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The use of Lean Manufacturing Practices in Cleaner Production: A Systematic Review

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Abstract

Lean manufacturing aims to eliminate waste in the production chain for cost reduction, quality improvement, delivery time, i.e. it seeks to make the most efficient production process. The Cleaner Production (CP) aims at environmental improvement of production processes, adopting a precautionary approach and seeking to reduce environmental waste and waste generation. Several studies have indicated that when applying the Lean companies can reduce environmental impacts. Given this context, the objective of this research is to investigate, through a Systematic Literature Review, which ones and how the Lean practices and tools are being used for improvements in environmental performance. The results show that the literature indicates a strong synergy between Lean and Cleaner Production and that many Lean tools can contribute positively to environmental sustainability.

Keywords: Lean Manufacturing, Cleaner Production, practices, tools.

1. Introduction

Organizations are constantly undergoing technological and management changes to meet requirements from its customers, the society, the government, the shareholders and all other stakeholders, at the same time that they seek to remain competitive in the market. The mere performance in cost, quality, flexibility and speed are not enough to remain competitive and satisfy the stakeholders. Thus, the reduction of the environmental impacts generated by the products and processes becomes an additional value to be added by organizations wishing to achieve good results.

In this context, it is very important that companies seek to adapt their technologies and management in order to ensure its survival in the competitive market. Several authors, such as Florida (1996), King and Lenox (2001), Rothenberg, Pil and Maxwell (2001), Yang Hong and Modi (2011), have pointed out that the integration of Lean Manufacturing with environmental strategies could be a solution to this problem. The first aim to eliminate systematically the waste throughout the production chain to reduce costs and delivery time, improve the quality and flexibility. While the second aims to reduce the environmental impacts caused by products and processes.

Along those lines, the research objective is to identify which and how Lean Manufacturing tools and practices can assist in environmental improvements practices, using as method the Systematic Literature Review (SLR).

The next section of the article brings a conventional literature review of the main concepts and tools from Lean Manufacturing, presenting next the definition of Cleaner Production (CP) and a discussion of the key relationships between Lean and CP. Subsequently the research method and the results are described. Finally, conclusions are presented in the last section.

2. Literature review

Lean Manufacturing, also known as Lean Production, is a production system originated at Toyota as the Toyota Production System (TPS) and is known worldwide, making it a way of thinking for organizations (LIKER, 2005). According to Womack and Jones (2004) this philosophy is the quest for using less of everything, which means to produce more with fewer resources, continually aiming to eliminate "waste", which is caused by activities that do not add value for the customer.

Shingo (1996) as well as Womack and Jones (2004) also state that the objective of the Toyota production system is based on the continuous and systematic elimination of waste (waste) in production systems, seeking to eliminate unnecessary costs. Lean is one of the approaches that many of the largest companies in the world have tried to adopt in order to make production processes more efficient and achieve resource optimization (WOMACK; Jones and Roos, 2004; SCHONBERGERM, 2007 KARIM; ZAMAM, 2013).

According to Womack and Jones (2004) Lean Production has five basic principles. The first is to specify the value from the perspective of the customer, which means understanding what the real needs of the client and what he is willing to pay. Later the authors recommended that you need to identify and understand the value stream for each product family, i.e. understand what steps and processes are required for the value to be created for the consumer. The third principle is to flow the value stream, which means to take the necessary steps to deliver the value without interruption. The next stage should be the "pull production", which aims to let the client trigger the production, only allowing the production to happen at the right time. The last principle is to seek perfection, which has the objective of promoting continuous improvement for the continuous elimination of waste through cyclic iteration in the previous principles.

Both Womack and Jones (2004) and Liker (2005) point out that it is very important to understand these principles and especially the continuous improvement principle of Lean, because it is considered essential for the company to achieve process improvement and waste elimination excellence. For these principles to be met there are several practices and tools used by Lean Production, the main ones are

presented in Table 1, which will be described in a random order.

