

# Sustainable Lean and Green Manufacturing: An Empirical Review of Their Strategies



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**Abstract** Sustainable lean green manufacturing research is the primary emphasis of this study (SLGM). Manufacturing Organizations can benefit from a combination of lean practices and environmental practices, according to this paper. Despite countless studies, there is no definitive definition of lean and green. In terms of social, economic, and environmental concerns, studies have linked lean manufacturing to green manufacturing. A review of previous research is undertaken in this study to assess the manufacturing industry's shortcomings. Research papers from well-known databases were analyzed to identify the gaps in sustainable lean and green manufacturing practices. After a thorough analysis, it is recommended that sustainable lean and green manufacturing be further developed. Reduced implementation gaps for lean and green manufacturing will increase industrial sustainability. The essay also discusses lean and green manufacturing, as well as lean waste, lean processes, and lean green implementation. Finally, the research closes with a literature survey in order to better understand the present state of lean manufacturing and its varied approaches.

**Keywords** Sustainability · Lean manufacturing · Green manufacturing · Systematic review

## 1 Introduction

Organizations of all kinds are using the term “sustainability” as a marketing gimmick. Previous research has suggested links between environmental sustainability and lean and green practices. Reducing the amount of resources used to manufacture something while also improving the environment is central to the lean philosophy. Literature reviews reveal that economic development and societal well-being are inextricably linked to environmental sustainability (Fig. 1). According to Dombrowski and Mielke [1], lean and green refer to the effective use of resources, pollution

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reduction, and waste optimization. Environmental sustainability and lean and green operations, according to [2], go hand in hand. Lean and green manufacturing methods require both technological and financial support in order to achieve long-term profitability while also improving the environmental performance of industrial processes. In spite of the fact that lean and green concepts are enticing instruments for waste reduction, most industrial organizations have difficulty sustaining long-term success with these concepts. Based on socio-technical processes, the lean manufacturing process is a decision-making technique designed to reduce waste in the manufacturing process. In order to get the best results, use a problem solving and training of staff to handle numerous tasks, and vendor management, customer satisfaction, and continuous improvement are all aspects of lean manufacturing. As a result, customer needs and environmental conditions drive the sustainability system. As a result of the environmental concerns in today's production systems, management should focus on reducing waste and increasing profitability through lean manufacturing. With the support of employee devotion and lean manufacturing, firms may achieve world-class production [3]. When lean management systems were not considered as a human resource management activity in the past, manufacturing performance was negatively affected. Communication of goals, training progress, ideas for development, awards and recognition, and employee health and safety are all part of good human resource management. Lean manufacturing relies on the most up-to-date technological expertise and clean manufacturing methods, all of which help to minimize manufacturing costs and, as a result, the final product's retail price [4]. Increasing the value of resources and ensuring that customers are happy are two key components of a productive and efficient manufacturing process [5]. Because of the intense competition in today's market, it is critical for businesses to embrace lean manufacturing practices in order to provide high-quality products at low cost. As a result, a lean workplace encourages people to use their natural abilities for process improvement and product quality control while also providing them with the tools to do so. For those looking for a production method that uses the fewest resources while also producing the least amount of waste, consider implementing the lean manufacturing technique [6]. Following the successful implementation of the Toyota Production System (TPS), the concept of lean manufacturing was introduced to reduce any non-value-added operations in a production process [7]. Green, on the other hand, refers to environmental sustainability, which includes waste creation and recycling, as well as pollution of the air, water, and land, as well as energy consumption and efficiency. As a result of green applications, such as the green economy, there is an increase in value while using a smaller amount of resources. While simultaneously decreasing environmental risk and ecological scarcity, the green economy, which propels economic growth while also encouraging new low-carbon technology innovation, would enhance human well-being and social fairness. Sustainability has become the new lean in the green industry, which was formerly known as the new lean. Reactive and proactive environmentally friendly solutions are the core of a business strategy known as "green manufacturing." When a company uses clean technology and renewable energy to reduce pollution and waste while reducing the use of resources, it is known as "Green" production, as



