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A Proposed Framework for Identifying the Impact of Adopting Lean Tools on Enterprise's Environmental Sustainability Performance

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ABSTRACT

In order to identify the effects of implementing lean tools on an enterprise's environmental performance, a framework is proposed in this study in order to explain the direct relationship between the two. In order to demonstrate lean and sustainability principles, sustainability's dimensions, pertinent lean tools, and the influence of adopting lean tools on corporate environmental performance, descriptive analytical techniques are utilised to evaluate the current literature. Additionally, a framework for assessing the effect of using lean technologies on an enterprise's environmental performance is proposed using a constructive approach. The analysis indicates that there may be a direct or indirect link between the application of lean and environmental performance. Only the direct link between lean implementation and environmental performance was examined in this article. When lean tools are used, environmental performance improves accidentally as a consequence of lower material, water, and energy consumption, waste generation, and emissions into the air, land, or water. On the other hand, future research can examine the indirect relationship between the application of lean and environmental performance. This study offers a novel academic methodology for assessing the influence of lean adoption on environmental performance. Additionally, managers can use the framework as a guide to find the best lean tools to apply in order to get rid of lean waste and the associated environmental waste.

1. INTRODUCTION

In recent years, enterprises in developing and developed countries are more likely to face many challenges in terms of managing their processes to

achieve sustainable development. It results in putting tremendous pressure on enterprises to adopt advanced manufacturing practises to achieve a sustainable competitive advantage. In addition, there is significant pressure on enterprises to manage their operations responsibly in the light of their environmental, social and economic impacts.

Lean manufacturing has become a dominant strategy for organising production systems, which was developed by Toyota Production System (TPS) in the 1950's. On the other hand, Martinez-Jurado and Moyano-Fuentes (2013) stated that enterprises should not only become lean enterprises but also be required to manage their activities responsibly and to consider the activities' impacts on environmental, social, and economic performance simultaneously. In other words, enterprises are required to be more proactive regarding their environmental, social, and economic impacts, moving towards adopting sustainable practises to improve their sustainable performance.

Nowadays, environmental sustainability has received increasing attention because of external regulations that result in imposed responses to environmental practices. It also results in increasing organisational commitment toward the environmental dimension of sustainability across the entire enterprise (Closs *et al*., 2011).

Also, Garza-Reyes (2015) and Thekkoote (2022) stated that a lean enterprise is faced with environmental challenges like climate change, environmental degradation, and natural resource scarcity. Bouazza *et al.* (2021) stated that lean enterprises can achieve a sustainable competitive advantage through making their operations more environmentally friendly. As a result, it is not enough for the lean enterprise to achieve operational and financial benefits; it must also reconsider how to make its processes and products more environmentally sustainable.It means that environmental sustainability is considered one of the strategic necessities for enterprises, which must be aligned with their traditional priorities of profitability and efficiency.

For instance, Chiarini (2014) claimed that the 1990s saw the first investigation into the connection between lean and environmental performance. However, the specifics of this connection have not yet been investigated. The nature of this link began to be investigated towards the start of the 2000s.

Even though there is no explicit purpose to lessen environmental impacts or adopt green practises, some academics contend that lean adoption has a substantial positive influence on the environment

nonetheless because waste may be eliminated by using the appropriate lean techniques (King & Lenox, 2001; Pampanelli *et al.*, 2013; Moreira *et al.*, 2010; Hajmohammed *et al.*, 2013).

Although lean implementation has considerable positive effects on the environment, few businesses are aware of how it affects their environmental performance (Bandehnezhad *et al.*, 2012). Additionally, there are some opposing views that have been expressed by Bandehnezhad *et al.* (2012), Dues *et al.* (2013), Pampanelli *et al.* (2013), Garza-Reyes *et al.* (2018), Hallam and Contreras, (2016), Galeazzo *et al.* (2014), Abualfaraa *et al.* (2020), Chen *et al.* (2020), and Oliveira *et al.* (2021), which

- There has been little research done in the literature on the nature of the relationship between lean implementation and environmental performance.
- No study has examined the effects of using all lean tools simultaneously on environmental performance.
- The effects of some lean tools could be favourable, bad, or indifferent.