Table 1. Description of Lean tools and practices
Source: prepared by the authors

Tools and Practices	Description
Value Stream Mapping (VSM	Simple tool that produce a diagram of the current situation with the processes steps and measures, identifying the potential improvements spots and then projecting the system's ideal future state (ROTHER; SHOOK, 1999).
5s	Is a set of simple tasks for improving working environment, which are represented by Japanese words beginning with the letter "s", which can be translated and added to the word "sense": Seiri (sense of use); Seiton (sense of organization); Seiso (sense of cleanliness); Seiketsu (sense of standardization); and Shitsuke (sense of discipline) (FELD, 2000; LEAN ENTERPRISE INSTITUTE, 2003).
kaizen	Kaizen is composed by Kai (change) and Zen (Best), and is a Lean practice applied to manufacturing that seeks continuous improvement of a single process or the entire value stream in order to add value and eliminate waste (LEAN ENTERPRISE INSTITUTE; 2003; ARAUJO; RENTES, 2006).
Standardized work	It Establishes standard procedures for each employee's work in a production process, The practice also involves the documentation of the current process and is aimed at reducing process variability (LEAN ENTERPRISE INSTITUTE; 2003).
Just in time	Involves controlling production so that everything is produced and delivered when needed and in the required amount. (SHINGO, 1996; LEAN ENTERPRISE INSTITUTE; 2003).
kanban	Kanban means "sign" in Japanese and is a Lean tool that works as a customer demand signal, i.e., authorizing the start of production or removal of items in a working system. It also controls the level of work in process and the products' delivery time of the also can facilitate immediate abnormalities detection (OHNO, 1997; FELD, 2001; LEAN ENTERPRISE INSTITUTE; 2003).
SMED *(Single-minute Exchange of dies)*	Also known as Quick Change tools set, aims to reduce the setup time (FELD, 2001).
Manufacture cells	Involves the equipment's disposition and workstations for producing similar products in a sequence that allows the continuous flow of materials and components for the process, with minimal transport or delay (LEAN ENTERPRISE INSTITUTE; 2003).
Operator balancing	It is used in processes that involve multiple steps and multiple operators and has the objective of distributing the operator tasks' elements according to the "takt time", leveling the workload (LEAN ENTERPRISE INSTITUTE; 2003).
Visual management	Involves measure such as making the parts, tools, production activities and performance indicators easy to see so all workers involved quickly understand the system status. (LEAN ENTERPRISE INSTITUTE; 2003).
TPM (Total Productive Maintenance)	It addresses three main aspects: preventive maintenance; corrective maintenance; and predictive maintenance, which aims to ensure the reliability and overall productivity of equipments, involving all employees, not just the maintenance staff (FELD, 2001; LEAN ENTERPRISE INSTITUTE; 2003).
Multifunctional operator	It encompasses practices in which the operators work in more than one device in a islands layout or in a layout-oriented product flow (LÉXICO LEAN, 2003, OHNO, 1997).
Poka-yoke or error proof device.	Poka-yoke is a set of methods that help operators to avoid mistakes in their work, such as choosing the wrong component, incorrect assembly, lacking a component (FELD, 2001; LEAN ENTERPRISE INSTITUTE; 2003).

2.2 Cleaner Production

The intensification of economic activities and their environmental impacts increased the concerns about the environment (Allen et al., 2002). The concept of sustainable development is a response to these concerns and considers the needs of present generations, while taking into account the needs of future generations (WCED, 1987). In the quest for sustainable development, various approaches have

emerged to deal with industries' environmental impacts.

One of the first approaches to deal with the industries' impacts on the environment was the simple dilution and dispersion of pollutants, which was only meant to make pollution less evident (UNEP / UNIDO, 2004). In the 1960s and 1970s arise efforts for the regulation of industrial activities aimed at reducing manufacturing impacts. In response to these regulations, companies came up with solutions called "end-of-pipe", which aimed to control pollution after it had already occurred (HAUSCHILD; JESWIET; Alting, 2005).

The terms Cleaner Production (CP) and Pollution Prevention (P2) can be considered synonymous, and its distinction tends to be geographic: P2 is generally used in North America, while CP is the preferred term in other parts of the world (UNEP, 2015). Both have the same goal: continuous reduction of pollution and environmental impacts through source reduction, i.e., eliminating environmental waste in the process.