**Fig. 1.** Relationship between Environmental stability , Economic and Social development

defined by Andrew [8]. Lean and green manufacturing can work together to increase operational efficiency by creating value and reducing waste. Many researchers are intrigued by the idea that working together can improve the productivity of both groups. A new era of eco-innovation ushered in the term “green manufacturing” in the early 1990s. Using an environmentally friendly production process reduces the environmental impact and another detrimental impact on resources. Environmentally friendly manufacturing is known as “green manufacturing,” and it is a way to reduce waste while boosting the economy without having to sacrifice the environment. Green manufacturing, according to Sezen and Cankaya [9], has the potential to spur economic development while also improving environmental and social conditions. A company’s environmental performance can be improved while also meeting customer needs through green management and innovation. To remain competitive, the manufacturing industry is looking for ways to integrate lean production with traditional manufacturing practices. Additionally, the companies are looking into ways to boost output while maintaining a healthy environmental footprint.

## 2 Methodology

Previous studies on lean and green manufacturing have been reviewed for this study. For this review, we used databases from well-known lean and green publishers such

as Springer, Elsevier, Wiley, and Taylor and Francis, as well as Emerald and Sage. The approaches and answers were discovered as a result of the literature review. The review also included the ideas, enablers, and challenges of lean and green manufacturing. The study excluded gray literature, such as book chapters, unpublished articles, and research papers written before 2000. To gain a better grasp of lean and green manufacturing practices and methods, this article was written.

The objectives of this study are:

1. Understanding the concept of lean and green strategies through literature review
2. Effect of lean and green implementation on business metrics
3. Integration of sustainable lean manufacturing (SLM) in socioeconomic and environmental indicators.

### 3 Literature Review

Using lean manufacturing, which has been popular since the Industrial Revolution, means reducing unnecessary steps in the production process [10]. The seven (7) wastes of lean manufacturing are based on the early breakthroughs that sparked the idea of waste removal. Early in 1910, Henry Ford's Model T assembly line, which created the first mass-produced automobile, achieved a manufacturing breakthrough when it featured interchangeable standard workpieces. FPS was the foundation for Toyota's TPS idea, which was based on Jidoka and Just in Time (JIT). Using Jidoka, or "automation with a human touch," TPS produces and meets demand without the need for additional production or inventory, whereas JIT utilizes JIT [11]. The quality circle and the importance of inventories were also recognized by Toyota. Both the Toyota Production System and lean manufacturing emphasize continual improvement and the Toyota principles, according to Kochnev. The lean technique has the potential to eliminate overproduction, waiting, transportation, overprocessing, inventory, motion, and faults. A basic premise of lean manufacturing is to identify which parts of a process flow contribute to the overall value of the product. A number of lean tools are used in lean manufacturing to assist detect and eliminate waste [12]. It has been proposed that every organization, regardless of the type of product they generate, can apply lean tools. However, if lean manufacturing technologies are used incorrectly, this can lead to extra waste of resources. It is a problem that has been addressed by Pavnaskar and colleagues in 2003, when they presented a classification method for lean tools that fits the waste to be avoided. According to Simona and Cristina [13], an organization must have a lot of expertise with lean manufacturing processes in order to get meaningful outcomes from the use of these fifteen lean tools. A combination of lean tools, such as Sig-Sigma and Agile systems, is often used by lean practitioners when conditions are optimal. With the use of DMAIC cycle, [14] built a conceptual model for integrating lean, Six Sigma, and Green ideas. According to study, a company's culture has a significant impact on the effectiveness of lean manufacturing initiatives. Lean manufacturing demands an organization's leadership to influence the behavior and attitudes of their

