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LEAN AND GREEN: THE CONTRIBUTION OF LEAN PRODUCTION AND ENVIRONMENTAL MANAGEMENT TO THE WASTE REDUCTION

Lean e green: a contribuição da produção enxuta e da gestão ambiental para a redução dos desperdícios

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ABSTRACT

In the current environment of high competitiveness between companies, production systems can constitute threats if the performance of their operational processes is not able to reduce costs, waste, controlling environmental impacts and increase productivity. So, this study aims to investigate the contribution of lean production (Lean) and environmental management (Green) to reduce waste in production processes. This is an exploratory and qualitative research and it was conducted through a multiple case study applied in three companies from Ceará state in different economic sectors, using the lean production system associated with the practice of environmental management. The results provided evidence indicating that lean production associated with environmental management contributes to reducing waste in production processes.

Keywords: Lean Production. Environmental Management. Waste.

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RESUMO

No atual ambiente de alta competitividade entre as empresas, os sistemas de produção podem se constituir em ameaças se o desempenho de seus processos operacionais não for capaz de reduzir os custos, os desperdícios, e o controle dos impactos ambientais e, com isso, aumentar a produtividade. Este estudo tem por objetivo investigar a contribuição da produção enxuta (Lean) e da gestão ambiental (Green) para a redução dos desperdícios nos processos de produção. Consiste de uma pesquisa exploratória e qualitativa, realizada por meio de estudo de caso múltiplos aplicado em três empresas do estado do Ceará de diferentes setores econômicos, que utilizam o sistema de produção enxuta associado a práticas de gestão ambiental. Os resultados forneceram evidências indicando que a produção enxuta associada à gestão ambiental contribui para a redução de resíduos em processos de produção.

Palavras-chave: *Produção Enxuta, Gestão ambiental, Desperdício.*

1 INTRODUCTION

Modern organizations have sought to invest resources and new management tools in order to promote continuous improvement of the manufacturing process, aiming at the reduction of operating costs and increasing the quality and productivity of their products and services.

In this scenario, the use of the Lean philosophy based on the applications techniques and tools of Lean Production System (Lean Production) have leveraged the improvement of processes seeking to achieve greater productivity in industrial operations (Corrêa and Corrêa, 2005).

Melton (2005) also highlights the benefits of the use of "lean thinking" in the production process of industries while Abdulmalek and Rajgopal (2007) adapt lean principles to a large steel plant and identify that the mapping of the value stream was the main instrument used to identify opportunities to support the implementation of various lean techniques .

On the other hand, despite the benefits arising from the use of these concepts, within the current context, we can see that many companies, when trying to implement lean manufacturing projects, have not achieved the desired results (Saurin, Ribeiro and Marodin, 2010).

Barros Neto (2004) also emphasize that the evidence found in some studies of failure in the implementation of lean production points to the introduction of the tool with focus turned to the operating room without a strategic discussion about the real contributions of improved results and still without a vision to guide the entire process of using the concepts of lean philosophy.

Environmental Management (here named Green), which is the other subject of this study, is the adoption of organizational practices that encourage the reduction of the environmental impact on industrial operations. This concept aligned to the strategic objectives of Lean Manufacturing (Lean) aims primarily to search for a total reduction of waste in manufacturing operations, helping to minimize air emissions and waste disposal on the environment.

Due to the complexity and generality of issues involving environmental management, in this article the "Green" concept is approached as a universe of environmental strategies already explored by many authors, and particularly involving the themes of: Corporate Social Responsibility (CSR) and Proactivity Environmental (Leite, 2010; Coelho et al, 2008; Lee, 2008; Nascimento, Lemos and Mello, 2008; Barbieri, 2007; González-Benito and González-Benito, 2006; Lacerda, 2002; Jimenez and Lorente, 2001).

Abreu, Alves and Moreira (2017) argue that the concepts of Lean and Green are complementary, because even when working in parallel, both develop operational mechanisms to intensify the waste reduction in order to increase efficiency productive performance in operations, thus adding value to the processes and, mainly, reducing the environmental impact.