One of the CP's greatest drivers, besides the reduction of environmental impacts, is to reduce the costs associated with environmental waste. All waste generated result in costs, they have been bought at the price of raw materials and inputs consumed such as water and energy. Once environmental waste is generated it continues to generate costs from their treatment and storage, or even in the form of financial noncompliance penalties, or sales decrease due to the damage to the image and reputation of the company (CEBDS, 2015).

2.3 Lean and Cleaner Production

According Parveen et. al, an integrated approach to reducing environmental waste and increasing productivity is required in all industries. In this scenario, the use of Lean concepts together and cleaner production is necessary.

Song and Liang (2011) point out that while Lean focuses on improving cost and time performance and can bring immediate economic value, environmental sustainability is considered a different aspect of value, which is related to reducing environmental impacts. Because of this difference in focus, there is a need to assess how Lean applications affect sustainability.

Sawhney et. al (2007) relates the Lean Manufacturing with the Cleaner Production affirming that it is natural that the Lean concept, its value chain of inherent vision and its focus on the systematic elimination of waste, fit perfectly with the overall strategy of environmental protection, identifying this as Environmental Lean (Environmental Lean - Lean-En).

Song and Liang (2011) also highlight the gains of Cleaner Production when associated with Lean, stating that the elimination of waste through management practices improved by Lean provide a unique approach to achieve the concept of "Free Green" in which the Lean practices by itself generate environmental improvements.

It is noteworthy that the waste reduction achieved by Lean practices are closely linked to the CP objectives. However, waste reduction alone does not completely translates CP principles, as it also include the premise that less harmful materials to the environment should be used, which in many cases may increase the production cost, going against a Lean principle.

Still, according to Song and Liang (2011), the environmentally sustainable perspective, Lean can result in environmental impacts that vary in type (e.g., negative, positive or neutral) and magnitude (eg, negligible or significant), reinforcing the perspective that the combined implementation of the two concepts can be often confrontational.

In an attempt to tackle the possible conflicts between Lean and the Cleaner Production, Lapinski et. al (2007) used an interesting approach to make use of Lean concepts and tools and add to Lean customer values a value related to environmental impacts. Other than the value related to cost, time and quality desired, other factors are included to the customer value, such as environmental occupation, environmental performance, and minimal environmental impact, among others; at the same time that

environmental waste is defined as waste.

In short, the concept of "value" in the Lean theory should be aligned with the sustainability to ensure a win-win relationship between Lean and CP (Song and Liang, 2011), as well as overcome properly the conflicts in the simultaneous implementation of these concepts.

3. Research method

This research used as a research method the Systematic Literature Review (SLR). According to Biolchini et al. (2005) SLR aims to assess and collect the existing evidence in the literature on the research subject. The research process using the SLR method is composed by a well-defined methodological steps sequence shown in the Figure 1.

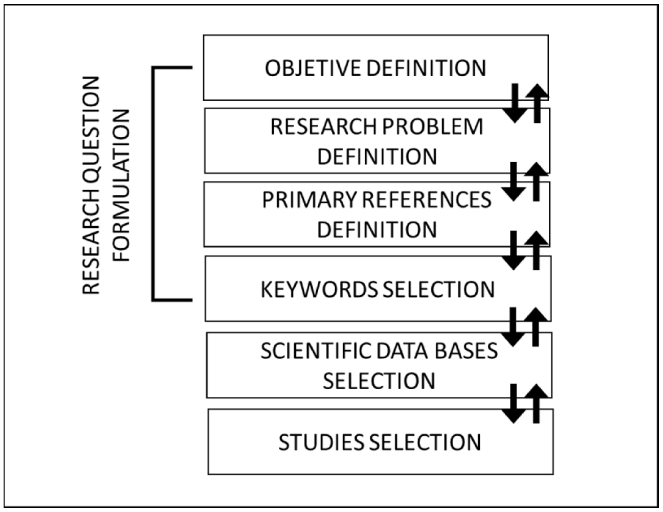

Figure 1. Research process framework
Source: Authors based on Comfort, Amaral e Silva (2011) and Biolchini et al. (2005).

The research process was recorded in a protocol and began with the question formulation. Initially the method objective was defined as "Identify what and how of Lean Manufacturing tools can assist in environmental improvements practices." Similarly, the research problem can be described as the companies need to improve the environmental performance of its products and processes and maintain itself competitive in the market.