Therefore, it can be stated that there is still uncertainty regarding the nature of the relationship between lean implementation and environmental performance and which Sustainable Development Goals (SDGs) may be achieved. The article offers a framework to assess how adopting lean techniques may affect an enterprise's environmental performance in order to close this gap. Thus, the following queries can also be addressed: What effect does using lean tools have on an enterprise's environmental performance? Which sustainable development objectives can be fulfilled?

The suggested framework can also help academics and practitioners identify appropriate lean techniques to apply to get rid of each sort of lean waste and its related environmental waste, which improves an enterprise's environmental performance.

The remainder of the essay is structured as follows: The literature review and theoretical background are presented in part 2, the methodology is presented in section 3, the proposed framework is presented in section 4, the results are shown in section 5, and the discussion is concluded in section 6, which also includes conclusions and suggestions for further study.

2. LITERATURE REVIEW AD THEORECTICAL BACKGROUND

Research material found in articles, trade journals, books, and web pages includes literature on lean manufacturing systems, sustainability, and the

impact of lean implementation on an enterprise's environmental performance. So the literature review can be divided as follows:

2.1. Lean Manufacturing System

Nowadays, enterprises are required to change their manufacturing systems in order to effectively compete in the new business environment, which is characterised by intense global competition. Enterprises compete on the basis of not only price but also quality, on-time delivery, and flexibility.

Consequently, enterprises are required to change the manner in which they produce and deliver products and services. It can be done through transforming from producing large batches of uniform products to producing individual products in small batches according to customers' needs. In other words, enterprises would adopt a new manufacturing system that is "lean manufacturing" and shift away from "traditional mass production" to increase customer satisfaction and achieve a reasonable return.

Both Karlsson and Ahlstrom (1996) and Oliveira *et al.* (2021) claimed that the concept of lean manufacturing has received much more attention from both researchers and practitioners. Lean manufacturing has become a dominant strategy for organising production systems, which helps enterprises gain a competitive advantage in the world market. The term "lean" emphasises the meaning of "shedding" and "losing" excess or waste (Johnson, 2006). The classical definition of lean is the identification and elimination of waste or non-value-added activities within a process as perceived by the customer (Womack and Jones, 2003).

Womack and Jones (2003) identified five lean principles, which are considered the cornerstone of implementing lean. These principles are: customer value, value stream, flow and pull, empowerment and perfection.

2.2. Sustainability

The current industrial environment is marked by growing globalization, which has changed the world as well as how customers judge the value of a product. It results in increasing the volume of complexity of the products, allowing customers to choose among more diversified products to meet their needs. Also, enterprises discovered that customers require not only value-added but also more environmentally friendly and socially safe products. Although many enterprises have already adopted lean thinking to become lean enterprises, they are increasing their focus on sustainability as well.

Sustainable development is considered a universal goal for each enterprise where it operates because it contributes to the environment's protection for present and future generations and also human needs' satisfaction. Salvado *et al.* (2015) defined sustainable development as the ability to meet current needs without compromising the ability to satisfy future generations' needs. This definition addresses three pillars of sustainability simultaneously, which is called triple bottom line (TBL).

According to Taucean *et al.* (2019), the Sustainable Development Goals (SDGs) are based on 17 principles that the United Nations endorsed in 2015 as a shared framework for promoting world peace, human prosperity, and environmental sustainability. These objectives, sometimes known as global goals, are meant to be accomplished by the year 2030. These SDGs include SDG1: end poverty; SDG2: end hunger; and SDG3: promote wellbeing. SDG4-Quality education; Goal 5: Gender EqualitySDG6 focuses on clean water; SDG7 focuses on clean energy; and SDG8 focuses on decent work and economic growth.SDG9-Industry, Innovation, and Infrastructure; SDG10-Reduced Inequality; SDG11-Sustainable Cities and Communities; SDG12-Responsible Consumption and Production; SDG13-Climate Action; SDG14-Life Below Water; SDG15.