Dhingra, Kress and Upreti (2014) argue that the integrated adoption of Lean and Green practices may contribute to a synergy between better operational performance and reduction of impacts, related to reducing the level of waste in productive process.

Considering the relevance and practical scope of the topic, and the low incidence of publications about the *Lean x Green* in the researched literature sources. It is expecting that this research will contribute to broaden and deepen the knowledge of the subject, although being in elaboration process and may interest the academic sector in the deepening of the themes and their theoretical interrelation. It can also contribute to the economic sector through a better conceptualization and identification of the practical application of this relationship in the development of organizational strategies aimed at reducing waste and conserving natural resources.

The objective of this research is therefore to investigate the contribution of the relationship between Lean Production (*Lean*) and Environmental Management (*Green*) to the reduction of waste in the production process. It is divide into four sections, and after this introduction, it is show the theoretical foundation that supports Lean Production (*Lean)*, Environmental Management *(Green)* and the relationship between the two themes. In the following sections, it is shown: the research methodology, the description and analysis of the results, concluding with the presentation of closing arguments of the study.

2 THEORETICAL REFERENCES

To start addressing the topic lean production, it is necessary to introduce concepts and definitions of the production function. Slack et al. (2010, p. 29) defines the production function as "central to the organization because it produces goods and services that are the reason for its existence". Barros Neto (2004) considers the production function as responsible for the transformation of raw materials, energy and information of goods and/or services. Thus, this organizational function can be characterized as the ability to transform inputs into final products, whether tangible or not, as well as all-internal activities of the organization that interact with this process.

Lean Manufacturing (*Lean Production*) is considered as a way of adding value to the production process, aligning the best possible sequence of actions, performing the activities effectively and without interruption.

Lean production is the elimination of waste in any area of production including customer relations, product design, supplier and factory management network (Yang, Hong and Modi, 2011). The basic difference between the philosophy of traditional management and lean production is clear mainly in the conceptual aspect, indicating that lean procedures ware applied in all industries that produce goods and services, while the traditional model is more aligned with tangible practical manufacturing

For King and Lenox (2001, p. 245):

> "The adoption of lean practices may lead inadvertently to pollution reduction. Some proponents observe that "zero waste" in the mantra of lean production and suggest that pollution reduction will inevitably follow from lean production".

Lean production thus requires a constant program of improvement of processes to increase efficiency and to reduce costs with waste, whether of time, materials, labor or financial.

With the release of the Lean concept and use of its tools by many companies, lean production and has expanded has its concept applied to all aspects of the supply chain. There are now many examples of the application of "lean thinking" in business processes, such as project

management, design and new product design, construction and in the manufacture of various products and services (Saurin, Ribeiro and Marodin, 2010; Melton, 2005; Elias and Magalhães, 2003; Simons and Mason, 2003; Lewis, 2000).

According Dhingra, Kress and Upreti (2014, p. 2): "lean practitioners who are successful in reducing process wastes in manufacturing often find more opportunities to reduce waste throughout the life cycle of the product, thereby having a possible domino effect on the entire supply chain."

About the benefits of lean production, Melton (2005) mentions several improvements observed in modern industrial processes giving as an example the automobile industry, which has been identify in a wide use of this methodology with the following results: reduction of delivery times to customers; inventory reduction for manufacturers; better management of knowledge. Besides these advantages, lean production can be applied throughout the supply chain and provide maximum benefits within the organization, that aims to operate sustainably and to achieve better results in the long term.

2.2 Lean Production and waste

The importance of lean production in the optimization of operational processes is underscored by Reis and Figueiredo (1995, p. 40) when they warn that "waste from overproduction refers to the manufacture of lots in a quantity exceeding immediate market demand, forming not only stocks, but also concealing losses with defective units, delays and errors". Elias and Magalhães (2003, p 2) also contribute when defining:

> Waste means any activity, which absorbs resources but creates no value. Value means the ability to offer a product/service at the right time at an appropriate price, as defined by the customer. The basis of lean production is once waste was disposed, it reduces production costs and maximizes customer satisfaction, in other words, the added value.

