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EFFECTS OF LEAN METHOD APPLICATION ON COMPANY ENVIRONMENTAL PERFORMANCE

Summary: *The strong commitment of the world's strongest economies to actively combat global warming has "forced" companies around the world to include in their long-term development strategies goals to reduce their own negative impact on the environment. In this regard, the question of the impact of certain production approaches on the environmental performance of companies has arisen. Lean production, whose philosophy with embed goals is to reduce waste, has prompted a number of authors to investigate the positive correlation between its implementation and the reduction of environmental pollution caused by emissions to water, land and air. Following these efforts, the aim of the paper is to, through a focus on relevant papers in this field, present the various conclusions reached by the authors in their research. Special emphasis is placed on the identification of Lean methods and tools that have proven to be the strongest tool in companies' efforts to reduce emissions and thus contribute to the fight against climate change. The paper uses scientific methods of description and compilation in order to highlight the basic characteristics of Lean production, on the one hand, and academically correct presentation of other people's conclusions and knowledge, on the other hand. The results of the research showed that the largest number of authors, who dealt with this topic, identified the existence of a positive impact of Lean production on the environmental performance of companies. What's more, the application of certain Lean methods or tools has enabled companies to exceed both business and Lean waste reduction goals. In this regard, it is concluded that, in addition to increasing profitability and competitiveness, environmental results have emerged as reasons for the implementation of Lean production.*

Key words: *Lean production, Lean methods, Lean tools, cost efficiency, environmental protection*

JEL classification: *Q 0, M 41*

INTRODUCTION

In addition to its worrying impact on the environment and people, climate change is also one of the greatest threats to the stability of the world economy. That is why, at a time when most of the world's inhabitants have become aware that unusual and extreme weather conditions are a direct consequence of climate change, it is important to highlight questions that still require adequate answers. This primarily refers to those related to the manner and intensity of the impact of climate change on the economy and business in general, as well as the strategies that companies create to reduce risk and find ways to achieve competitive advantage in a changing world. The negative impact of climate change on the world economy is reflected, above all, in the domains of resource availability, variations in energy prices, variations in the value of companies and stock price trends. The most endangered are those industries and communities whose economy depends on resources

that are sensitive to climate change, as well as those located in areas exposed to extreme weather and climate influences. An increasing number of companies, aware of the consequences caused by climate change, on the one hand and more rigorous legislation, on the other hand, are significantly approaching the modifications of their development strategies. In this regard, the focus is increasingly on continuous improvement of production approaches; adjusting the offer to the wishes and needs of customers, with significant improvements in the field of product quality and functionality; reducing costs and maintaining the existing price level or lowering it, in situations that allow it. Research has shown that in today's constellation of relationships Lean manufacturing represents the broadest manufacturing paradigm, currently applied in the industry. In addition to significantly contributing to increased profitability, effective response to changes in customer requirements, improving product quality and functionality of production processes, and positive changes in organizational culture and employee motivation, Lean production can improve environmental performance of companies. The reason for this is the fact that Lean production and environmental measures have common elements: a focus on reducing waste and increasing the efficiency of production processes (Abualfaraa et al. 2020; Abreu et al. 2017; Ng et al. 2015). It is important to point out, in this context, that various authors have investigated the impact of certain Lean methods and tools on the environment. Some authors (Vinodh et al. 2011, 469) point out that Lean initiatives result in significant environmental benefits and that companies should therefore consider the extent of their own environmental impact, and in this regard quantify the sustainable benefits that can be associated with Lean initiatives. Some authors (Garza-Reyes 2015, 227) claim that Lean's focus on waste reduction creates an excellent starting point for reducing environmental waste such as excessive consumption of water, energy or any other natural resource. In addition, he believes that Lean, in its individual segments, is "naturally" in line with good environmental practices. This is the view of other theorists (Carvalho et al. 2011, 157) who emphasize that with the rapid growth of long-distance trade, supply chains are becoming longer, leading to a significant increase in fossil fuel energy consumption for transport, emitting much more carbon dioxide than was the case in earlier decades. Eliminating unnecessary or excessive transport of products and / or raw materials (which is one of the seven types of waste defined by Lean production) significantly reduces operating costs, on the one hand, and unnecessary consumption of natural resources and carbon dioxide emissions, on the other. Given the wide range of Lean production methods and related tools, a legitimate question was raised about their impact on improving companies environmental performance and to what extent, as well as the existence of a positive correlation between indicators used to measure Lean companies' environmental performance, on the one hand, or Lean methods and tools, on the other hand. In an attempt to find answers to the questions posed, the paper presents the results of individual studies that have addressed this issue. The rest of the paper is structured as follows: the first part gives a brief overview of the history of Lean production, the second part discusses the Lean production paradigm, Lean methods and tools, while the third part presents the results of individual research to find and analyse links between Lean production and green initiatives that greatly improve the environmental performance of companies and contribute to their involvement in the struggle to preserve the environment.

