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Lean Manufacturing Practices and Environmental Performance

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Abstract

Lean manufacturing is considered a rewarding production strategy due to its positive effects on organizational and economic efficiency in various industries. Given the growing ecological consciousness, environmental achievements of lean manufacturing also incorporate a strong economic relevance. The main objective of this chapter is, therefore, to investigate the impact of lean manufacturing practices on environmental performance and the existing coherences between Lean and ecologically oriented variables such as resource usage, energy consumption, and air pollution. The methodology is literature review evaluating the findings of research in this sphere. Besides the discussion of its principles and methods, current trends and challenges regarding lean production as a business model that supports eco-efficiency are presented. The implications of this study will allow executives to better recognize and simultaneously solve both the economic and environmental problems posed by their companies.

Keywords: lean manufacturing, environmental impacts, eco-efficiency, lean, environmental performance

1. Introduction

Lean Manufacturing, also known as Lean Production [1], has long been considered an advantageous manufacturing method in various companies and industries on a global level as it aims for continually improving quality and efficiency in production process [2, 3]. It is essentially about eliminating the activities that do not add value in the production and seven types of waste, also referred as muda in lean settings [4] and includes several techniques such as Total Quality Management, Just-in-Time [5], Kanban, and Jidoka [6]. It has become essential with the increased price competition that companies experience in face of changing customer demands for goods and services by helping them produce same amounts at the lower costs.

In response to growing concerns for environmental issues since the early 1990s, stemming from the climate change and exhaustion of natural resources, the relationship between Lean and environmental performance has been a critical topic in business and manufacturing literature especially from 2008 onwards [7]. Moreover, numerous companies adopted lean measures to advance their manufacturing methods for decreasing their environmental burdens since Lean Manufacturing focuses on increasing production efficiency and decreasing waste.

Considering the higher efficiency provided by lean systems, which is the reduction in energy and material resources needed per unit output, the waste of production such as the emissions to air and water, generation of solid or hazardous waste,

and chemical hazards abated along with the high costs of production. Thus, lean methods may alleviate environment by means of its inherent emphasis on waste reduction even though they do not automatically involve environmentally responsible intentions [8]. Research shows that although lean systems may not directly aim for reducing environmental effect, changing the production system to lean resulted in higher efficiency in energy consumption and in less waste [9].

The fact that incorporating lean manufacturing techniques may address environmental waste problem even without prioritizing it led companies to adopt lean activities. By integrating environmental considerations, lean manufacturing may provide businesses with long-term benefits such as environmental sustainability and recognition as a responsible corporate citizen. In this regard, companies embraced lean practices to reduce their ecological footprint for maintaining a better public opinion. Furthermore, many of them considered the “triple bottom line” of economic, environmental, and social concerns into consideration and took precautions on a bigger scale than those necessitated by the regulatory bodies [10].

The main objective of this study is therefore to provide insights into the contribution of lean manufacturing practices and measures for achieving a better environmental performance of manufacturing systems and the existing relationship of these two concepts. This is accomplished through a literature review along with a critical discussion of the findings. Focusing on the meaning of the green concept waste, lean manufacturing is described as a rising business model for endorsing environmental efficiency. The most effective lean practices and their tools in relation to supporting greener production are underlined. The improvement of the environmental measures of the firms that adopt the lean manufacturing principles, the reduction in ecological impacts stemming from their industrial operations are highlighted. The results of this study are of interest to scholars as well as to business managers to better understand and overcome environmental problems encountered by their business organizations.

2. Lean and green manufacturing: environmental impacts

2.1 Lean manufacturing concept and practices

Lean manufacturing techniques and methods, which provides higher efficiency than that its successor mass production processes, is based in Toyota Production System [2, 11] and the term ‘Lean Production’ was first coined by John F. Krafnick [12, 13]. To accomplish the aims like productivity, efficiency, profitability, product diversity, improved product quality, and customer satisfaction at higher levels [2, 14], the most vital practices of lean approach according to several scholars in the literature [5, 15–19], the tools they employ and their main contributions to production are presented in **Table 1**.

These practices, namely just-in-time (JIT), total productive maintenance (TPM), autonomation, value stream mapping (VSM) and kaizen or continuous improvement (CI), have been implemented by manufacturing businesses across the globe to realize the above-mentioned purposes of lean systems.

The five principles of Lean Production concept [1], displayed in **Figure 1**, are established to manage and minimize waste, which in turn protect the environment. Within the context of lean, waste which is considered any activity that does not add value to a product comes in seven main types and eighth types is included by Jeffery K. Liker [24]. These are in the form of overproduction, waiting, unnecessary transport, over processing, excess inventory, unnecessary movement, defects, and unused employee creativity as they are shown in **Table 2** along with their effects on environment.