2.3. Sustainability's dimensions

Traditionally, enterprises focused on some of the aspects of sustainability, especially the economic issues, and ignored environmental and social aspects. In other words, the enterprises did not consider three aspects of sustainability at the same time.

Gbededo *et al.* (2018) stated that the advent of the Brundtland report places pressure on enterprises to consider three dimensions of sustainability simultaneously and holistically to occupy a better position in the market. Tasdemir and Gazo (2018) and Oliveira *et al.*, (2021) demonstrated that enterprises are required to consider the environmental and social perspectives alongside the economic perspective to respond to stakeholders' pressure. Economic, environmental, and social aspects of sustainability, which are also considered as pillars of sustainability, can be demonstrated as follows:

Environmental Sustainability

Environmental sustainability is considered as a philosophy and an operational approach that can be adopted to improve enterprises' environmental performance (Mesquita *et al.*, 2022). Helleno *et al.* (2017) refer to environmental sustainability as any action that will preserve the

environment for future generations. Martinez and Javier (2016) stated that environmental sustainability is concerned with the consequences of utilising energy, water, and other natural resources. In addition, pollution and emissions from production and transportation and utilisation of materials or recycled materials in production are considered issues related to environmental sustainability (Piercy & Rich, 2015).

Economic Sustainability

Nowadays, economic sustainability is considered one of the most critical issues that enterprises face. It is stated that economic sustainability is linked to the profitability of the enterprise. It is concerned with the maximisation of financial benefits for internal and external stakeholders (Martinez and Javier, 2016).

Social Sustainability

Social sustainability is still the least analysed field among the three pillars of sustainability. Salvado *et al.* (2015) stated that social sustainability is concerned with improving the well-being of an enterprise's stakeholders.

2.4. The Impact of Lean Implementation on Enterprise's Environmental Performance

Nowadays, enterprises are faced with increasing pressure to engage in sustainable development and to integrate environmental and social dimensions alongside economic dimensions. It was stated by Tan and Zailani (2009), Choudhary *et al.* (2019), and Thekkoote (2022) that lean enterprises have been encouraged to improve their environmental performance due to the increasing level of globalisation and stakeholders' awareness about environmental protection. Also, lean enterprises are faced with increasing demands from various stakeholders to improve the environmental performance of their products and processes, which can be summarised as follows:

- Increasing pressures from government and regulatory bodies have led lean enterprises to improve their environmental performance.
- Increasing customer demands for environmentally-friendly (green) products have led lean enterprises to provide more value to customers with lower environmental impacts.
- Employees are also concerned with health and safety aspects during the manufacturing stage to ensure a safe working environment.

In the previous studies, it was found that there may be a direct or indirect relationship between lean and environmental performance. According to Hajmohammad *et al.* (2013), Dues *et al.* (2013), and Caldera and Dawes (2017), lean implementation has positive and indirect impacts on environmental performance via the mechanism of adopting green practices.

Thekkoote (2022) stated that only adoption of lean tools can improve environmental performance, which means that green practises should be adopted besides lean tools.

In other words, green practises operate as a mediator between the effects of lean adoption and environmental performance. So, when lean and green are implemented together, lean enterprise becomes greener than non-lean organisations, and more benefits can be realised.

On the contrary, lean allegedly accidentally enhances environmental performance, according to Galeazzo *et al.* (2014), Hopp and Spearman (2004), Hassan and Pasha (2022), and Garcia-Alcaraz *et al.* (2022). In other words, the use of lean tools causes lean implementation to have direct, positive, or negative effects on environmental performance.