1. BRIEF HISTORY OF LEAN PRODUCTION

Although Lean production and Lean philosophy are linked to Toyota's production system, it is important to emphasize that the pioneer of Lean production is considered to be the American industrialist and business magnate Henry Ford. In its car factory called Ford Motor Company, Ford in 1913 managed to make a revolutionary shift from previous production practices, by integrating production processes into a completely new concept called mobile production. Until the introduction of Ford's approach, the production process took place in classic production workshops that consisted of general-purpose machines and were grouped according to the type of processing.

Each of the workshops produced large quantities of identical parts that would be stored until the production of other parts of the product, after which they would be assembled into the final product. The disadvantage of this method of production was reflected in the large amount of costs contained in the unfinished production, as well as in a large number of defective final parts, which very often could not be joined (due to differences in thermal treatment of metals). Henry Ford divided the production process into production steps, which he then arranged into production lines. For the needs of production, machines were used that were specialized for the production of a certain part of the car, as well as control devices that did not allow defective products to pass to the next step of the process. Mass production enabled the delivery of perfectly assembled, replaceable parts, and another novelty - the conveyor belt on the car assembly line - enabled the continuous movement of parts through the production process and significant acceleration of production. Nevertheless, Ford's push production concept had a number of shortcomings (Krafcik 1988, 43): long delivery times, weaknesses in responding to customer demands, stock increases, reduced quality, increased non-value-added activities, increased hierarchy and bureaucracy, additional costs, higher capital requirements, inability to offer a variety of products, simple, repetitive jobs by unskilled workers . In 1933, Kiichiro Toyoda founded Toyota as a division of Toyoda Automatic Loom Works, which in 1937 changed its name to Toyota Motor Corporation, under which it still operates today. Kiichiro was delighted with the idea of mass production at Ford's factory, which he visited along with two other directors, Eiji Toyoda and Taiichi Ohno, in the 1950s. That visit was a key moment in creating the philosophy of Toyota's business. Upon their return to Japan, Toyoda and Ohno realized that the mass production used by Ford could not simply be replicated in Toyota, because the Japanese market was too small and did not require quantity but variety: from compact to luxury cars. The most important finding in America was the identification of key shortcomings of mass production, which they defined as seven types of losses: overproduction, transportation, waiting / downtime, over-processing, stocks, unnecessary movements, scrap. These seven types of losses became part of their Toyota Production System concept. In addition, the main moment, which redirected Kiichiro's thinking during his stay in America, was the principle of filling the shelves in stores, which were supplemented by the pace at which customers emptied them. By combining this concept of pull production and Ford's approach to production with the identified shortcomings removed, a basic methodology was created that was the forerunner of Lean production.

2. BASIC POSTULATES OF LEAN PRODUCTION

At a time when business conditions and customer requirements are increasingly unstable and complex, companies must find ways to shorten their time-to-market cycles by continuously improving production approaches, identifying and responding to customer requirements, applying methods and approaches that reduce costs, focusing on improving product quality and functionality, while maintaining or lowering prices. Lean (or slender) production, as a production methodology, but also a philosophical approach, builds its foundations on the already mentioned Toyota production system. The basic Lean paradigm implies the creation of products (services) that perfectly meet the wishes and requirements of customers, created in a perfect process without defects and waste. To achieve this, each organization must incorporate the following five principles into its (Emiliani 2004, 177):

1. understand and define value from the user's perspective and incorporate it into the characteristics of the product (service).
2. identify, map and understand each process within the value stream, and identify value added activities, support activities and non value added activities.
3. establish a continuous flow of materials, services and information from the beginning to the end of the process.

