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INVESTIGATING THE ROLE OF LEAN TOOLS IN MINIMIZING CONSTRUCTION WASTE ACROSS THE TRIPLE BOTTOM LINE

Zeina Malaeb[1] and Farook Hamzeh[2]

ABSTRACT

The prevalence of waste in the construction industry and its contribution to project failure challenges sustainability targets. Therefore, waste reduction is key to sustainable construction. Lean construction recognizes the criticality of waste elimination and proposes tools and practices to minimize waste and maximize value. Nevertheless, the categorization of waste in the literature focuses on economic waste and gives less attention to environmental and social waste. Moreover, research on the role of lean tools in waste management primarily addresses economic advantages and overlooks the other sustainability pillars, thereby providing an unbalanced targeting of sustainability goals. Accordingly, there is a need to adopt a holistic perception of waste and address the contribution of lean in eliminating waste across the triple bottom line, representing environmental, social, and economic dimensions. For that, this paper conducts a literature review of existing studies to identify, categorize, and analyze the different waste categories and the role of lean tools in minimizing them. It fills the gap in the literature and presents two main contributions: (1) a well-rounded table of wastes across environmental, social, and economic dimensions and (2) a figure identifying and matching the waste management role of each lean tool to its corresponding sustainability pillar.

KEYWORDS

Environment, lean tools, sustainability, triple bottom line, waste

INTRODUCTION

Waste in construction projects is a main cause of project failure and has been proven to result in low productivity, lack of health and safety, time overruns, cost overruns, and diminished competitive advantage (Emuze and Saurin, 2015). The current state of projects shows a prevalence of waste, where cost overruns extend to 14% of the contract sum, around 70% of projects are delayed past the planned completion dates, and almost 10% of construction material is wasted (Babola et al., 2019). In fact, Dupin (2014) found that 68% of the time spent on sites comprises non-value adding activities. Additionally, Khanh and Kim (2014) estimated the cost of construction waste to be 9.4% of the total construction budget. Furthermore, Bajjou and Chafi (2020) confirmed that around 95% of project tasks include wasteful actions.

In this regard, lean construction recognizes the adverse effects of waste on projects and the criticality of waste elimination, the latter being a chief principle of the lean philosophy and practices as inspired by the Toyota Production System (TPS) (Emuze and Saurin, 2015). To this end, lean proposes various tools and practices to minimize waste and maximize value, and

1 Ph.D. Student, Civil and Environmental Engineering Department, University of Alberta, Edmonton, Canada, malaeb@ualberta.ca, https://orcid.org/0000-0002-1979-3923

2 Professor, Civil and Environmental Engineering Department, University of Alberta, Edmonton, Canada, hamzeh@ualberta.ca, https://orcid.org/0000-0002-3986-9534

its application has shown positive enhancements in productivity and cost savings on construction projects (Arroyo and Gonzalez, 2016).

However, the definition and categorization of waste in the lean literature tend to focus on the economic characteristics and effects of such waste (Arroyo and Gonzalez, 2016). In fact, the term "waste" is often associated with financial connotations, conceptualized as unneeded cost to the affected stakeholders (Emuze and Saurin, 2015). Nevertheless, an essential type of waste that is often overlooked is environmental waste (Belayutham and Gonzalez, 2013), which is especially significant in construction projects since construction activities are ranked among the "leading environmentally unfriendly endeavours globally" (Babola et al., 2019). On the other hand, the wasteful effects on the project stakeholders and society have also been largely neglected (Arroyo and Gonzalez, 2016). Therefore, the popular conception of waste in the construction industry lacks a complete representation of non-value added activities across the three pillars of sustainability: environment, society, and economy. Furthermore, while lean construction has introduced promising techniques to reduce construction waste, research has focused more on the role of lean tools in eliminating economic waste as opposed to environmental and social wastes.

Considering the significance of targeting sustainability goals in the construction industry, there is a need for a well-rounded list of environmental, social, and economic wastes in construction to facilitate the identification and elimination of these wastes for optimized project outcomes (Arroyo and Gonzalez, 2016; Emuze and Saurin, 2015). Moreover, there is a strong necessity to explicitly establish the role of the main lean tools in reducing wastes across the triple bottom line (TBL), representing environmental, social, and economic dimensions. To this end, this paper conducts a comprehensive literature review to identify the various wastes from previous studies and subsequently categorizes them under the three pillars of sustainability. Next, the paper provides an overview of the five main lean tools: 5S, just-in-time (JIT), prefabrication, value stream mapping (VSM) and the last planner system (or LPS) to pinpoint the contribution of each tool in eliminating wastes across the three pillars of sustainability. Finally, the paper presents two significant outcomes: (1) a well-rounded table of wastes along the TBL and (2) a figure matching the waste management role of each lean tool to its corresponding sustainability pillar. The contribution of this research is in its presentation of a holistic assessment of construction waste and the utilization of lean in all aspects of sustainable waste management.