According to Taucean *et al.* (2019), implementing lean can help businesses achieve SDGs 9, 12, and 13. As a result of using lean manufacturing techniques, wastes like errors, inventories, excess output, excessive processing, waiting, and motion are all eliminated. It results in fewer resources, energy, and water use; avoids reuse or remanufacturing; and reduces emissions and pollution releases. As a result, adverse environmental effects have decreased, which allows for an improvement in environmental performance.

Environmental performance and lean implementation were investigated by Bouazza *et al.* in 2021. According to one claim, implementing lean results in the elimination of both lean waste and the accompanying environmental waste, improving environmental performance. Additionally, the study was limited to looking into how using 5S, kaizen, and poke-yoke lean techniques would affect environmental performance. It was discovered that the use of these lean technologies directly and favourably impacts environmental performance.

Liu *et al.* (2022) investigated the connection between operational and environmental performance and lean tools (jidoka, standardised work, 5S, and total productive maintenance). The goal of the study was to better understand how lean tool application status changes could affect operational and environmental performance. Environmental performance was found to be less responsive to changes in the adoption level of lean techniques than operational performance.

Chiarini (2014) and Garza-Reyes *et al.* (2018) examined the impact of adopting some lean tools like 5S, total productive maintenance (TPM), value stream mapping, cellular manufacturing, and single minute exchange of dies (SMED) on environmental performance. The studies indicated that adoption of 5S, TPM, and cellular manufacturing has significant impacts on environmental performance. But adoption of VSM and SMED does not have an impact on environmental performance.

As a result, it can be noted that the nature of the relationship between lean implementation and environmental performance is still unclear in the literature for the following reasons:

- Some of the lean tools' adoption may have positive impacts, while others may have negative or no impacts on environmental performance.
- Not all lean tools have been examined at the same time.

3. METHODOLOGY

The research technique for this study entails a thorough evaluation of the literature. Lean and sustainability principles, sustainability's dimensions, pertinent lean tools, and the influence of adopting lean tools on enterprise environmental performance.

The impact of lean implementation on environmental performance was not clearly defined, according to a survey of the literature that deals with the connection between lean implementation and an enterprise's environmental performance. Previous research had not simultaneously looked at the effects of all relevant lean techniques on environmental performance. Additionally, the adoption of certain lean tools may have good, negative, or no effects on environmental performance.

The study offers a framework in the part that follows to analyse the effects of implementing all lean techniques on an enterprise's environmental performance in order to close this research gap.

4. THE PROPOSED FRAMEWORK

In light of the direct relationship between lean and environmental performance, a lean enterprise focuses on identifying and eliminating all types of waste to eliminate all non-value-added activities. It results in not only operational and financial improvements but also environmental improvements in terms of reduction of resources, energy and water usage and emissions to the air, land or water.

The U.S. Environmental Protection Agency (U.S. EPA, 2007_a) defined environmental waste as excess consumption of resources or substances released into the air, water, or land that can damage the environment or harm human health. It was stated that although environmental wastes are not involved in lean wastes, they are naturally implied within eight deadly lean wastes. Abreu *et al.* (2017); Moreira *et al.* (2010) state that most environmental wastes are consequences of more than one lean waste. So, all lean wastes have negative impacts on environmental performance.

Therefore, it can be concluded that green/or environmental wastes are considered as an extension of lean wastes. When lean wastes are eliminated, green wastes are simultaneously reduced, which results in enhanced environmental performance. Lean wastes and their effects on environmental performance can be summarised in table 1.

Table 1
Lean Wastes and Associated Environmental Impacts (Prepared by Researcher)