4. establish a pull system that allows the user to give a signal when there is a need for a type of product, or more precisely, the production and delivery of products upstream, just in time, when they are needed and in quantities needed downstream.
5. continuously improve, or have a constant desire for improvement and striving for perfection. Although it is only a theoretical category, the pursuit of perfection, which would be a process in which all activities bring value and in which waste is reduced to zero, must be permanent.

Achieving the set goals and achieving the set principles requires a detailed re-examination of the method of production and delivery of goods and services, as well as abandoning the paradigm of mass production "batch and queue", and focusing on production systems that are compatible with the product and based on the system of "pull production, one piece flow. Batch processing and waiting systems involve mass production of large quantities of products or parts and moving them to the next operation before they are really needed there. This creates large amounts of stocks that "captures" costs and achieves long production cycles. Products are tailored to potential or anticipated rather than actual customer requirements, due to the fact that production by series and functional divisions arranged in a given order causes significant time delays. Due to all this, the system is inefficient and wasteful in many of its segments. On the other hand, Lean means grouping the equipment, workers and resources necessary for production into one cell, which creates a continuous and one-part flow, which allows the processing of different product segments to take place directly next to each other in the so-called “Product teams”. A very important feature of Lean is the systematic elimination of all forms of costs that have no added value. This includes all types of waste and pollution resulting from deficiencies in the production design or production process. *Muda* is a Japanese term for waste, futility, nonsense, and their "biggest enemy" was the already mentioned Toyota CEO Taiichi Ohno. For Taiichi, muda is (Barraza et al. 2016, 5): any human activity that does not create value but absorbs resources; errors that must be corrected; production of unnecessary parts that accumulate stocks; unnecessary processing steps; insignificant movement of employees and insignificant transport of goods from one place to another; a group of employees who are waiting idle because the process in the previous activity has not been completed; products and services that are not in line with the needs and desires of customers. The goal of Lean production is to achieve a state in which waste and pollution will be reduced to zero, which can be achieved through a systematic assessment of costs and values associated with the product realized through four strategies:

1. *accepting the view of the whole system* by shifting the focus from the functional departments, to the whole production system and the corresponding total costs. The essence of this strategy is a different approach to financial decision-making that accepts higher costs for individual components that are procured for certain functional departments, in order to achieve overall savings at the level of the entire production cycle. Thus, for example, although it is cheaper to procure larger quantities of raw materials on a regular basis, by abandoning this practice, the total price of the product is reduced, because the costs of keeping stocks are eliminated.
2. *valuation of the value chain* in order to identify activities that do not create value for the customer. Such activities need to be redefined to reduce waste.
3. *Inter-functional production adapted to the product,* which through production / process-focused cells allows a combination of processes and equipment from different functional areas, and the formation of Lean teams composed of experts of different profiles engaged in different parts of the production process.
4. *product design* that has lower material consumption, is better quality, cheaper and easy to produce. This is achieved by "using standard parts, removing unnecessary components, integrating multiple components, selecting components that are easy to assemble, etc.".

Some authors (Belekoukias et al. 2014, 5348; Shah and Ward 2007, 801) in basic Lean production methods, which enable organizations operational excellence on the one hand, ie the realization of goals related to profitability, efficiency, rapid response to changes in customer desires and needs,

quality and customer satisfaction, on the other hand, include: just in time (JIT), total productive maintenance (TPM), Jidoka (automation with human intelligence), value flow mapping (VSM) and kaizen (Table 1).

Table 1. Lean production methods and tools (Garza-Reyes et al. 2018, 174)

JIT	One piece flow, Pull system, Takt time, Levelled production, Cell manufacturing, Visual inspection, Kanban/pull production system, Multifunctional employees, JIT purchasing.
TPM	Overall equipment effectiveness (OEE), Single minute exchange of die (SMED), 5S, Autonomous maintenance, Planned maintenance, Quality maintenance, Initial control before the starting of production, Safety, hygiene and the environment.
JIDOKA	Mistake proofing (Poka -Yoke), Andon/visual control system, Full work system.
VSM	Curent state map, Future state map, Flow diagrams.
KAIZEN	5S, Brainstorming, Continuous flow, Kanban, Data-check sheet, Five whys, Pareto chart, Flow Chart, Gantt chart, VSM, Process map, Mistake proofing (Poka -Yoke)