METHODOLOGY

As a first step, a background study was carried out on the types of construction waste, on one hand, and the role of lean construction in waste management, on the other, to identify the problem statement and set the scope of this paper. Accordingly, two ultimate aims of the study were set, (1) to identify and categorize the different wastes under the three pillars of sustainability: environment, society, and economy, and (2) to determine the role of the main lean tools in eliminating waste across the triple bottom line. The second step was literature collection whereby a search was performed to identify articles with the following phrases in subjects, titles, keywords or abstracts: construction waste, non-value added activities "and" economy, environment, green, lean, society, and sustainability. Another parallel search was conducted using the words: lean tools, lean processes, 5S, just-in-time (or JIT), prefabrication, value stream mapping (VSM) and the last planner system (or LPS) "and" construction waste, non-value added activities. All the journals and conference papers selected were peer reviewed to ensure quality information. In the third step, literature filtration was performed through reviewing the abstracts of the articles to assess their relevance. From the first search, articles that did not explicitly identify types or sources of construction waste were removed. From the second search, articles which insufficiently described the use of lean tools to minimize waste were eliminated. The fourth step was literature synthetization, whereby the various types of waste were obtained from the different papers, filtered, grouped, and categorized under the relevant sustainability headings. Furthermore, the influence of lean tools on environmental, economic, and social aspects of waste management was identified. Finally, an analysis of the findings was done to present two main contributions, the first being a well-rounded table categorizing the different types of waste under environment, society, and economy and the second being a diagram matching each lean tool to the waste it targets.

LITERATURE REVIEW

DEFINITION AND CLASSIFICATION OF CONSTRUCTION WASTE IN LEAN CONSTRUCTION

Traditionally, construction waste was conceptualized as purely physical or material waste but later evolved to include other types of waste (Francis and Thomas, 2020). Detailed investigations conducted in the field of construction waste management over the last 20 years reveal that waste is generally classified into three categories of 19 factors (Khanh and Kim, 2014), including (1) direct conversion waste from materials, labor, and equipment (2) non-contributory time waste pertaining to delays from waiting, traveling, inactivity and rest and (3) contributory time waste related to transportation, inspection, supervision, instructions and communication (Arroyo and Gonzalez, 2016; Koskela et al., 2013). With the emergence of lean construction, inspired by the lean production philosophies of the Toyota Production System (TPS), waste took on a broader meaning (Francis and Thomas, 2020). From a lean perspective, waste is defined as “activities that consume time and resources but fail to add value to the final product” (Macomber and Howell, 2004). Waste relates to both the processes involved, such as the overuse of resources, and the output of the system, comprising the final product (Bolviken et al., 2014). In lean, construction processes are classified into value-adding and non-value adding activities, the latter being the wastes (Francis and Thomas, 2020). Since the capacity of any production system is the sum of value-adding work and non-value adding waste in the system, minimizing waste is essential for maximizing the production capacity (Ohno, 1988).

The classification of lean wastes follows those set by Ohno (1988), who defined seven types of waste in production: overproduction, rework, material movement, processing, inventory, waiting and motion. Alarcon (1997) built on Ohno’s previous work and defined 17 wastes for construction, which included: work not done, rework, unnecessary work, errors, stoppages, waste of material, deterioration of material, loss of labor, unnecessary movement of people and of material, excessive vigilance, extra supervision, additional space, delays, extra processing, clarifications, and abnormal wear and tear of equipment. Garas et al. (2001) sorted construction waste into material wastes, which included over-ordering, overproduction, wrong handling, wrong storage, manufacturing defects, and theft or vandalism, and time wastes, which covered waiting periods, stoppages, clarifications, variation in information, rework, ineffective work, interaction between various specialists, delays in activities, and abnormal wear of equipment. Josephson and Saukkoriipi (2005) defined waste along four categories: (1) defects and checks, covering defect costs and costs of checks for insurance and vandalism, (2) inefficient use of resources (3) health and safety injuries and illnesses, and (4) systems and structures, relating to ineffective planning, procurement, and managerial processes. Koskela et al. (2013) introduced construction-related wastes not explicitly defined by the TPS, including rework, design errors and omissions, and work accidents. They also added an eighth type of waste to Ohno’s list, “making do”, which occurs when a task starts before all its preconditions have been met, which results in unfavourable side-effects, including rework and health and safety hazards. Bolviken et al. (2014) categorized wastes based the transformation–flow–value (TFV) theory of production control, where transformation wastes included material loss, flow wastes covered time loss, and value wastes comprised value loss.