Lean Wastes	*Associated Green (Environmental) Wastes*
Defects	• Wasted raw materials, resources and energy consumed in making defective products.
	• Extra space and energy used for repairs and reworks.
	• Recycling or disposing of defective units.
Inventory	• Excessive energy used for cooling, heating and lighting inventory storage.
	• Excessive resources used for packaging stored WIP or replacing damaged WIP.
	• Waste generated from deterioration or obsolete products.
Over-Production	• Excessive raw materials/or hazardous materials (chemicals) used in making unwanted products.
	• Wasted energy used for extraction and conversion of natural resources into raw materials, transportation of raw materials to the shop floor and processing of raw materials into finished products.
	• Waste generated from potential of damaged or obsolete products.
	• Extra emissions releases to air resulted from transportation.
Over-Processing	• Wasted materials, resources and energy used.
	• Wasted water usage according to process specifications.
	• More pollution or emissions generated.
Transportation and Motion	• Excessive energy usage for transportation.
	• Excessive emissions released to air from transportation.
	• Extra materials, energy and space required for packaging during unnecessary motion.
	• Waste generated from potential of damaged products during movement.
Waiting	• Wasted energy from heating, cooling or lighting during production downtime.
	• Waste generated from potential of damaged or spoiled materials.
Under-Utilized Talents	• Fewer suggestions of pollution prevention.
	• Fewer opportunities for waste elimination.

According to the previous table, it can be concluded that environmental wastes are associated with lean wastes. Also, lean tools can be adopted to eliminate lean wastes, which results in their associated green wastes being eliminated, improving environmental performance as well. Therefore, a proposed framework is presented in figure (1) to determine the impact of adopting lean tools on an enterprise's environmental performance.

From the previous figure, the impact of adopting lean tools on environmental performance can be demonstrated as follows:

5.1. Value stream mapping (VSM)

VSM is a key lean enterprise waste identification and improvement tool that is adopted to identify all types of waste and appropriate improvement opportunities across the enterprise. So, VSM is considered an umbrella for other lean tools. Traditional VSM focuses only on economic issues and ignores environmental and social issues. Faulkner and Badurdeen (2014) stated that VSM should be adapted to capture environmental and social performance together with economic performance.

The U.S. Environmental Protection Agency (U.S. EPA, 2007_a) provided a lean and environmental toolkit to identify and eliminate environmental waste through monitoring material and water usage. The U.S. EPA (2007_b) created another toolkit to monitor energy consumption. Wills (2009) proposed environmental VSM to address and monitor environmental waste in terms of energy, resources, water usage, emissions, and garbage. Faulkner and Badurdeen (2014) proposed sustainable-value stream mapping (Sus-VSM) to assess and monitor economic, environmental, and social performance and improvement areas to be addressed.

Also, 5 Whys is a lean tool which can be used to determine root causes of lean and green waste and select relevant lean tools to be adopted in order to eliminate lean and green waste.

5.2. Total Productive Maintenance (TPM)

The TPM lean tool is adopted to improve not only operational performance but also environmental performance. From the previous figure, it can be noted that TPM has both positive and negative impacts on environmental performance. A positive impact on environmental performance can be achieved through the elimination of defects, over processing and waiting wastes and associated green wastes like excessive usage of resources, energy and water, reduction of emissions releases and rubbish because of:

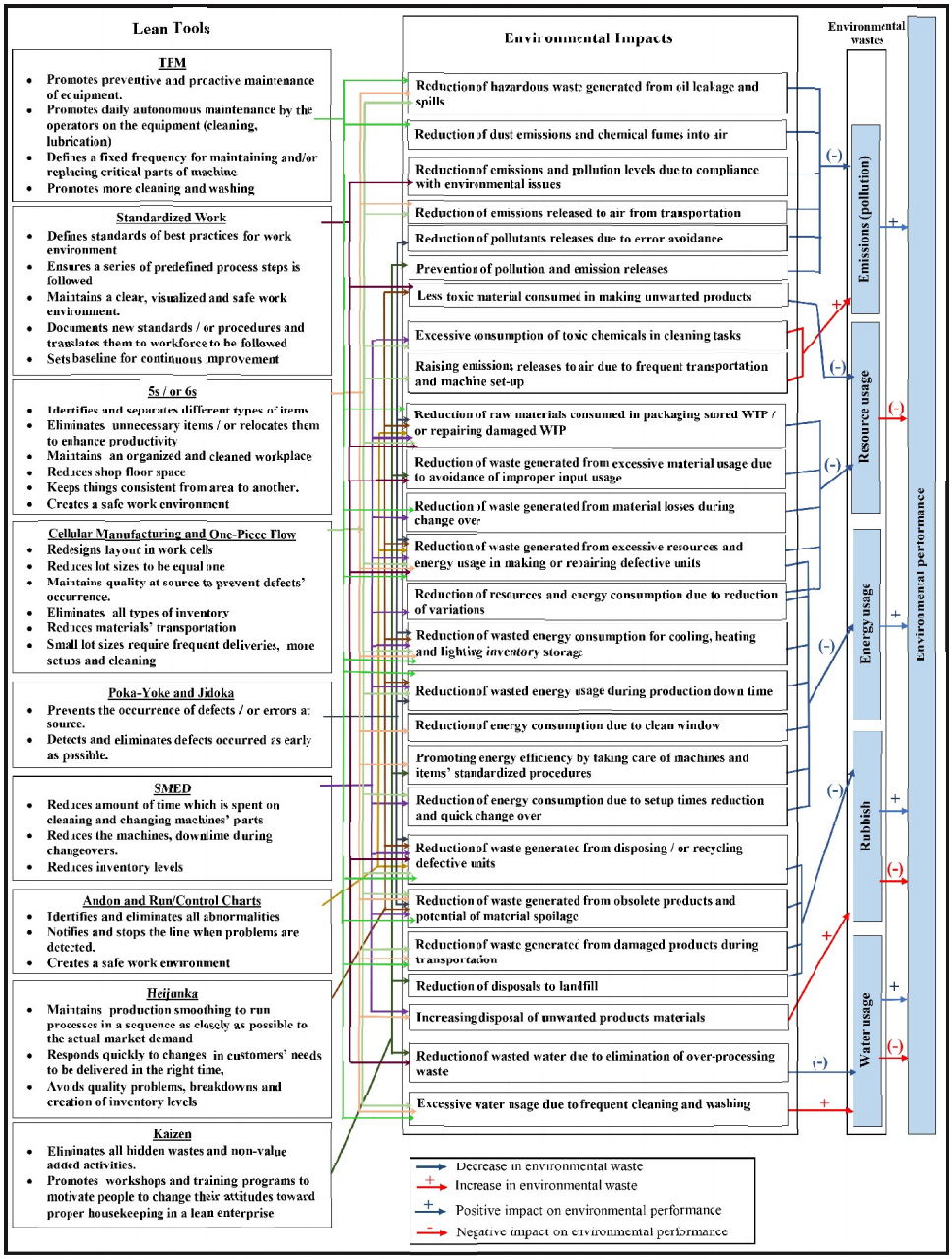

Figure 1: The Impact of Adopting Lean Tools on Enterprise's Environmental Performance (Prepared by Researcher)

- encouraging proactive and preventive equipment maintenance in order to reduce the defect rate, the number of equipment failures, and the useful life of the equipment
- promoting daily autonomous maintenance by the operators on the machine to raise equipment reliability, durability, and efficiency.
- Defining a fixed frequency for maintaining or replacing critical parts of the machine

On the other hand, a negative impact on environmental performance can be achieved from increasing waste water generated from more washing and cleaning

5.3. Standardized Work

Standardized work is an essential lean tool for improving operational stability on the way to sustainable development. Adoption of standardised work results in not only lean improvements but also environmental improvements. Adoption of standardised work results in eliminating defects, over-processing, over-production, and motion as lean wastes and their associated green wastes like:

- reduction of resources and energy usage due to a reduction in variations.
- reduction of pollution levels due to compliance with environmental issues.
- Less waste is generated from obsolete products or unnecessary materials, and less energy is used in making unwanted products.
- reduction in water usage due to the elimination of over-processing waste.

Therefore, adoption of standardised work has a positive impact on environmental performance.