employees. The human factors play a critical role in the effective implementation of a lean manufacturing strategy. This requires a systematic approach from the top-down that empowers people to ensure the effective adoption of lean manufacturing in an organization. Green manufacturing is just as important as mean manufacturing because both approaches focus on reducing waste and implementing environmentally friendly production techniques. There were no environmental considerations because of the lean manufacturing system's only focus on waste reduction. As a result, businesses began placing an emphasis on environmental safety. An ecologically friendly manufacturing method known as "green manufacturing" can be used to increase profitability while reducing negative impacts on human health and the environment [15]. When eco-innovation emerged in the 1990s, the concept of green manufacturing was born [9]. Environmental risk and other negative effects of production can be reduced by eco-innovation methods. Green manufacturing is a waste reduction strategy based on environmentally friendly and cost-effective processes, products, and materials [16]. Green manufacturing was defined by Mittal and Sangwan [17] as a strategy to improve the economy without hurting the environment. All activities that reduce waste are considered green production, according to Mohanty and Deshmukh [18]. To bridge the Lean-Green divide, [19] recommended aligning green and lean waste. Verrier et al. [20] proposed that combining lean waste and green trash could increase operational efficiency. Green wastes include GHG (greenhouse gas emissions), eutrophication, overconsumption of natural resources, and pollution, according to the report's authors. Both lean and green approaches have established similar targets for reducing non-value-added commodities and improving operational performance. According to [14], Lean and Green is referred to as the lean environment rather than the green environment, which is incorrect. Lean manufacturing and green manufacturing are significant tools for increasing production efficiency and global competition, and they demonstrate a strong commitment to waste-free practices. When it comes to improving operational and environmental outcomes, both green manufacturing and lean manufacturing have a lot in common [21]. Green manufacturing has a positive impact and generates a synergy between environmental management and operational success. There is a strong correlation between Lean and Green in industrial businesses. The two methods complement each other and are mutually beneficial. Both lean and green manufacturing have the same goals, which are to improve performance, product quality, and time to minimize operation and to provide value for stakeholders. As a result, the manufacturing system's Lean-Green link is formed [2]. According to the study, lean manufacturing is focused on reducing costs while green manufacturing is focused on reducing environmental risks. This shows a symbiotic relationship between the two systems.

### ***3.1 Green and Lean Integration***

According to the study, there is a strong connection between green and lean principles [22]. According to the research, combining green and lean projects has significant

synergistic impacts [21]. In light of the natural synergy between green and lean because they complement each other, it makes sense for businesses to implement strategic initiatives such as changing company culture and implementing continuous improvement and waste elimination as well as resource optimization to achieve the desired result [23]. As a result of this integration, the environmental impact of the production process is minimized to the greatest extent. As a result of initiatives like value stream mapping and Kaizen events, a new approach of controlling industrial operations is adopted. Lean and Green practices can be combined to manage supply chains, according to [24], for example. Lean and green approaches may be combined into a single model to improve energy flow in production environments. To find any flaws, [14] uses Six Sigma to examine the link between the green and lean paradigms. Green and lean practices have generated encouraging results, but organizations with limited resources might benefit from incorporating them. According to Garza-Reyes, there are a number of drawbacks to integrating a green and lean approach (2015). Johansson and Winroth [25], stated that an understanding of the relationship between green and lean methods is needed. The assessment approach of [26] is likely to help resolve this issue (Fig. 2).

The literature review analysis of lean and green manufacturing systems can be diagrammatically represented as shown in the Fig. 3:

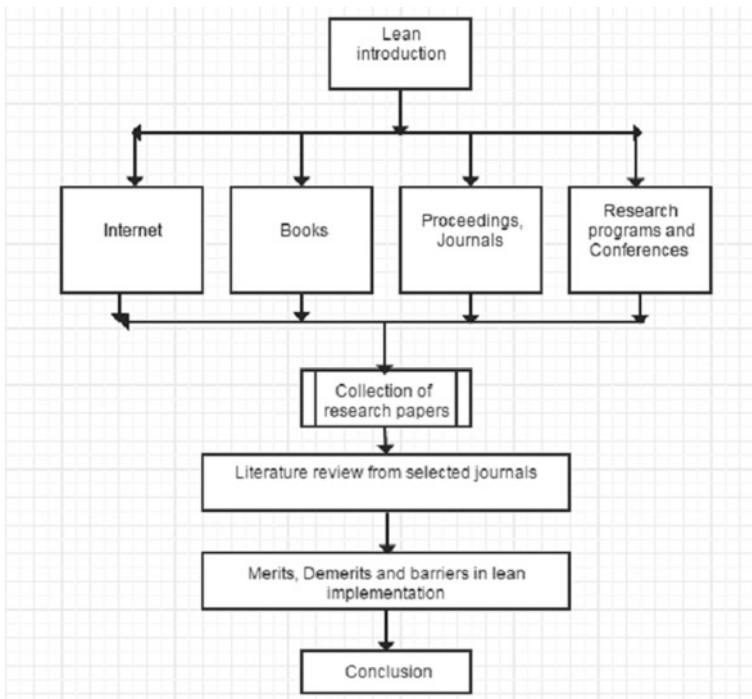
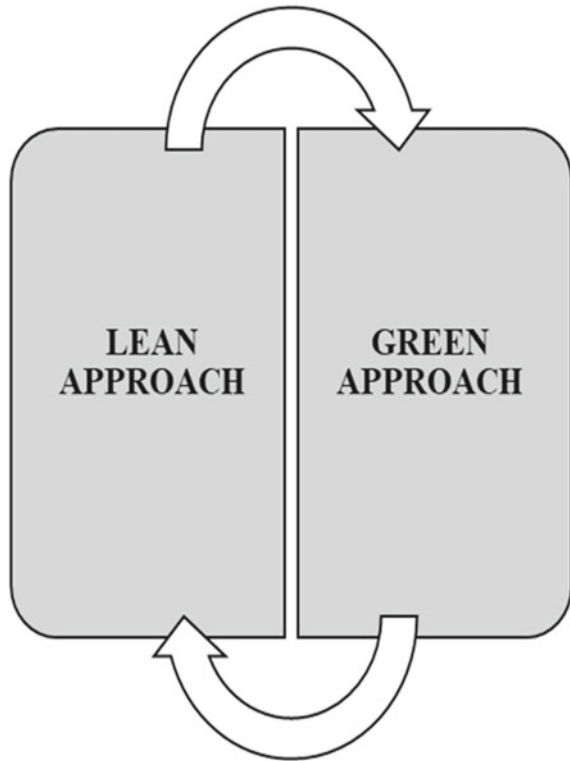


Fig. 2 Lean and green manufacturing cycle for collected literature review

**Fig. 3** Relationship between lean and green approaches

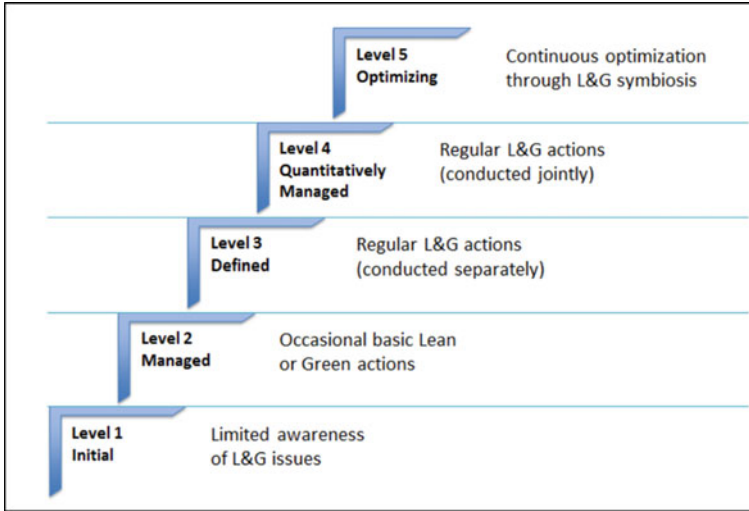


#### 4 Lean and Green Maturity Model

Progress in performance enhancement methods has been made possible in part thanks to the Lean and Green Maturity models [27]. The Capability Maturity Model Integration (CMMI) is one of the best and most widely used models, which has five phases and serves as a framework for assessing an organization's deployment maturity. Manufacturing companies have a wide range of needs and approaches, and this model seeks to satisfy those differences. This concept has been incorporated into the Lean and Green strategy in order to improve the practical evaluation and deployment. Models of Lean and Green synergies are proposed based on the prior literature review. Lean and Green best practices improve the proposed maturity model (Fig. 4).

The Lean and Green maturity model suggests five levels which have been discussed below as follows:

**Level 1, Initial:** The organizations have limited understanding of Lean and Green issues and the knowledge that they both can co-exist. At this level, there is no supervision or controls regarding environmental indicators from the top management. The organization is not aware of the competitors move with regard to lean and green strategies.