Although the above listing of wastes appears to be exhaustive, it is largely associated with economic connotations and calculated as unwanted costs, in the form of "direct cost", due to wasting resources, and "indirect costs", such as low return on investment resulting from excessive inventory and low output (Bolviken et al., 2014; Emuze and Saurin, 2015). Nevertheless, environmental waste is a significant type of waste that is overlooked in the literature and in lean management (Arroyo and Gonzalez, 2016; Belayutham and Gonzalez, 2013). On the other hand, the social dimension of waste is often neglected as lean implementation in construction focuses on technical rather than human and social factors and limited studies on waste management consider the triple bottom line of sustainability (Arroyo and Gonzalez, 2016). In this regard, Francis and Thomas (2020) reviewed the studies published in the domain of lean construction and environmental sustainability to identify environmental wastes and discussed air emissions, energy waste, GHG emissions, and material waste. Moreover, Arroyo and Gonzalez (2016) conducted a comprehensive literature review on the types of construction waste and suggested the addition of certain environmentally harmful factors, including air emissions, solid waste, wastewater, noise, over-illuminating, and overuse of soil as well as social factors, such as lack of health and safety, suboptimal working conditions, loss of employment, and unused innovation, among others. Although they did not explicitly define wastes, Johnsen and Drevland (2016) determined indicators of environmental, social and economic sustainability to show how lean principles assist in improving the positive rating of those indicators. More recently, Waheed et al. (2024) conducted an exploratory literature review of papers published between 2018 and 2023 to investigate the intersection of lean and sustainability practices during the early construction design stage. They identified that the main sources of design waste were the lack of clarity and communication, poor information supply, coordination issues, and insufficient design expertise. Moreover, they described the most effective lean tools for early design waste reduction to enhance environmental, social, and economic performance.

THE ROLE OF LEAN TOOLS AND TECHNIQUES IN WASTE MANAGEMENT

Garcia-Alcaraz et al. (2022) used Structural Equation Modeling to investigate the relationship between eight Lean Manufacturing Tools (LMT), grouped under continuous improvement, supporting tools, and machinery/equipment, and sustainability in the Mexican maquiladora industry. They proved that LMTs contribute to social, economic, and environmental sustainability by reducing waste, energy consumption, and environmental emissions, while also improving workplace safety and labor relations. On another hand, Hasan et al. (2024) investigated the synergies between lean construction principles and the United Nations Sustainable Development Goals (SDGs) to evaluate their effectiveness in reducing the environmental impact of the construction industry. The authors identified 63 extremely important and 251 very important linkages between lean principles and SDG targets, primarily environmental (42%), economic (39%), and social (19%) in nature, with the core lean principles of reducing non-value-adding activities, focusing on all processes, and continuous improvement being central to these synergies.

Along similar lines, this research investigates the sustainability impact of five main lean tools and techniques, being 5S, JIT, Prefabrication, VSM, and LPS, selected due to having directly evolved from the principles of lean construction as classified by Francis and Thomas (2020). The following section describes the role of the main lean tools in minimizing different types of waste, as described in the literature.