5.4. 5S

5S is a housekeeping lean tool that can be adopted to maintain an organized, clean, and ordered workplace. Adoption of 5S or 6S can lead to the elimination of defects, inventory, motion, waiting, over processing, and transportation as lean wastes and their associated green wastes. As presented in the previous figure, it can be noted that adoption of 5S has both positive and negative impacts on environmental performance. The positive impacts on environmental performance can be achieved because of:

- sorting, ordering, and cleaning a workplace, which results in reducing resources and energy usage.
- reducing toxic chemicals used in cleaning and washing due to early detection of leaks and spills.
- reducing emissions released into the air due to the elimination of transportation waste.
- reducing waste generated from damaged products due to the elimination of inventory waste.

On the other hand, negative impacts on environmental performance can be achieved from excessive water usage due to more cleaning and washing and increased rubbish due to disposal of unwanted items.

5.5. Cellular manufacturing and one-piece flow

The adoption of cellular manufacturing and one-piece-flow lean tools has positive impacts on environmental performance, which can be achieved through eliminating defects, inventory, transportation, motion, and waiting as lean waste. Also, associated green wastes can be reduced, like energy and resource usage due to the elimination of defects, inventory and transportation wastes. Emissions released to the air during transportation, leaks and spills during material transfer, and waste generated from damaged or obsolete products will be reduced.

On the other hand, adoption of cellular manufacturing and one-piece-flow have negative impacts on environmental performance. Because a small lot size requires frequent deliveries and more machine setups, that leads to increased emissions released into the air. Also, a small lot size requires more cleaning tasks, resulting in excessive water and chemical usage.

5.6. Poka-yoke and jidoka

Adoption of poka-yoke and jidoka can eliminate defects, inventory, and waiting waste, which results in reducing environmental waste, like less energy and resources used in making or repairing defective units; less energy consumed in cooling or heating due to inventory reduction; and reduction of waste generated from recycling or disposing of defective units, obsolete products, or spoiled materials due to waiting.

5.7. Single Minutes of Exchange Dies (SMED)

Tasdemir and Gazo (2018) stated that adoption of the SMED lean tool contributes to sustainable development by reducing changeover times and inventory levels. Also, it was stated that SMED has negative impacts on

environmental performance because of the increasing consumption of chemical materials and the disposal of unwanted products.

On the other hand, Chiarini (2014) stated that SMED has neither positive nor negative impacts on environmental performance. In other words, no environmental gains can be observed from adopting SMED. Chiarini's point of view can be criticised because adoption of SMED results in the elimination of defects, inventory, overproduction, and waiting as lean wastes and their associated green wastes, which lead to improved environmental performance. It can be concluded that SMED has both positive and negative impacts on environmental performance. The positive impacts can be achieved through:

- reduction of resources and energy consumed in making or repairing defective parts.
- energy usage to store inventory or during production downtime.
- reduction of waste generated from disposing of unwanted or obsolete products and spoiled material due to waiting.

On the other hand, SMED may have negative impacts on environmental performance because of increasing garbage resulting from disposal of unwanted products and excessive usage of toxic materials due to more cleaning and washing.

5.8. Andon and Run/control Charts

Andon and run/control charts are relevant lean tools for the purpose of visualising all lean and green waste to be immediately eliminated. It can be noted that adoption of andon and control charts results in eliminating defects and inventory waste, resulting in a reduction of resources and energy used in making/or repairing defective parts; raw materials used for packaging stored WIP or replacing damaged WIP; and waste generated from disposal of defective products. Therefore, adoption of andon and control charts has positive impacts on environmental performance.

5.9. Heijunka

Heijunka is a relevant lean tool to identify true patterns of customers' usage to support the enterprise in producing products in predictive patterns. It can be concluded that adoption of heijunka results in lean and environmental improvements. Its implementation results in the elimination of defects, inventory, overproduction, and waiting as lean wastes, as well as the associated environmental wastes such as reduced energy and resource usage in manufacturing or repairing defective parts; toxic materials

used in manufacturing unwanted products; wasted energy for cooling or heating inventory storage or during production downtime; and waste generated from disposing of damaged or obsolete products.