**Fig. 4** Lean and Green maturity model (inputs taken from the model proposed by Verrier et al. [20])

Level 2, Managed: An organization's basic Lean or Green initiatives are carried out at level 2. There is a realization that the companies are losing money because of the amount of non-value-added waste that occurs. Major environmental indicators such as water use and trash output are managed at the organizational level. EPA Organizations shift their focus to managing production space at this level (5S). The organization recognizes that in order to succeed in today's competitive marketplace, Lean and Green practices must be adopted.

Level 3, Defined: Lean and Green environmental practices are implemented on a daily basis, and enterprises realize that they can offer value to the company. Top management is now compelled to implement modern lean and green techniques as soon as possible as a result of this new understanding. Organizations are making waste reduction their main goal. The most important environmental indicators are reduced at operational levels to serve as process-related indicators. The most important thing to the company's top executives is to improve the system. Internal communication on Lean and Green topics is limited, and monitoring is carried out. Continuous feedback is collected to determine the impact of lean and environmentally friendly activities.

Level 4, Quantitatively managed: Organizations at this level consider Lean and Green techniques essential to their growth. At this level, there is strong top-down and bottom-up management in place to guarantee that the action is quantified and monitored on a regular basis. Waste reduction is tracked to improve Lean and Green performance. Critical indicators are put up and monitored in accordance with those objectives in order to meet the company's demands. Employee meetings are organized on a regular basis to encourage involvement and request suggestions



for improvement. It is common practice to include workers in the process of improving the business.

Level 5, Optimizing: Lean and Green approaches come together at this last stage. Process improvement and waste reduction are mutually reinforcing at this level. The plan is developed in tandem with the lean and green initiatives. With an understanding of both good and negative repercussions of combining Lean with Green, the organization has taken steps to strengthen the positive ones. A proactive approach is taken by the organizations to ensure that they are always improving. An efficient Lean and Green strategy sustainability is achieved at this level. All Lean and Green strategies are closely monitored by the organization to ensure maximum advantages are realized at all levels. Lean and Green philosophy is fully implemented at this level of the organization.

## 5 Conclusion and Discussion

Lean and Green techniques appear to be challenging to implement in firms with a wide range of processes and specificities. The goal of this research is to make it easier for people to understand and put into practice Lean and eco-friendly practices by identifying the most effective methods (such as TPS and FPS). For lean and green initiatives to succeed, there must be a strong link between top-down and bottom-up management. To maximize formalization and deployment of Lean and Green in manufacturing businesses, a Lean and Green maturity model was developed, which analyzes the organization's philosophy at every level to promote the synergistic adoption of Lean and Green in manufacturing firms. A motivated workforce is important to achieving Lean and Green efficiency. Waste optimization, process orientation, staff involvement, and top management commitment and review were the main points of the study. Results can be evaluated on the basis of competition, strategic planning, and economic sustainability as a result of lean and green implementation. Everyone participating in the project has made it a priority to learn the fundamentals of lean and green. The integration of Lean and Green practices improves an organization's operational and environmental performance. This article discusses some of the barriers and challenges that lean and green implementation has to deal with. The organization's top-down dedication to Lean and Green adoption is largely responsible for its success. An influential theory, lean manufacturing, has also been discovered to be applied as a guiding principle in the manufacturing industry. Lean manufacturing is becoming more widely accepted as the most profitable method for both manufacturers and their customers. Lean techniques were addressed either explicitly or implicitly by academics for this study. As stated in the report, lean manufacturing is crucial in all areas of innovation, but the industry has yet to implement it. Incorporating lean and green practices can decrease waste, save money, limit excess production and inventory, remove delays, encourage systematization, raise staff dedication, and improve customer satisfaction. Businesses and their customers will be able to achieve better success with lean as its base. Using the lean and green maturity model conceptual,

it is possible to measure the performance effects of each lean and green practice. To improve our understanding of Lean and Green, further research is needed on the relationship between Lean tools and their impact on Green performance. An additional focus for future research might be the extension and adaptation of Lean and Green techniques to various phases of the product life cycle.

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