1) 5S

5S is a tool that is generally adopted by construction companies as a first step to introducing "lean" into processes (Francis and Thomas, 2020). As its name suggests, this tool includes five S's: Sort, Straighten, Shine, Standardize, and Sustain, which Salem et al. (2014) described as follows: (1) Sort: removing tools and items not used in the construction process, (2) Straighten: arranging tools and equipment by sequence of use to set the work-zone in order, (3) Shine: cleaning and keeping the work areas in order, (4) Standardize: standardizing all operations and processes to ensure consistency and make workers aware of their responsibilities, and (5) Sustain: confirming that the management follows the above 4 S's, once established, and does not go back to the previous, less-effective operation methods. Although primarily associated with economic benefits, a more in-depth analysis of the advantages offered by this tool reveals its contribution to all pillars of sustainability. From an economic perspective, 5S results in considerable cost reductions and increased efficiency of processes, since workers are able to find what is needed without wasting time (Salem et al., 2014). Moreover, 5S improves productivity, quality, set-up-times, lead times, cycle times, and machine uptimes (Spoore, 2003). On the other hand, through appropriate labeling and organization of material inventory, 5S improves the ability to quickly identify hazardous spills and leakages and to reduce air pollution (Vieira and Cachadinha, 2011). Furthermore, implementing 5S on highway construction and maintenance projects can minimize the waste and pollution produced in work zones (Salem et al., 2014). To contribute to social sustainability, 5S increases safety, minimizes accidents, reduces injury rates, enhances morale, and improves poor health and safety conditions on projects by keeping tools and equipment organized and the workspace clean (Salem et al., 2014; Spoore, 2003). In fact, Bae and Kim (2008) confirmed that 5S can facilitate securing credits in the LEED rating system since it ensures a healthy, safe and organized work environment for the workers.

2) Just-in-Time (JIT)

The just-in-time technique (JIT) mandates procuring the right resources at the right time to maintain optimally sized inventories (Bamana et al., 2019). JIT describes more frequent deliveries to the project site, with a smaller number of components in each batch (Kong et al., 2018). The chief lean goal behind employing JIT is to eliminate different types of waste, including overproduction, waiting, transportation of material on site, motion of workers, processing, storage, and defective products (Akintoye, 1995). Applying JIT to projects improves quality and productivity through reducing on-site waste and optimizing the movement of inventory and the utilization of equipment (Pheng et al., 2012). In precast construction, JIT allows for the delivery of precast components to site directly to assembly, resulting in zero inventory and avoiding double-handling, which saves the time and cost of using on-site resources, such as temporary holding areas, expensive cranes, and manpower (Kong et al., 2018). The reduced cost of inventory is significant, as material inventories generate several costs, including storage costs, insurance costs, costs related to obsolescence, and monitoring against theft (Bamana et al., 2019). From an environmental perspective, JIT minimizes waste by reducing damage to stored material on site which, in turn, reduces unnecessary energy use and emissions that would occur in case of material damage and replacement (Francis and Thomas, 2020). Nevertheless, in order to ensure optimum environmental benefits when using JIT, local material is preferable to reduce the need for stocking, and transportation distance and traffic must be minimized to reduce carbon emissions from the frequent deliveries (Kong et al., 2018).

3) Prefabrication

A critical component of lean supply, prefabrication is the process of preparing construction elements in a controlled off-site environment and subsequently transporting them to the construction projects for installation (Francis and Thomas, 2020). Prefabrication has proven economic benefits, including improved quality and productivity, shorter and more reliable schedules, reduced material consumption, and diminished overall life cycle costs (Luo et al., 2005). Bhattacharjee et al. (2016) compared façade construction using prefabricated components to another using conventional construction methods and confirmed an improvement in cost, quality and time and reduction in rework for the former method. On the other hand, prefabrication reduces energy and water requirements and enables facilitated recycling and waste management (Francis and Thomas, 2020). Prefabrication also decreases air and noise pollution due to minimized site operations (Luo et al., 2005). Peng and Pheng (2011) reported an 8.3% decrease in carbon emissions due to lean implementation in precast concrete factories. Nevertheless, the location of the prefabricating yard must be considered in order to minimize energy consumption and pollution from excessive transport for delivery (Luo et al., 2005). From the social perspective, using prefabrication reduces work activities on site which minimizes worker exposure to heights, bad weather and hazardous operations and therefore provides safer working spaces (Luo et al., 2005).

4) Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is an essential lean tool that provides a visual presentation of a process by mapping the flow of information and material from start to end (Francis and Thomas, 2020). To implement VSM, the existing state of the process is represented through a current state map to detect various wastes embedded in the value stream and eliminate them (Rosenbaum et al., 2013). VSM promises economic benefits in construction similar to those obtained in manufacturing. Gunduz and Naser (2017) adopted a cost-based VSM with Line of Balance scheduling to improve the productivity in underground pipeline projects. They were able to achieve a cost reduction of 20.8% between current and future states. On the other hand, Ramani and KSD (2019) applied VSM to a structural steel erection project to observe the possible productivity improvement. In their case study, they substantially enhanced the productivity and reduced the project duration by 13 days, which represented a 30% time saving on the project. While VSM is primarily targeted at eliminating economic wastes in the process, it has significant potential to reduce environmental waste. Rosenbaum et al. (2013) conducted a study to improve the construction of structural elements for a medical center in Chile. In their application of VSM, they introduced environmental indicators to detect material waste, such as steel and concrete, and energy wastes, such as fuel. Moreover, Faulkner and Badurdeen (2014) proposed a Sustainable-VSM that includes environmental parameters, such as water, energy, and emissions, to quantify their flow and identify potential sources of environmental waste. In addition, Vinodh et al. (2011) added further environmental criteria to the VSM, including environment health and safety data, water usage, material usage. In order to assess social sustainability, the "Sustainable-VSM" proposed by Faulkner and Badurdeen (2014) also included social metrics, comprising the physical work metric and the work environment metric. The physical work metric measures the physical ergonomics of the workplace while the work environment metric covers cover four risk categories related to electrical systems, hazardous chemicals/materials used, pressurized systems, and high-speed components.

5) Last Planner System (LPS)

The Last Planner System (LPS) is a collaborative planning and control system, used to assist in leveling variations in construction workflow, develop planning foresight, and minimize uncertainty in construction operations (Hamzeh et al., 2012). LPS focuses on the collaborative management of the stakeholder network required for project delivery and promotes conversations between trade foremen and site management (Salem et al., 2014). LPS proposes numerous benefits to the project processes, which ultimately translate to economic improvements in project time and cost, including (1) smooth workflow, (2) predictable work plans, (3) improved productivity (4) reduced cost and (5) reduced time of project delivery (Fernandez et al., 2013). Even though LPS is not chiefly focused on reducing environmental wastes, researchers have found that this system does provide environmental advantages. Salem et al. (2014) demonstrated that implementing LPS on pavement projects enabled the reduction of traffic due to better activity coordination and eventually resulted in minimizing environmental emissions as well as noise pollution. Moreover, Ghosh et al., (2014) found that using LPS facilitated the identification of constraints beforehand to minimize rework and its resultant material and labor wastage, which ultimately promoted a reduction of material waste by 6% and a decrease in emissions of 7.5 MT CO_2 equivalent in a single component process. From a social viewpoint, using lean construction tools such as LPS was found to reduce accident rates by around 45% (Thomassen et al., 2003).

RESULTS AND DISCUSSION

IDENTIFICATION AND CLASSIFICATION OF ENVIRONMENTAL, SOCIAL, AND ECONOMIC WASTE

Based on a thorough identification and categorization of the wastes in previous studies, Table 1 presents a rounded classification of the different types of construction waste under the three pillars of sustainability: environmental, social, and economic. This presentation fills the gap in the literature, where the primary focus is on economic or monetary wastes and adds to the contributions by Francis and Thomas (2020), who introduced a number of environmental wastes, and Arroyo and Gonzalez (2016), who considered a number of environmental and social wastes, by providing additional types of waste across the triple bottom line and outlining the intersection of these wastes along the different categories. For instance, certain wastes can have both environmental and economic implications, such as material waste, overuse of equipment, transport to site, inventory, and energy consumption. In fact, those factors are harmful to the environment and result in unneeded cost at the same time; therefore, eliminating these causes benefits two pillars of sustainability. On the other hand, particular wastes, such as the unnecessary movement of people and work accidents, affect both economic and social aspects since these factors impose additional cost, on one hand, and impact the social well-being of project stakeholders, on the other. Accordingly, it is essential to recognize the various types and categories of waste and understand their interactions for optimized waste management on construction projects.

