation in the eyewear sector: the role of industry 4.0 enabling technologies. Sustainability, 13(1), pp. 1-17.

Nahmens, I. & Ikuma, L. H., 2009. An empirical examination of the relationship between lean construction and safety in the industrialized housing industry. Lean Construction Journal, pp. 1-12.

Nahmens, I. & Ikuma, L. H., 2012. Effects of Lean Construction on Sustainability of Modular Homebuilding. Journal of Architectural Engineering, Volume 18, pp. 155-163.

Nesensohn, C., Demir, T. & and Bryde, D. J., 2012. Developing a 'True North' Best Practice Lean Company with Navigational Compass. s.l., s.n.

Ng, R., Low, J. S. C. & Song, B., 2015. Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric. Journal of Cleaner Production, Volume 95, pp. 242-255.

Ng, S. T., Zheng, D. X. & Xie, J. Z., 2013. Allocation of construction resources through a pull-driven approach. Construction Innovation, 13(1), pp. 77-97.

Nikakhtar, A., Hosseini, A. A., Wong, K. Y. & Zavichi, A., 2015. Application of lean construction principles to reduce construction process waste using computer simulation: A case study. International Journal of Services and Operations Management, 20(4), pp. 461-480.

Ogunbiyi, O. & Goulding, J., 2014. An empirical study of the impact of lean construction techniques on sustainable construction in the UK. Construction Innovation, 14(1), pp. 88-107.

Pekuri, A., Pekuri, L. & Haapasalo, H., 2014. Lean as a buisness model. Oslo, s.n., pp. 51-60.

Piercy, N. & Rich, N., 2015. The relationship between lean operations and sustainable operations. International Journal of Operations & Production Management, 35(2), pp. 282-315.

Pinch, L., 2005. Lean construction: Eliminating Waste. Construction Executive.

Poleise, P., Frodell, M. & Josephson, P., 2009. Implementing Standardisation in Medium-Sized Construction Firms: Facilitating Site Managers' Feeling of Freedom. s.l., s.n., pp. 317-325.

Porwal, V., Ferandez-Solis, J., Lavy, S. & Rybkowski, Z. K., 2010. Last Planner System Implementation Challenges. s.l., s.n., pp. 548-556.

Radhika, R. & Sukumar, L., 2017. An overview of the concept of Lean Construction and the Barriers in its Implementation. International Journal of Engineering Technologies and Management Research, 4(3), pp. 13-26.

Rodrigues, J. et al., 2019. Lean management "quick-wins": results of implementation. A case study. Quality innovation prosperity, 23(3).

Rosa, C., Silva, F. J. G., Ferreira, L. P. & Sa, J. C., 2019. Lean manufacturing applied to the production and assembly lines of complex automative parts. In: Lean manufacturing: Implementation, opportunities and challenges. New York: Nova Science Publishers, pp. 189-224.

Rosenbaum, S., Toledo, M. & Gonzalez, V., 2013. Improving environmental and production performance in construction projects using value-stream mapping: case study. Journal of Construction Engineering and Management, 140(2).

Roser, C., 2020. [Online]

Available at: https://www.allaboutlean.com/lead-time-development/concurrent-engineering/

[Accessed 12 February 2023].

Rothenberg, S., Pil, F. S. & Maxwell, J., 2009. Lean green and the quest for superior environmental performance. Production and Operations Management, pp. 228-243.

Salem, O., Solomon, J., Genaidy, A. & Luegring, M., 2005. Site implementation and assessment of lean construction techniques. Lean Construction Journal, 2(2), pp. 1-21.

Salontis, K. & Tsinopoulos, C., 2016. Drivers and barriers of lean implementation in the Greek manufacturing sector. Proceedia CIRP, pp. 189-194.

Sandberg, E. & Bildsten, L., 2011. Coordination and waste in industrialised housing. Construction Innovation, pp. 77-91.

Santos, G. et al., 2019. Value creation through quality and innovation- a case study on portugal. TQM Journal, 31(6), pp. 928-947.