Just in Time (synchronous production according to requirements) is a production and delivery strategy in which the material necessary for production is delivered exactly on time and in the quantity in which it is needed, to the production process that is needed. In doing so, it is important to point out that the emphasis is on word-time. This means that the material should arrive within a few minutes before its use on the production line. Precisely because of this, and only in this way, it is possible to eliminate waste in forms such as overproduction, waiting for delayed deliveries and excess stocks (Kootanaee 2013, 8). This strategy aims to design the flow of materials from the point of view of the recipient production company in such a way that all the necessary materials are in the right place and at the right time. Unlike the classic procurement, which requires the harmonization of logistics, procurement, production and sales, and a large number of external suppliers and service providers, in Just in Time delivery procurement is much easier because all items are ordered from a central supplier. He takes over the coordination between individual suppliers, orders the necessary materials from them according to the production plan and takes care of the receipt and storage of goods. Uninterrupted and reliable communication between participants is the key to the success of the Just in Time strategy.

Total productive maintenance (TPM) aims to maximize the efficiency of plant and equipment, which seeks to ensure the optimal life cycle of production equipment. This can be achieved through: "minimizing machine downtime, production losses and material waste, and improvement the work efficiency and productivity of employees and equipment" (Wakjira and Singh 2012, 26).

Jidoka is a Lean method that is also known in the literature as automation with human intelligence. It has its roots in the time when Toyota produced automated looms, and it includes an automatic shutdown system. Automatic shutdown of machines occurs in two cases (Szmelter 2012, 5): at the time of completion of production of the planned quantity of products and in case of errors in the production process which can be either a machine error or an error due to incomplete product manufacturing. The main goal of Jidoka is to prevent the production of scrap parts or defective products, along with meeting the prescribed standards in the field of quality, and to enable only the correct parts or products to reach the next stage.

Value stream mapping involves mapping, that is combining and pictorially displaying all parts of the process and its value flow. Mapping shows in a very simple way all production operations, the state of stocks between operations, the time needed to change tools, all unnecessary waiting, use of practical capacity, etc. This method allows visual identification and measuring the waste

resulting from inefficiency or unreliability of information, time, money, space, people, machines, materials and tools, during the process of product transformation (Pavnaskar et al. 2003, 3087).
Kaizen process of continuous improvement is both an action plan and a philosophy. Kaizen, as a philosophy, creates a work climate in which each employee is motivated to personal and professional progress, continuous search for improvements in work processes and procedures, and initiating positive changes in the organization. As an action plan, Kaizen is in fact a kind of guide on how to implement changes in the organization and stay on the path of continuous improvement. After becoming part of the organizational culture, kaizen becomes a platform for maintaining Lean initiatives.

3. LINK BETWEEN LEAN PRODUCTION AND ENVIRONMENTAL PROTECTION

Given the fact that the Lean production paradigm is most prevalent in the modern production environment (In this regard, it is interesting to mention some of the companies that implement Lean: Coca-Cola, Nestle, Boeing, General Electric, Airbus, Mayo Clinic, Bank of America, Intel, Ford, Nike, Zara, Ikea, ..), and that the issue of environmental performance of companies, in terms of pollution prevention and waste of resources, has become one of the key postulates of business, it is understandable increased interest of both academic and business public on the topic of the impact of Lean production on environmental protection. In this regard, it should be noted that a significant number of papers have been published in this area in which individual authors have developed models that allow the joint application of both paradigms in different sectors and different countries (Ng et al. 2015; Pampanelli et al. 2014 ; Kurdwe et al. 2014; Verrier et al. 2016; Bae and Kim 2008; Colicchia et al. 2017; Thanki et al. 2016; Zhan et al. 2018;), while some studied barriers that can be a significant obstacle in their implementation and evaluation (Cherrafi et al. 2017; Mittal et al. 2016). Lean production is, in essence, focused on reducing waste and pollution, and in this regard, it is reasonable to ask the following: a) have organizations that have applied the methods and principles of Lean improved their environmental protection measures?, and b) which Lean methods have proven to be the most effective in the process of positive impact on environmental performance? Most research studies have concluded that the implementation of Lean has significantly improved the environmental performance of companies. One of these was conducted by the US Environmental Protection Agency in 2000, which, following the example of Boeing, the world's leading manufacturer of aircraft and aeronautical equipment, showed that a dramatic paradigm shift is a key strategy to maintain a competitive advantage in a highly competitive market of the 21. century. The Lean manufacturing philosophy and strategy, which Boeing decided to implement in February 1996 throughout the commercial aircraft division and subsequently throughout the company, has resulted in significant improvements that could be classified into five segments:

1. *Lean production is mainstream.* By reorienting and investing significantly in Lean, Boeing expresses its belief that Lean plays the most important role in their efforts to meet the wishes and needs of customers, reduce costs and systematically and continuously improve their operational performance. In addition, it is important to point out that Boeing's experience coincides with the experience of other industrial sectors in the United States, and that is why the Lean philosophy represents (and will continue to represent) the basic building block of American industrial production.
2. *Lean contributes to a significant increase in resource efficiency with important implications for the environment and sustainability.* Thanks to Lean, Boeing has made significant improvements in the field of saving energy and raw materials, and reducing non-production outputs associated with the production process. Energy savings are the result of reduced space utilization, reduced transport and less product refinement (The most significant results, achieved in Boeing's Auburn machine business unit, show that as a result of Lean, the total

space used by the business unit was reduced from 650,000 to 450,000 square meters, and 8,000 square meters of temperature-controlled atmosphere were eliminated.

3. The effects of these efforts are reflected in comprehensive product-based energy savings related to all aspects of energy use for building space (e.g. heating, cooling, lighting, etc.). Thanks to improved use of space, better control of stocks, reduced rate of shortages and waste, use of fewer (or elimination) of lubricants and sealants, and reduced use of vehicles, significant savings in raw materials have been achieved (Efforts at the Auburn business unit have reduced raw material consumption by $ 22 million and reduced damage and spoilage, resulting in better overall raw material utilization). Lean has also enabled very significant improvements in the field of production that is not directly related to the final product, but to production and assembly operations (for example, waste related to defects and materials outside the specification, packaging materials and material losses). The savings are reflected in the reduction of defective products, as well as in the reduction of the total cost of lost dollars due to the occurrence of defective products. (The study states that the Auburn plant reduced product shortages from 1,200 / 10,000 in 1996 to less than 300 / 10,000, and that it reduced the amount of quality cost, measured as the total cost of dollars lost due to deficiencies, by more than 51 percent).
4. *Lean creates a strong waste elimination culture.* This is achieved by creating Lean teams consisting of representatives of management, toolmakers, quality assurance, safety, health and environmental protection (SHEA), production staff, IT, etc. The task of the teams is to first perform a systematic evaluation of waste generated in production processes, development of procedures for its elimination, measurement of results, development of additional procedures for its minimization, and to continuously repeat the described cycle.
5. *Lean thinking brings powerful financial incentives to preserve resources and improve pollution prevention.*
6. *Lean strategies could not be applied to environmentally sensitive processes.* The study showed that operations, which are part of the metal production process and assembly activities in all industries, such as painting, chemical treatment and drying, could not become Lean. This fact has certain significant implications for the company itself, other companies and the environment. Namely, first Boeing faced the impossibility to create a single piece flow for its products, which led to an increase in the number of flow days, as well as higher demands for space, raw materials, energy and supplies. Second, the research has shown that in the parts of the production process that have become Lean, a significant increase in resource productivity has been observed, ranging from 30-70 percent. In addition, due to the fact that traditional production methods had to be retained for certain production operations, Boeing could not completely eliminate the production of large series of similar parts over longer production cycles.

The results were the basis for a new study conducted jointly by the Agency's Office for Solid Waste and Emergency Response (OSWER) and the Office for Policy, Economics and Innovation (OPEI), all with the aim of further establishing the relationship between Lean production, environmental efficiency and regulatory framework. The research was conducted on a sample of four American companies (The study involved: Apollo Hardwoods Company, General Motors Corporation, Goodrich Corporation – Aero-structures Group and Warner Robins U.S. Air Force Base), and resulted in the following important findings: a) Lean creates a working and cultural environment that has proven to be extremely suitable for minimizing waste and preventing pollution; b) by filling in the key "blind spots" that may arise during its implementation (which will be discussed later in the paper), Lean can be used to achieve significant improvements in environmental protection; c) in situations where organizations are considering applying the Lean method to environmentally sensitive processes, regulatory uncertainties or delays may occur. This can lead to situations where either there is an increased risk of potential non-compliance with environmental regulations, or

improvements in environmental performance are limited. A very interesting part of the research is the correlation observed between the seven common types of waste (which Lean is focused on eliminating) and the impact that each of them has on the environment (Table 2).