The goal of reducing waste visualized by lean production should be aligned with the objectives developed by the practices of environmental management, since this reduction contributes significantly to minimize the environmental impacts of industrial operations.

For Ritzman, Krajewski and Malhotra (2009, p. 288):

> The Just-in-time (JIT) philosophy is simple but effective - eliminates waste by reducing excess capacity or inventory and removing activities that do not add value. The goals are to create products and services when needed and continually increase the benefits of the added value of operations.

Thus, the JIT is not characterized only as a technical operations management, or as a work philosophy, that integrates concepts and practices of material management, quality management, process management, delimitation of physical arrangement, the management of the supply chain and human resources. Before, it has as main objectives the quality and flexibility by applying continuous improvement practices and relentless pursuit of reducing waste in the production process (CORRÊA & CORRÊA, 2005).

In the view of Ballestero-Alvarez (2010, p. 255) "the ultimate goal of JIT is to provide fast answers to customers while minimizing inventories." Authors such as Slack *et al.* (2010, p. 355) conceptualize JIT as a way to "produce goods and services just when they are needed - neither

before so they do not become stock, nor after so customers do not have to wait." So, it aims to meet the demand instantaneously, without compromising the quality and further reduce waste the most, by reducing the size of lots of shopping, and acting in a continuous evolution of processes and learning of employees (LIKER & MEIER, 2007).

According Abreu, Alves and Moreira (2017, p. 4) the Lean-Green management, includes "lean indicators, green performance indicators and green intentions indicators, for a benchmarking repository". The authors use it to benchmarking for lean and green practices of a consortium of companies in order to target a improve operation results.

In this way, the adoption of lean manufacturing practices to reduce waste and maximize the resources used in production could be consider as the starting point for raising efficiency and minimizing the environmental impacts caused by industrial production (SALVADOR, PIEKARSKI & FRANCISCO, 2017).

2.3 Environmental Management

Companies seek profit and profitability as a top reason for its existence and finds in meeting the needs of customers, the main way to achieve this profit. In the current business world, society exacts the organizations a policy of environmental management in order to enhance the use of environmentally friendly products, in other words, products and services designed to cause the least possible impact on the environment.

According to Barry and Rondinelli (1998, p 38), the world entered a new Industrial Revolution and, due to the pressure from the market, organizations need to act proactively on the management of the environment and natural resources. "Environmental sustainability is a new value that should be adopted by multinationals so that they can become more competitive and successful."

In enterprise management, the term sustainability is constantly refer to as the perpetuation of conditions favorable to the organization. Furthermore, this concept is incorporate, through systemic view, into the social and ecological dimensions, so that they form a broader knowledge about the economic goals of these companies and the need of customers.

In Barbieri's concept (2007, p. 25), environmental management is formed in "guidelines and administrative and operational activities, such as, planning, direction, control, resource allocation, and others performed with the aim to achieve positive effects by human actions, or preventing them from arising."

For Yang, Hong and Modi (2011, p. 252) "Environmental management practices refer to programs to improve environmental performance of process and products in the form of eco-design, recycling, waste management and life-cycle analysis".

This new "environmental conscience" of society has driven the search for organizations by methods and techniques of production operations that preserve the natural and/or reduce the impact generated by its production process, in order to improve its competitive advantage and image related to its products and services (Almeida, 2009; Nascimento, Lemos and Mello, 2008).

From the same perspective, Sanches (2000, p. 77) highlights that "industrial companies seeking to maintain competitive increasingly realize that, given the environmental issues, new positions are required, in a continuous renewal process." In this sense, environmental management can interpreted as the science that seeks to identify, assess and control the reduction of environmental impacts and develop strategies for the conservation of natural resources. Similarly, the concept of Green Supply Chain seeks to ensure the minimization of environmental impacts in the supply chain acting directly on the suppliers that adopt good environmental practices as assert Nascimento, Lemos and Mello (2008).

According Srivastava (2007, p. 54), Green Supply Chain Management (GSCM) is a "integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumer as well as end-of-life management of the product after its useful life".