Lean practice	Tools	Principle
Just-in-time (JIT)	Pull systems Takt time One piece flow Levelled production Cell manufacturing Visual control Kanban JIT purchasing Multifunctional employees	Reducing space utilisation, inventory cost and wastes that result from the overproduction
Total productive maintenance (TPM)	Single minute exchange of die (SMED) Overall equipment effectiveness (OEE) Planned maintenance 5S Quality maintenance Autonomous maintenance Initial control before starting production Safety and hygiene environment	Optimising predictive, preventive and corrective maintenance activities to achieve efficient and proficient production equipment
Autonomation/jidoka	Visual control systems A full working system mistake proofing devices	Reducing quality defects
Value stream mapping (VSM)	Flow diagrams Current and future state maps	Illustrating, identifying and measuring waste during the production process
Kaizen/continuous improvement (CI)	5S Continuous flow Run charts Five whys Brainstorming Data check sheet Kanban Pareto chart Gantt chart Mistake proofing Process maps VSM	Removing waste by improving operations gradually and continuously and sustaining lean system after its adoption

Table 1.
Most Essential Practices of Lean Manufacturing, adapted from [15, 16, 20–23].

2.2 Green lean concept and principles

Recently, carbon footprint and the environmental efficiency of the manufacturing companies has been an important topic [25] and green manufacturing concept whose goal is to continually incorporate better environmental conditions of manufacturing operations with the aims of mitigating air, water and land pollution that may pose threats to humans and other species and lessening the use of raw materials and energy, has emerged [26, 27]. It is defined as a series of activities that focuses identifying, measuring, evaluating, and managing the environmental waste created in various areas of production such as designing, manufacturing and planning [28].

Green manufacturing has both product and process perspectives. Concerning the product perspective, green manufacturing intends to produce eco-friendly products, keep the use of resources at a minimum level, and use materials that does not damage the nature. As for process perspective, it aims for minimum consumption of raw materials and energy, minimum dispersion of hazardous substances and minimum generation of waste [29].

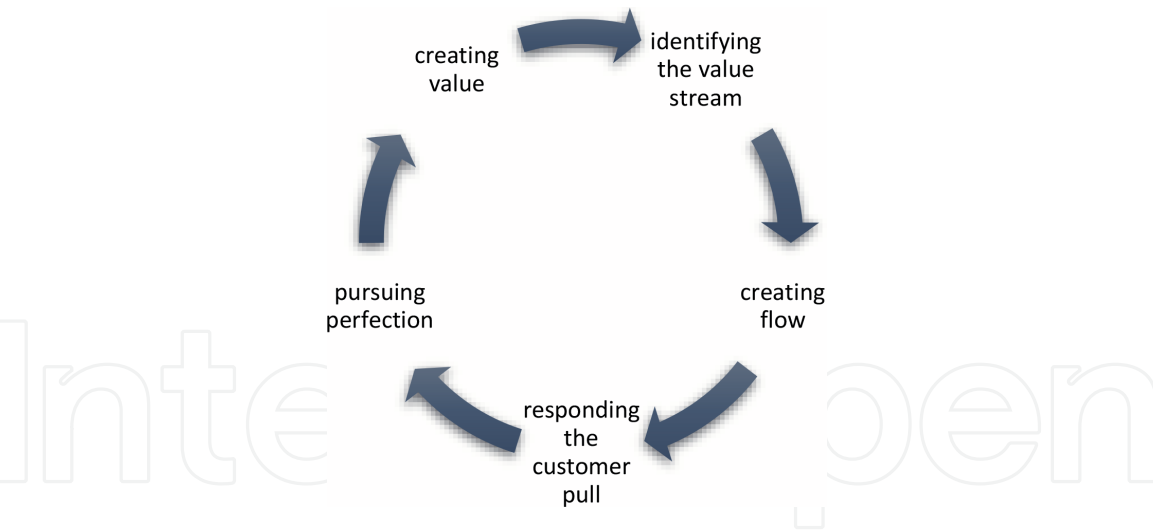


Figure 1.
Five Principles of Lean Manufacturing, adapted from [1].

Waste type	Main effects
Overproduction	More pollution and more raw material use
Waiting	More energy consumption, risk of damage on materials, overuse of space
Transport	More energy consumption, risk of damage on products
Over processing	More material and energy consumption, more pollution
Inventory	More material consumption, risk of damage on products, overuse of space
Movement	RISK of damage on equipment and product, overuse of energy
Defects	More resource consumption, rework, less recycling opportunities

Table 2.
Seven Types of Waste and Their Effects, adapted from [14].