Therefore the- primary studies were defined as, Florida (1996), Womack and Jones (2004), Liker (2005) and Allen et al. (2002). From those the following keywords were obtained: clean / cleaner production; pollution prevention; resource efficient / efficiency (production, manufacturing, methods); (Sustainab * (sustainable, sustainability); green; environmental, environmentally, lean manufactur * (manufacture, manufacturing); lean thinking, lean production, agile manufactur * (manufacture, manufacturing); lean system * (system, systems); agile production; toyota production system * (system, systems).

The studies search procedure was based on the use of defined strings in order to retrieve results containing at least a keyword related to Lean Manufacturing and a keyword related Cleaner Production, considering the search fields: title, abstract or keywords. The definition of each string was adapted to each database searched, since they have different search engines.

The third phase of the research was the selection of studies, based on the criteria of inclusion, exclusion and qualification of articles and filters. The inclusion and exclusion criteria were: to be written in English; to have the main theme related to the two areas of interest (Lean and CP); availability of the full text file for download; no to have been already added to the downloaded studies folder (duplicate exclusion). All types of study were accepted, such as articles, theses and conference publications.

The qualification criteria for their turn are related to the study of classification according to specific features. In this study the classification criteria were: type of study (theoretical and conceptual, case study and survey); Lean Production tools that have been addressed and an evaluation of how the tools are used for environmental improvements.

The initial search results determined by the keywords and the strings were 918 studies. Filters were applied to this search results, the first was the primary filter, designed to select studies in English and that had full text downloadable file available, retrieving 595 files. Later we applied the filter 1 consisting of reading the title, abstract and keywords for the evaluation of inclusion and exclusion criteria, the total amount of files obtained after this filter was 90. Finally, the filter 2, which sought to qualify the articles and find works that focused on the Lean Manufacturing tools by reading the introduction and conclusion, resulted in 12 articles.

4. Results

In this section the information extracted from the studies selected are going to be described in order to identify which and how Lean Manufacturing tools can be used in Cleaner Production in order to promote environmental improvements.

Miller, Pawloski and Standridge (2010) deal with the integration of Lean tools with concepts of environmental sustainability, focused mainly in the Environmental Management System (EMS). Three case studies where carried out and found the application of Lean tools to result in environmental gains. The authors also consider that Lean is broader than the concept of sustainability, which for them means that Lean is naturally environmentally sustainable.

In the first case study, the Discrete Event Simulation was applied to the design of a production cell, resulting also in a reduction of several environmental wastes. In the second case study, a recycling Kaizen was carried out, resulting in both Lean gains and environmental benefits. In the third case study, the Mathematic Optimization was used the suppliers selection, which also resulted in a reduction of the environmental waste.

Dakov and Novkov (2007) state that the Lean adoption is a step towards sustainability (i.e. Lean is naturally sustainable). The authors discuss the theory of Lean and Green and propose some environmental indicators to assess the Lean production impacts on sustainability. However, these indicators are not tested or validated.

The authors mention the tools, Kaizen, 5S, TPM, Cellular Manufacturing, Just-in-time, Six Sigma, Production Preparation Process, Lean Enterprise Supplier Networks - however, do not explain how these tools can affect sustainability.

Maxwell et al. (1998) discuss the history of the environmental management of Honda in the US compared to the production goals (Lean) and the subordination to the Japanese headquarters. According to the authors, the ISO 14001 standard has been enthusiastically received by Japanese headquarters, while the environmental manager in the US was concerned about the fact that the new requirements of the standard could be a "burden" to the factory.

Honda sought to integrate environmental management to the existing Lean manufacturing strategy (this was a great advantage in comparison to other companies in the U.S. by then). Yet, how did the Lean contributed to the environment? The Lean waste reduction policy could be directly applied to the environment. The Human Resources policy focused on employee selection, training and problem solving skills development, also contributed to the environment area. In addition, information systems were readily available and the performance indicators made it easy to identify and solve problems.