Table 2. Environmental impacts associated with manufacturing waste (United States Environmental Protection Agency 2003, 28)

Type of waste	Environmental impact
Defects	Raw materials used to make defective products; Defective components require recycling or disposal; More processing and repair space is needed, which increases the use of energy for heating, cooling and lighting.
Waits / delays	Potential material deterioration or waste caused by component damage.
Excessive production	More raw materials used to make unnecessary products; Additional products may be defective or obsolete and may require disposal.
Movements and transport	Greater use of energy for transport; Emissions from transport; More space needed for work in the process (WIP); movement, increasing lighting, heating and cooling, energy demand and consumption; More packaging needed to protect components while moving.
Stocks	Multiple WIP storage packages; Waste from deterioration or damage to stored WIP; More material needed to replace damaged WIP; Higher energy consumption for heating, cooling and lighting of stocks.
Complexity and over-processing	More consumed parts and raw materials per unit of production; Unnecessary processing that increases waste, energy consumption and emissions.
Unexploited creativity	Fewer suggestions regarding options for minimizing pollution and waste.

Although very detailed, research conducted by the EPA has failed to answer the question regarding the ability of certain Lean methods and tools to influence the reduction of identified and quantified environmental impacts. In this regard, it is important to note that some authors (Garza-Reyes et al. 2018) researched the existence of a correlation between five Lean methods: JIT, TPM, Jidoka, VSM and Kaizen and environmental performance of companies. The research concludes as follows: in general, TPM and JIT methods result in the most significant impact on the overall environmental performance of an enterprise; the application of the Kaizen method has a positive effect only on material use and contamination, while Jidoka and VSM have shown no effect (Garza-Reyes et al. 2018, 175). Table 3 shows the summary results of the correlation analysis.

Table 3. Summary of the results of correlation analysis (Garza-Reyes et al. 2018, 175)

Lean method	Use of materials	Energy consumption	Non-production outputs	Pollutant discharge
Kaizen /CI	+	0	0	+
VSM	0	0	0	0
Jidoka	0	0	0	0
TPM	+++	+++	+++	+++
JIT	++	++	++	++

Explanation: +++: highest degree of correlation; ++: second strongest degree of correlation; +: the third strongest degree of correlation - all are statistically significant; 0: statistically insignificant correlation.

Some authors, in addition to VSM and TPM methods, also researched the impact of individual Lean tools: cell production, 5S and one-minute matrix change, on the environmental performance of companies (Chiarini 2014). The results of this research showed that the application of certain Lean tools significantly improved the environmental performance of the companies that were the subject of the research (The research was conducted on five European companies engaged in the production of motorcycle parts. The companies were selected on the basis of the following criteria: a) similar products, production processes and size; b) they all operate in the EU, which means that

they are subject to the same EU environmental legislation; c) each has been ISO 14001 certified since 2008 and publishes an environmental balance sheet and policy once a year quantifying all environmental performance together with related investments; d) all typical Lean tools have been implemented since 2008 and each of the companies is very committed to Lean production; e) five types of Lean tools are used in each company: VSM, 5S, cell production, SMED and TPM; f) the application of Lean tools has been observed on machines of the same type, which produce the same products and have the same impact on the environment). Namely, the implementation of the *5S tool* (defined with five precise steps: separation, tidying up, shine and cleaning, standardization and maintenance) resulted in better identification and separation of different types of industrial waste, reduction of workshop space required for production activities, reducing the amount of lubricated and soluble cloths that are a type of waste, and by reducing oil leaks on the floor. *Cell production,* which involves grouping machines and equipment into a single cell in a u-shape, has resulted in reduced material transport to the cell, resulting in significant energy savings needed to charge the electric truck battery. SMED is a tool invented by Toyota and serves to better organize activities at the moment when production is stopped in order to change parts of the machine or mould. With a significant increase in efficiency in the field of technical interventions on machines, research has shown that the implementation of SMED tool does not bring significant environmental benefits. *TPM* is used for two-level management. The first level is at the same time basic and is called autonomous maintenance, and includes daily cleaning and basic maintenance of machines by workers who handle them. The second level is engineering and involves the collection of data on the frequency of failures by supervisors, all with the aim of creating a preventive maintenance program. The research showed that the application of TPM achieved a significant reduction in oil leakage to the floor (especially in the base of machines), and a reduction in dust and smoke emissions of volatile organic compounds, isocyanates and ammonia.