The pursuit of improvement in environmental performance in organizations, done by reducing waste and air emissions, or a better mix of inputs, will represent a gain of energy or materials within the production process. So that these companies can transform the expenses coming from this reduction process in positive financial results, either by reducing costs of production or reusing waste and increasing recycling possibilities of these materials (Donaire, 1995).

For King and Lenox (2001, p. 246):

> "Environmental management systems (EMS) share many characteristics with lean production. Most EMSS emphasize formal monitoring and improvement of facility waste streams. Like lean production systems they often include opportunities for collaborative problem solving and continuous improvement".

The environmental management strategies that have their goals aligned to those developed by lean production, and seek the joint use of methods and techniques of different prominent environmental strategies, can help to raise the level of effectiveness of lean production. This is achieved through systemic view that organizations have, thus, contributing to reduce waste and increase productivity.

Similarly, authors such as Simons and Mason (2003) argue that the reduction of waste and emissions can be cause by the use of lean production in the production process of industrial organizations. Therefore, it can assumed that modern organizations are able to use tools of lean manufacturing to enhance the development of environmental management in their production processes (LEWIS, 2000).

2.4 The relation between Lean and Green

Organizational systems are composed of subsystems of internal processes that are interrelated. Thus, the different areas of the company perform specific activities, but all are acting together in pursuit of achieving the strategic goals set by senior management. This systemic relationship is essential to the achievement of results and the control of the operation of organizational processes, since the entire organization must be engaged in meeting the expectations of stakeholders and achieving better economic development.

Dhingra, Kress and Upreti (2014, p. 2) agree:

> "Manufacturers that are already on the lean production path are beginning to realize that lean to green is a natural progression, and that monetary savings can be realized not just by the implementation of lean practices but by implementing cleaner production methods as well."

The systemic approach allows the examination of a number of interrelationships, by crossing the boundaries of functional departments, and can be faithfully represent by the concept of environment.

For Yang, Hong and Modi (2011, p. 253):

> "Lean manufacturing creates, within an organization, the orientation to increase employee responsibility and involve employees in waste reduction effort. Such lean orientation may

> also help firms to adopt environmental management practices which aim at reducing wastes and pollutants reduction".

Simpson, Power and Samson (2007) agree suppliers of a supply chain if the show more engaged when their clients have a higher requirement on environmental indicators, thus raising the level of relationship and improving environmental performance. They also suggest that the conditions in the relationship with these suppliers run of environmental performance requirements (investments, contracts and monitoring routine) adopted by customers, encouraging environmental commitment and responsibility.

The systemic approach of the companies can still make use of different production strategies to achieve better operating results when associating the best practices of different strategic models in key areas of the organization. Thus, the combined use of techniques of lean production and environmental management can contribute in a systematic way to achieve better business results and enhance the care of customer needs (Johanson and Sundin, 2014; Yang, Hong and Modi, 2011; Rothenberg, Pil and Mawell, 2001).

According to Abreu, Alves and Moreira (2017, p. 1):

> "Lean is a strategy that encompasses a wide variety of management practices, in an integrated system, to streamline business processes, minimize waste and improve financial performance. When lean and green are associated in the called Lean-Green link, many of those savings also result in environmental benefits."

Elias and Magalhães (2003) emphasize that the tools developed by lean production contribute to the achievement of environmental, technological and economic benefits, as they minimize the need for resources, energy and raw materials.

Saurin, Ribeiro and Marodin (2010) also reinforce that the emphasis of lean production in waste reduction helps to reduce the environmental impact of production systems providing opportunities for the integration of lean efforts and environmental management.

In this scenario, we seek to identify the Lean Manufacturing (*Lean*) as an example of competitive advantage, reducing waste in the production process and Environmental Management (*Green*) as a competitive strategy for reducing the environmental impact caused by production operations in organizations. Thus, environmental management has a strong interaction with the objectives of operations in organizations as "efforts to reduce pollution and efforts to maximize profits share the same basic principles, including the efficient use of inputs, materials substitution and minimization activities unnecessary" (Porter and Linde, 1995, p 122).