The work also argues about the creation of volunteer groups to solve environmental issues, based on previous training and a reward program. Employees were trained in troubleshooting tools: Y gaya discussions, brainstorming, fishbone diagram (cause and effect), Pareto diagram, PDCA. The groups used the process of environmental information from the visual management as a evidences to identify the problems which needed to be solved.

Aguado, Alvarez and Sunday (2012) developed a method which is based on environmental innovation and the waste elimination in order to help companies connect efficiency and sustainability so that they add more value to the product and increase market competitiveness. The method was developed based on the synergies of sustainability and efficiency. Aguado, Alvarez and Sunday (2012) show that the method follows the logic of pull production, the fourth principle of Lean Manufacturing in order to create a system based on the consumer needs and identify the value. The authors state that the pull production can provide benefits to the environment, since the intermediate stocks are eliminated and production is performed only when necessary.

Nevertheless, the model proposed by these authors use the VSM expanded to make visible the environmental parameters. This extended VSM aims to identify and quantify the improvements in efficiency and sustainability, considering both time and number of operators and environmental aspects. Finally, the authors conclude that there is a synergy between sustainability and efficiency and that a company, which applies the proposed model can be rewarded with competitive advantages from cost reduction resulted from decreasing the material and energy consumption per output unit.

The study conducted by Graham and Reardon (1997) is aimed to compare the efficiency of batch and continuous processing, the survey results showed that the amount produced was the same, but the continuous production was less waste and more variety of products. This study did not measure the intensity of the environmental impact, but presented the results achieved with the use of continuous process, which has reduced the amount of waste generated by the process, due to the use of materials, and waste from the energy generation. The survey did not address the relationship between Lean and CP and limited itself to the process type.

The study by Peng (2010) identify how the Lean philosophy can be applied in the factories of precast concrete to reduce carbon emissions. The study sought improvements in plant layout to avoid unnecessary transport. Yet, as shown by the author, the product should be delivered to the customer "fresh"(within 40 days). Thus the production cycles could not be delayed, so the pull production and the just-in-time control logic should be used to avoid the disposal, recycling and additional energy consumption and as a result, avoid carbon emissions. Finally, the author states that there is potential for energy savings by eliminating activities that do not add value to the customer, concluding that the Lean philosophy can be applied to reduce carbon emissions through improvements in layout, quality control, stocks and operation activities.

The study prepared by Vinodh, Arvind and Somanaathan (2010) proposed techniques that integrate the sustainability principles with lean techniques, presenting strategies and lean techniques to improve the results in lean while achieving environmental performance goals:

• pulled Production: reduction in process, waste disposal from damaged products in stock, less use of space;

• Cell Layout: Reduced setup times and therefore less energy and resource consumption, defects reduction;

• VSM: can be expanded to include the inputs and outputs information about the flow associated with the use of energy, water and other materials. The authors note that the inclusion of environmental waste in VSM require the proper selection of performance metrics. The authors also consider that the extended VSM can enhance the waste reduction due to fewer defects, less waste and lower energy consumption, among others;

• 5s: Lighting needs reduction, due to clean windows, immediately attended leaks, reducing material consumption. Moreover, the authors add 2 'S, safety and sustainability. Claiming that the seven 'S' can help organizations reduce waste, improve the environmental performance and increase the productivity;

• TPM: less hazardous waste due to the reduction of leaks and spills, increased longevity of the equipment;

• Kaizen: elimination of hidden waste and unwanted activities

• Visual Management: identification and elimination of unwanted entities use, resulting in less materials and waste;

• Poka yoke: defect reduction, so less waste, less energy use.

Besides associating the Lean Production practices, the author highlights that environmental waste refer to the unnecessary use of resources or substances emitted into the air, water or land which can harm human health and / or the environment. Finally, the study suggests that Lean Production makes significant contributions to achieve good results in both environmental performance and operations performance.

Torielli et al. (2011) make a literature review and describes how Lean and Green can provide an important framework for the frontiers of economic and environmental sustainability. The authors discuss a conceptual framework to investigate this relationship. The authors also point out that the waste reduction is seen as the Lean philosophy's essence and present how Lean wastes can generate impacts on the environment. The Lean Manufacturing tools Green VSM (GVSM) and the 5s are cited by the authors.