Some authors have analysed the impact of Lean production on common indicators used to measure the environmental performance of Lean companies, which include material use, energy consumption, non-productive outputs and pollutant discharges into soil, water or air. Studies have shown that Lean production has the most positive impact on reducing harmful gas emissions, energy efficiency, and reducing solid waste (Deif 2011; Fliedner 2008; Gustashaw and Hall 2008; Hajmohammad et al. 2013; Wiese et al. 2015).

In addition to a number of positive effects, some studies have shown that the application of Lean methods and tools leads to the occurrence of so-called blind spots). Namely, Lean methods do not explicitly identify pollution and environmental risk as "waste" that needs to be eliminated. Further, the staff in charge of environmental protection in many companies is not well integrated into Lean implementation processes, and therefore it happens that activities aimed at environmental protection take place in parallel and separate from the Lean process. And finally, the expertise and knowledge held by environmental protection agencies on waste minimization and pollution prevention is not always available to Lean practitioners, which significantly holds back and complicates implementation tasks. Some of the authors believe that Lean, in addition to positive, may have negative implications for the environment (Carvalho et al. 2017; Dües et al. 2013; Rothenberg et al. 2001). The reason lies in the fact that the pursuit of a higher level of productivity and efficiency is often in conflict with environmental sustainability in production. This is supported by the fact that increasing business activities means increasing production, transport, deliveries and inventories, which results in increased waste. In this regard, some authors consider the JIT method to be particularly problematic, which, due to maintaining a low level of stocks and the consequent more frequent transport, increases carbon dioxide emissions and thus reduces the environmental performance of companies. In addition, by increasing distance and including more production lines, the production process becomes less environmentally friendly (Venkat and Wakeland 2006, 3; Zhu and Sarkis 2004, 272).

CONCLUSION

The paper presents the results of several relevant studies whose common link was the identification of the impact that Lean production has on the environment. The focus was on improving the environmental performance of Lean companies, on the one hand, and identifying Lean methods and tools that have the highest degree of correlation with indicators used to measure environmental impact, on the other hand. The most detailed research in this area includes case studies conducted by the US Environmental Protection Agency in four US companies and Boeing, investigating, among other things, the effects of Lean production on the prevention of environmental pollution. The results showed that the decision to switch to Lean proved to be completely correct because it enabled a significant improvement in business performance and a visible reduction of the negative impact on the environment. Lean also enabled a significant increase in resource efficiency, which had a very positive effect on reducing environmental pollution and sustainability. Furthermore, Lean has enabled the creation of a strong organizational culture of waste elimination and strong sources of financial incentives to preserve resources and improve pollution prevention. Lean has become Boeing's most powerful tool in quickly adapting to and responding to changes in customer preferences and needs, reducing costs, and systematically and continuously improving operational performance. Several authors have analysed the impact of Lean production on common indicators used to measure the environmental performance of Lean companies (which include: material use, energy consumption, non-production outputs and pollutant discharges into soil, water or air). In this regard, they learned that the implementation of Lean has significantly reduced harmful gas emissions, increased energy efficiency, and reduced solid waste. The results of research conducted by individual authors, which relate to the individual ability of certain Lean methods and tools to contribute to a significant improvement in the environmental performance of Lean companies, are also very interesting. In this regard, it is important to note that the TPM and JIT methods showed the highest degree of correlation with all indicators, while Kaizen / CI showed the weakest, but still statistically significant correlation with material use and pollutant release. Among Lean tools, 5C and cell production stood out the most, while SMED, despite a significant increase in efficiency in the field of technical interventions on machines, did not show results in the segment of environmental protection. Not all authors agree that Lean production brings only positive effects when it comes to improving the environmental performance of companies. Namely, a number of researchers believe that Lean, in addition to positive, can also have negative implications for the environment. At the heart of the criticism is the JIT method, which the authors consider problematic due to the fact that maintaining low stock levels requires more frequent transports of activities that cause increased carbon dioxide emissions, that is in general, the pursuit of higher levels of productivity and efficiency inevitably leads to an increase in production, transport, delivery and inventories, resulting in increased waste, and thus creating a production process that can not be characterized as environmentally friendly.

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