The studies of Saurin, Ribeiro and Marodin (2010) therefore argue that adopting lean practices influences environmental proactivity on business, or the more widespread lean production in these organizations, the less waste and costs at the end of the process productive. Therefore, the implementation of a policy of lean production in organizations, aiming at the reduction of waste, tends to influence in any way the development of environmental management practices by promoting growth of this area of performance in organizations.

Bergmiller and McWright (2009) suggest that in turn modern industrial organizations are adopting the goals of lean and green in their business models in a more incisive and yet transcending the Cleaner Production (CP) as a natural evolution culture of waste reduction continuously integrating its programs to minimize the environmental impacts of its productive operations.

King and Lenox (2001) propose that lean production is complementary to environmental performance and the adopt practices of lean on companies contribute to minimize pollution and waste. While Yang, Hong and Modi (2011) agree that as an organizations uses lean manufacturing practices to reduce wastes and could reduce the environmental impact.

Rothenberg, Pil and Maxwell (2001) agree that lean manufacturing contributes to improving environmental performance, but other features as are necessary: the participation of stakeholders includes top management support and engagement of suppliers in order to have greater efficiency these results.

3 RESEARCH METHODOLOGY

This study began with the collection of secondary data, starting with a review in literature which supported the construction of the theoretical framework on the subjects: lean production, environmental management and the relationship between Lean and Green, exposed in the section 2 of this article.

We complemented the source of secondary data collection with document analysis in management reports available on the web sites of the three companies in the study, which made it possible to observe the performance indicators shown in the processes and practices of the areas analyzed reinforcing what Godoy (1995, p.21.) says: "the documents are normally considered important sources of data for other types of qualitative studies, thus meriting special attention." It also emphasizes that the documentary research should be treated as an increase in resources, seeking complementarity of the research methods used for a better understanding of the subject.

To meet the formulated objective, the study was based on exploratory model. This choice is justified once it offers the researcher the possibility to know more details about the matter investigated and to understand its interactions, as is the purpose of this investigation. It is also possible to generate propositions for future research (Severino, 2007).

By the nature of the empirical study, we chose a qualitative approach recommended by Cervo and Bervian (2002), when it is need to observe record, analyze and correlate facts or phenomena of a reality. Minayo (2000) also indicate a qualitative approach in studies dealing with the universe of phenomena and relationships that cannot be reduce to the operationalization of variables.

To obtain the primary data, field research was done, mediated by the case study strategy once it was the most appropriate when one wants to investigate a phenomenon in a real context, and its borders are not clearly defined from the studied organizational structure and from the existent interactions between different organizations, but multiple sources of evidence are used to prove the achievement of objectives (Campomar, 1991; Godoy, 1995; Stake, 2011).

The case study is also recommended by Yin (2010, p. 39) when it "investigates a contemporary phenomenon in depth and in its real life context, especially when the boundaries between phenomenon and context are not clearly evident". Roesch (2006) also identifies as an advantage of the case study its ability to explore the social processes during its development within the organizations and the interrelationship between the various simultaneous processes performed in a period. Thus, the use of the case study "allows a procedural contextual lengthwise analysis of many actions and meanings that are manifested and built within organizations."

Because it is a little explored topic and by the reduced amount of local companies with all the features (ISO 14001 certification and lean production practices) required for this research, the multiple case study is seen the most appropriate strategy to achieve the proposed objectives. As a unit of analysis, it is sought to identify the contributions of the relationship between the use of lean production process and environmental management practices to reduce waste.

Data collection was conducted through questionnaires, whose data allowed a quantitative presentation format, and qualitative, in which the contents of each of the researched subjects were aggregated. It was also used a summary table with information of the researched

companies, seeking to facilitate by a comparative manner, the analysis of the evidence together, besides encouraging the achievement of triangulation of obtained data.

The research was applied in 3 companies located in Ceará State who have the certification of ISO 14001, from different economic sectors that use lean manufacturing system in their production processes associated with the practice of environmental management to encompass required features for the experiment were selected. The criterion for the choice of this sample was intentional and was based on accessibility to managers for the implementation of research with the aim of giving greater coverage to the results.

The research was carried out in 2012, with 12 employees (4 managers, 2 analysts, 4 engineers and 2 assistants) who work in activities related to lean production or the environmental management system of the three companies selected.