5.10. Kaizen

Kaizen is a relevant lean enterprise cultural tool that results in lean and environmental improvements. All types of lean waste and associated green waste are eliminated in their entirety. So, kaizen's adoption has a positive impact on environmental performance.

6. DISCUSSION

Companies must adapt to considerable changes in the current business climate, including lower entry barriers, increased global competition, swift changes in customer needs, and shorter product life cycles. To answer these demands from the competition, businesses should implement a lean system and adapt their company strategy. Although adopting a lean mentality is becoming a must-have requirement for businesses everywhere, doing so is not enough to make an organisation lean. To improve their sustainable performance, the firms should run their operations sustainably as well. It means that, in recent years, sustainability has emerged as a crucial issue for businesses, one that needs to be integrated into their strategy and spread throughout all levels to take into account not only economic factors but also environmental and social ones.

Only the direct link between lean implementation and environmental performance is investigated in this study. The results of this study showed that adopting lean tools directly impacts environmental performance in a positive or negative way, which is consistent with studies by Galeazzo *et al.* (2014), Hopp and Spearman (2004), Taucean *et al.* (2019), Hassan and Pasha (2022), and Garcia-Alcaraz *et al.* (2022), but not Thekkoote (2022).

Additionally, the study looked at the effects of adopting lean technologies like 5S, total productive maintenance (TPM), value stream mapping (VSM), cellular manufacturing, and single-minute exchange of dies (SMED) on environmental performance. According to research by Garza-Reyes *et al.* and Chiarini (2014), adoption of 5S, TPM, and cellular manufacturing has a considerable impact on environmental performance (2018). According to Chiarini (2014) and Garza-Reyes *et al.* (2018), the adoption of VSM and SMED has no effect on environmental performance. However, it was discovered in this study that VSM and SMED significantly affect environmental performance.

Additionally, according to the study's findings, using poka-yoke and jidoka lean tools improves environmental performance, which is contrary to a study by Garza-Reyes *et al.* (2018). Additionally, this study found that implementing heijunka, standardised labour, andon, and run/control charts has an advantageous effect on environmental performance.

The results of the study also showed that lean implementation helps businesses achieve some SDGs. SDG3 "good health and well-being" can be achieved by offering more socially responsible and environmentally friendly products, while SDG6 "clean water" and SDG7 "clean energy" can be achieved by reducing emissions that are released into the water supply and increasing the use of renewable and clean energy sources, respectively. Lean philosophy adoption can also be seen as a driver for implementing green practises to get even more environmental benefits. According to a study by Taucean *et al.*, SDGs 9 ("industry, innovation, and infrastructure"), 12 ("responsible consumption and production"), and 13 ("climate action") may all be achieved (2019). These objectives can be met by employing more eco-friendly, cutting-edge, and inventive manufacturing techniques; conserving resources, energy, and water; increasing byproduct recycling, reusing, and remanufacturing; and decreasing air pollution and emissions releases.

7. CONCLUSIONS AND FUTURE RESEARCH

With the help of a literature review, the study focuses only on investigating the direct relationship between lean implementation and environmental performance. The main contribution of this study is to propose a framework to determine relevant lean tools to be adopted to eliminate each type of lean waste and its associated environmental waste. The proposed framework can help both researchers and practitioners understand the internal mechanisms of lean tools and the impact of adopting them on environmental performance and can support enterprises in attaining some of the SDGs. It is noted that lean implementation enhances environmental performance unintentionally through the adoption of lean tools. Adoption of lean tools may have positive, negative, or both impacts on an enterprise's environmental performance. Finally, there are many opportunities for future research that can be done, like: investigating the indirect relationship between lean implementation and environmental performance; determining the impact of integrating lean and green practises on environmental performance; and determining the nature of the relationship between lean implementation and other sustainability dimensions.

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