Table 1: Types of Waste across the Three Sustainability Pillars

Pillar	No.	Type of Waste	Source(s)
ENVIRONMENTAL	1	Air emissions	EPA (2015), Johnsen and Drevland, 2016
	2	Solid Waste	EPA (1998)
	3	Wastewater	Arroyo and Gonzalez (2016)
	4	Over Illuminating	Simpson (1990)
	5	Excess soil use	RCCAO (2012)
	6	Carbon emissions from material choice	Johnsen and Drevland (2016)
	7	Material waste*	Johnsen and Drevland (2016)

	8	Overuse of equipment *	Johnsen and Drevland (2016)
	9	Transport to site*	Francis and Thomas (2020)
	10	Inventory (higher energy consumption for space lighting and ventilation) *	Francis and Thomas (2020)
	11	Energy use/ consumption*	Johnsen and Drevland (2016)
SOCIAL	1	Unused employee creativity and innovation	Arroyo and Gonzalez (2016), Macomber and Howell (2004), Von Geibler et al. (2006)
	2	Lack of health and safety**	Von Geibler et al. (2006), Johnsen and Drevland (2016)
	3	Suboptimal and inefficient working conditions	Von Geibler et al. (2006)
	4	Lack of education, training, and professional growth	Von Geibler et al. (2006)
	5	Knowledge not capitalized and recorded for learning	Von Geibler et al. (2006)
	6	Lack of contribution to societal benefits	Von Geibler et al. (2006)
	7	Lack of communication with involved stakeholders	Von Geibler et al. (2006)
	8	Lack of equality in workplace	Johnsen and Drevland (2016)
	9	Excessive Stress	Johnsen and Drevland (2016)
	10	Excessive Overtime	Johnsen and Drevland (2016)
	11	Noise disturbance	Johnsen and Drevland (2016), Salem et al. (2014)
ECONOMIC	1	Errors and Rework	Alarcon (1997), Johnsen and Drevland (2016), Koskela et al. (2013), Ohno (1988)
	2	Productivity Loss	Johnsen and Drevland (2016)
	3	Profitability Loss	Johnsen and Drevland (2016)
	4	Cost (Budget Overrun)	Johnsen and Drevland (2016)
	5	Time (Schedule Overrun)	Johnsen and Drevland (2016)
	6	Unacceptable Quality	Johnsen and Drevland (2016)
	7	Changes	Johnsen and Drevland (2016)
	8	Unnecessary work	Alarcon (1997)
	9	Stoppages and waiting	Alarcon (1997), Ohno (1988), Shingo (1981)
	10	Inefficient use of resources*	Josephson and Saukkoriipi (2005)
	11	Overproduction/ material wastage*	Alarcon (1997), Ohno (1988), Shingo (1981)
	12	Material damage/defects*	Alarcon (1997), Ohno (1988), Shingo (1981)
	13	Unnecessary movement of people**	Alarcon (1997), Ohno (1988), Shingo (1981)
	14	Unnecessary movement of material*	Alarcon (1997), Ohno (1988), Shingo (1981)
	15	Extra processing*	Alarcon (1997), Ohno (1988), Shingo (1981)
	16	Inventory*	Ohno (1988), Shingo (1981)
	17	Work accidents**	Josephson and Saukkoriipi (2005), Koskela et al. (2013)
	18	Theft and vandalism	Garas et al. (2001), Josephson and Saukkoriipi (2005)

**Common waste between environmental and economic; ** Common waste between economic and social*

ROLE OF LEAN TOOLS IN MINIMIZING WASTE ACROSS THE TRIPLE BOTTOM LINE

The second contribution, Figure 1, depicts the role of the different lean tools in construction waste management across the triple bottom line. The relationships were established based on a comprehensive review of the literature, accumulation and categorization of the various roles that lean tools play along different sustainability pillars. This exerctblise involved additional analysis from the author's part since some studies described benefits of these tools without specifically identifying their contribution to sustainability factors. Moreover, some studies identified certain roles as related to one sustainability pillar, while the same roles could be related to other pillars as well. For example, although not discussed in the literature, both JIT and prefabrication can have social benefits through reducing congestion of material and equipment on site, which minimizes accident rates and increases safety. Moreover, while prefabrication may negatively affect on-site job opportunities as most operations are moved to the factory, a solution to maintain its social benefits is to create other jobs for these workers in the factories or on site. On the other hand, an additional significant social advantage of LPS is its inclusion of all project stakeholders in the collaborative planning process, where every member is heard and can contribute.

Analyzing the figure further, it is apparent that the application of lean in construction is not largely focused on economic sustainability, as described in the majority of the literature, but has significant environmental and social benefits. Nevertheless, lean tools should be judiciously utilized, considering certain constraints, with the intention of maximizing value and minimizing harm for optimum sustainability benefits.