Considering this definition of green manufacturing, lean and green production have common features as both endeavors to diminish waste and to boost the efficiency of production operations [30–34]. Green manufacturing is seen as the positive side-effect [34], a natural extension of lean manufacturing [25] in academic literature.

2.3 Lean manufacturing and its impact on environmental performance

Since its introduction, lean manufacturing has become a significant model in manufacturing industry as a successful process in contributing to competition capacity of organizations [35]. Nevertheless, the growth in ecological concerns due to climate change, environmental degradation and exhaustion of natural resources has compelled the manufacturing establishments to take steps beyond organizational quality by adopting more environmentally sustainable activities and strategies. Therefore, the study of lean and green production has grown into a crucial component of the environment protection agenda [2, 36, 37] and the relationship between these two concepts along with their impacts on environmental performance captured the attention of scholars.

Most studies refer that lean manufacturing supports environmental performance of organizations. Evidence shows that adoption of lean systems minimizes waste and pollution [32, 34, 38]. With its fundamental principle being zero waste [39], lean manufacturing reduces emissions of contaminants by decreasing

many types of operational waste such as disposed materials and unnecessary use of energy or water [40]. Furthermore, waste reduction aims of lean are inherently ecological such as unnecessary transportation of products or raw materials [27, 31, 37], whose elimination reduces the unnecessary use of resources along with operational costs [31], and overuse of inventory whose reduction has both financial and environmental benefits [25].

In addition, organizations engaged in lean systems tend to embrace environmental innovations [41]. Lean practices result in less pollution through lower marginal cost of activities that aim for pollution reduction or through lower cost of finding new ways of pollution prevention. Research indicates that capacity of improving operations is enhanced by adoption of lean practices [42], and that higher search costs may prevent managers from discovering new opportunities for environmental protection and investing in them [43].

Being a multifaceted concept, lean approach corporate several practices that intends to achieve the objective of efficiency. Among them JIT practices are used the most and considered one of the most beneficial lean practice with its tools serving to show environmental wastes in production [44, 45]. Also, studies show that VSM generates less emissions to air, less energy use, and more savings [46, 47] and positively affects the amount of solid waste, hazardous substances, water consumption and water pollution [48, 49]. As for kaizen, also known as continuous improvement, it detects and removes hidden wastes and ameliorates the amounts of hazardous chemicals use, water use, savings, water pollution, solid waste [48], material use and emissions to air [48, 50]. TPM affects positively the use of materials as it optimizes the condition of production equipment which in turn supports more efficient use of raw materials with less waste [20, 51] whereas JIT reduces the consumption of material through increasing quality by reducing inventory [15, 21, 52]. In addition, Vais et al. [53] confirmed that adoption of lean practices and tools such as 5S, kaizen and autonomous maintenance optimizes the number of resources used and products manufactured which improve the environmental performance of organizations.

In contrast to positive effects of implementing lean practices on environmental performance, some studies show that lean manufacturing adoption may cause negative effects [25, 32, 54, 55]. For instance, a study demonstrated that firms may incorporate lean systems but air emissions of volatile organic compounds during the production is not reduced [56]. Furthermore, it is presented that quality may be improved by way of consuming more hazardous substances to secure rust-proofing [57] and that more frequent trips for delivery of supplies generates more greenhouse gas emissions [58].

However, overall there is a strong evidence that there is a positive opinion on the effects of lean manufacturing on improved ecological performance particularly in the context of continuous improvement and waste reduction. Most scientific work on the subject shows that lean production reduces overuse of material and energy by continuously advancing operational productivity.

3. Conclusion

Lean manufacturing is accepted as a worthwhile production technique in many industries by the importance of leading higher efficiency and waste (muda) reduction. Alongside the lean concept, environmentally friendly production strategies have also become an issue of interest. Many companies aim for developing products in a way that reduce environmentally detrimental effects of production such as overconsumption of resources and energy, using of hazardous chemicals,

and emissions to air, water and land. Lean and Green manufacturing practices both concentrate waste reduction and thus synergic effects on environment. Several studies presented that lean systems inadvertently create ecological gains.

Concerning the air emissions, the findings are controversial suggesting that organizations should critically manage JIT activities as they may cause more air emissions [39, 59]. Although there are a few environmental drawbacks of lean systems, most of the studies demonstrates that there is a positive correlation between adopting lean manufacturing practices and improving environmental conditions.

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