Sarhan, S. & Fox, A., 2013. Barriers to Implementing Lean Construction in the UK Construction Industry. The Built & Human Environment Review, 6(1).

Sarhan, S. & Pretlove, S., 2021. Lean and Sustainable Construction: State of the Art and Future Directions. Construction Economics and Building, 21(3).

Simpson, D. F. & Power, D. J., 2005. Use the supply relationship to develop lean and green suppliers. Supply Chain Management, 10(1), pp. 60-68.

SketchBubble, 2023. [Online]

Available at: https://www.sketchbubble.com/en/presentation-daily-huddle.html

[Accessed February 2023].

Solaimani, S. & Sedighi, M., 2020. Towards a holistic view on lean sustainable construction: A literature review. Journal of Cleaner Production, Volume 248.

Sundar, R., Balaji, A. N. & Kumar, R. M. S., 2014. A review on lean manufacturing implementation techniques. Procedia Engineering, pp. 1875-1885.

Teixeira, P; Sa, J, C; Silva, F, J, G; Ferreira, L, P; Santos, G; Fontoura, P., 2021. Connecting lean and green with sustainability towards a conceptual model. Journal of cleaner production, Volume 322.

Tommelein, I. D., 2015. Journey toward Lean Construction: Pursuing a Paradigm Shift in the AEC Industry. Journal of Construction Engineering and Management, 141(6).

Varela, L; Araujo, A; Avila, P; Castro, H. & Putnik, G., 2019. Evaluation of the relation between lean and manufacturing, industry 4.0, and sustainability. Sustainability, Volume 11.

Verrier, B; Rose, B; Caillaud, E. & Remita, H., 2014. Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository. Journal of Cleaner Production, Volume 85, pp. 83-93.

Verrier, B., Rose, B. & Caillaud, E., 2016. Lean and Green strategy: the Lean and Green House and maturity deployment model. Journal of Cleaner Production, Volume 116, pp. 150-156.

Viana, D; Mota, B; Formoso, C, T; Echeveste, M; Peixoto, M. & Rodrigues, C, L., 2010. A Survey on the Last Planner System: Impacts and Difficulties for Implementation in Bazilian Companies. s.l., s.n., pp. 497-507.

Vinodh, S., Arvind, K. R. & Somanaathan, M., 2011. Tools and techniques for enabling sustainability through lean initiatives. Clean Technologies and Enviornmental Policy, Volume 13, pp. 469-479.

Wandahl, S., 2014. Lean construction with or without lean- challenges of implementing lean construction. Oslo, s.n., pp. 97-108.

Wijerathne, M. D. I. R., Gunasekara, K. A. & Perera, B. A. K. S., 2019. Overcoming the challenges of sustainable development in sri lanka using lean construction principles. s.l., s.n., pp. 473-483.

Womack, J. P. & Jones, D. T., 1996. Lean thinking: Banish Waste and Create Wealth in Your Corporation. London: Simon and Schuster.

Yang, M., Hong, P. & Sachin, B. M., 2011. Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. International Journal of Production Economics, 129(2), pp. 251-261.

Yin, S, Y-L; Tserng, H, P; Toong, S, N. & Ngo, T, L. 2014. An improved approach to the subcontracting procurement process in a lean construction setting. Journal of Civil Engineering and Management, 20(3), pp. 389-403.

Zaeri, F., Rotimi, J. O. B., Hosseini, M. R. & Cox, J., 2017. Implementation of the LPS using an excel spreadsheet: a case study from the New Zealand construction industry. Construction Innovation, 17(3), pp. 324-339.

Zhang, X., Azhar, S., Nadeem, A. & Khalfan, M., 2017. Using Building Information Modelling to achieve Lean principles by improving efficiency of work teams. International Journal of Construction Management, 18(4), pp. 293-300.

Zott, C., Amit, R. & Massa, L., 2011. The Business Model: Recent Developments and Future Research. Journal of Management, 37(4), pp. 1019-1042.