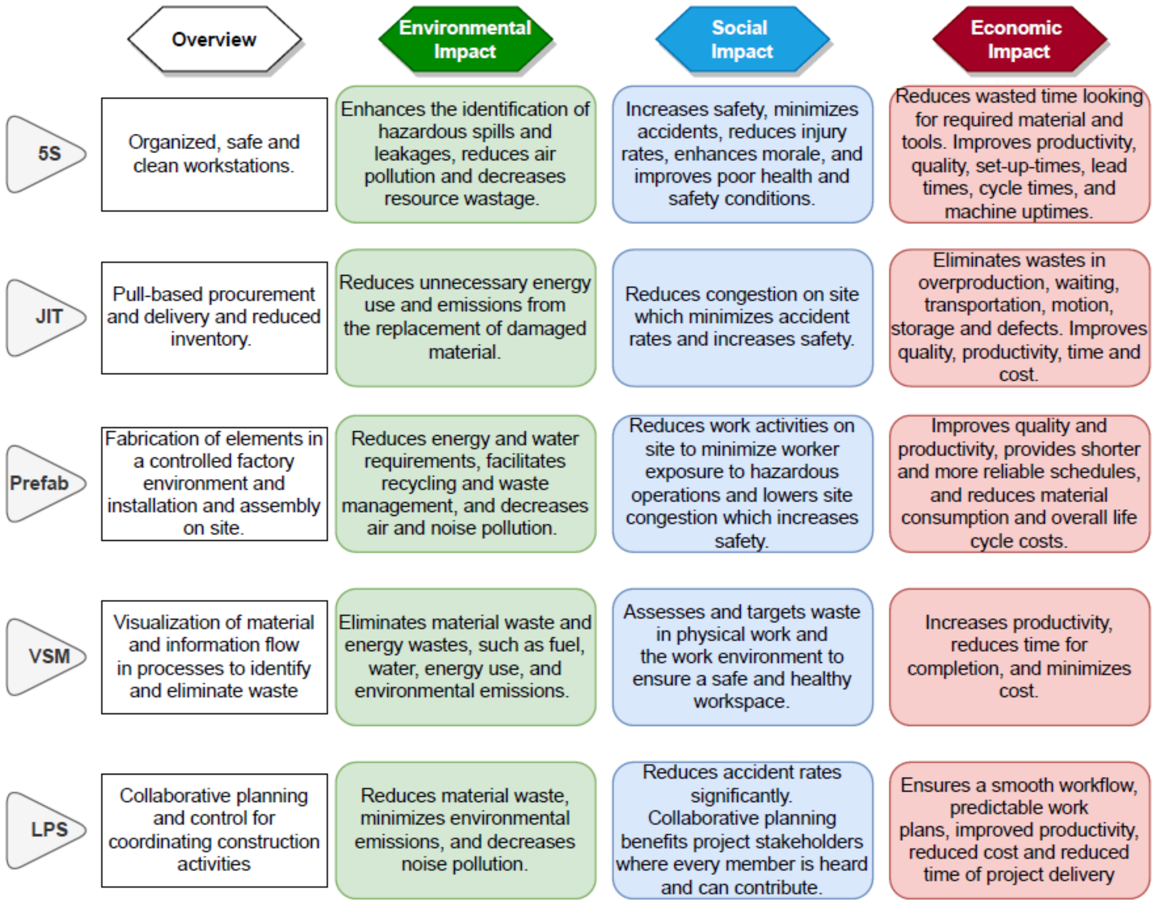

Figure 1: Role of Lean Tools in Minimizing Wastes across the Triple Bottom Line

CONCLUSION AND FUTURE RESEARCH

Considering the substantial waste generated in the construction industry and recognizing the potential of lean construction in reducing this waste, it is crucial to investigate the role of the main lean tools in maximizing value and minimizing harm. This paper presents a rounded categorization of construction waste along the three pillars of sustainability: environment, society, and economy, and outlines the contribution of 5S, JIT, Prefabrication, VSM, and LPS in eliminating waste across the triple bottom line. This research adds to the body of knowledge two holistic diagrams, the first highlighting a more comprehensive documentation of sustainability wastes and the second identifying the specific impacts of lean tools on the three dimensions of sustainability, to shed light on the importance of avoiding a segregated investigation of sustainability as all its pillars are interrelated and important. However, lean is not a "silver bullet" that will provide all these benefits without proper implementation and therefore there is a need for future research to identify the optimal setting to harness lean's sustainability benefits, in terms of the adopted project delivery method and other applicable factors.

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