They emphasize that the GVSM can be used to identify the sources of emissions, improvement opportunities in the use of materials and energy, activities that do not add value and can further provide a path to possible technological innovations and partnerships. Yet, it may be a way of communicating with stakeholders about the company's activities and flows of material, energy and waste. Torielli et al. (2011) also point that this tool can be used to analyze the product life cycle, showing the path from of raw materials extraction to final waste disposal, helping to identify and quantify the environmental impacts at each stage.

As for 5s Torielli et al. (2011), the 5S is the key element of an operational management system in which items that need attention of management and supervision must be clearly visible to all, promoting common understanding of what is important and what is within the established standards. From the environmental sustainability perspective, the 5S draws attention to the waste and / or uncontrolled emissions because they fall outside the established standard, so this practice can contribute to energy efficiency, indicating the machines and items that are not working according to the operating standard procedures. One example cited is the case of a floor cleaner that would quickly show a leak in its system from which material is being wasted.

Lapinski, Horman and Riley (2007) show a case study on the design and construction of the southern campus property of Toyota Motor Sales, USA. The Lean tools and practices associated with the Green concepts provided Leadership in Energy and Environmental Design (LEED) gold certification from the US Green Building Council, relying on costs similar to those from a conventional construction.

The implementation of the project was developed from the TPS premises with the integration of Lean and Green concepts. Such integration started with the definition of values: besides the issues related Lean, such as quality, functionality and cost reduction, issues related to Green such as environmental efficiency, were grouped and defined as values to the client. In addition to the TPS, the Kaizen system was also used to improve the proposed methodology for future projects of this type.

Parveen Kumar and Rao (2011) relates of several tools used in Lean Manufaturing with the Lean Supply Chain and Green Supply Chain, identifying which practices are the most interesting for integrating Lean and Green Supply Chain. The article identify VSM, 5S, Kaizen, JIT and Kaban as the Lean tools that bare the best performance potential for combining "Lean" and "Green". Additionally TPM and the Poka Yoke also have a considerable degree of integration. Finally, tools such as Visual Management and Mobile arrangement were considered to be Lean tools with little integration with Green.

Song and Liang (2011) present a case study for a lean methodology designed for civil construction projects, with gains in sustainability ("Green") related to the waste generation reduction during the

design and construction process. Despite not having a deeper discussion of the relationship between "Lean" and "Green", the authors address the issue in a coherent manner, explaining that, although different, the approaches can work together in a "win- win "perspective. Regarding the tools used, most of the tools presented in this article are related to project management, however pull production and visual management are used to achieve the proposed objectives.

The pull production was used for programming activities from the operators, raw materials available and the steps already undertaken. The Visual Management, for its turn, was used as a simple and effective way to show the progress of the project to the workers involved.

In Vaisl et al. (2006), although the title of the study refers to concepts Lean and Green, the study practically only shows the advantages of the application of lean manufacturing in a paper company. The environmental benefits ("Green") are derived from consumption reductions achieved with the implementation of Lean and environmental compliance. The tools used in the implementation of Lean were Kaizen, 5S, TPM, cellular manufacturing and the JIT.

5. Conclusions

Throughout the development of this work, it was possible to conclude that many tools used by Lean Manufacturing can be used for obtaining environmental benefits. The tools used in the studies analyzed were: Kaizen, VSM, Pull Production, Manufacturing Mobile, TPM, JIT, Performance Indicators, Worker Multifunctional Continuous Flow, Physical Arrangement, Poka Yoke, Kanban, Visual Management and Labor Training.

Among the results presented, the Kaizen methodology was mentioned, in five studies. This is due to the fact that this practice may be applied to perform any kind of improvement, as highlighted by Allen (2006). Another recurring tool in four of the studies analyzed is the VSM, occurrence which can be explained by the fact that it is a simple tool that helps in a better visualization of the processes. With respect to the other tools, the studies have shown that it is possible to obtain environmental benefits from its application, by reducing the materials and energy consumption.

The method utilized helped to identify some practices that favor of lean environmental performance. However, it is not possible to generalize the results because only 12 articles were analyzed, among which only success stories were presented. For a better understanding of the study subject, it is suggested that further studies are conducted, to quantitatively evaluate the environmental benefits achieved.

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