4 RESULTS DESCRIPTION AND ANALYSIS

In order to contextualize the research environment, the three companies taking part in the study were nominated by sector of activity that they integrate, "Energy", "Industry" and "Steel" and the respondents, by the positions or roles they occupy.

4.1 Contextualization of the companies

The three researched companies and respondents of the research showed the following characteristics:

4.1.1 Electric Power

"Electric Power" consists of a holding company that works with distribution, generation, transmission and sale of energy. It was established in 2005 and is controlled by its head office in Spain, located in the states of Rio de Janeiro (where its headquarters are located), Ceará, Goiás and Rio Grande do Sul, serving approximately 5,4 million customers in 240 cities. Its activities are carrie out based on Environmental Management Systems (EMS), certified by ISO 14001:2004, and mostly avoiding risks to the environment and people's health. It also develops environmental programs to reduce the consumption of water and energy, reduction of atmospheric emissions and reforestation (according to standard ISO14064) and the management of waste materials used in the administrative and operational areas, serving thus to environmental legislation.

4.1.2 Industry

"Industry" from the automotive sector is located in the metropolitan region of Fortaleza, the main city of Ceará state. Its operations began in 1985 and the company seeks to invest in the modernization of the industrial park, to ensure the production of parts with high quality and productivity. In 2006, it joined, through a joint venture, to a keeper international group that owns industrial plants in Brazil and in countries like the United States and Mexico, as well as the European and Asian continents.

It currently employs about 500 people, conducting ongoing development programs and training people, internal promotions, and practicing remuneration compatible with the market, and benefit policies, which include, among others, participation in company profits. It is certify by ISO 9001:2008, ISO 14001:2004 and ISO / TS 16949:2009.

4.1.3 Steel

110 years since its foundation, the company "Steel" is the leading producer of long steel in the America Continent and one of the world's leading providers in this segment. It employs approximately 40,000 people in all branches, present in 14 countries and with operations in the Americas, Europe and Asia, which together represent an installed capacity of 25 million tons of steel. It is currently the largest recycler in Latin America and owns it is trade in São Paulo's Stock Market, with approximately 140,000 shareholders.

It operates in almost all Brazilian states, which produce common long steel and special plans. Its products serve the civil construction, industry and agriculture. It also has certifications: ISO9001/1991, ISO9002/1994, ISO14001/2010, NBR 7480/1998 (according to ABNT for bars and steel wires), QS9000/1999, OSHAS18001/1999.

4.2 Research Results

After the compilation of data obtained, it was proceeded the triangulation of sources of evidence, starting for the individual characterization of each of the researched companies. For a better visualization of the results is present a joint analysis of the cases, as illustrated in Table 1, to enable the features, observed by the collected information in the research instruments, to be exposed in a comparative manner, facilitating the analysis together.

Company	Electric Power	Industry	Steel
Capital Control	Foreign (Spain)	Private National	Traded (Brazil)
Market Field	Generation, transmission and distribution of eletric energy	Manufacturing of automobiles, trailers and bodies	Metallurgt
Total Number of Employees	3,000	500	40,000
Scope of Practice	National	International	International
Quality Certification	ISO14001 e ISO14064	ISO9001, ISO14001 e ISO/TS16949	ISO9001, ISO9002, ISO14001, NBR7480, QS9000. OSHAS18001
System of Lean Production	From 5 to 7 years	From 8 to 10 years	More than 10 years
Why adopting lean	Reduction of cost and waste	Customer demand	Reduction of cost and waste
Where we can find reduction of waste caused by lean	Productive processes/ Quality Management	Productive Processes / Logistic and Supplies	Productive Processes / Logistic and Supplies
Most used Lean Tools	*Kanban* / Visual Control	*Kanban* / *Pokayoke*	Production Cell / *Pokayoke*
Monitoring Results with Lean	Yes	No	Yes
Main reason to use green	Environmental Legislation / Corporate Image	Client Requirements/ Environmental Legislat.	Environmental Legislation/ Corp. Image
Identifying the complementarity of "*lean*" and "*green*"	Yes	No	Yes
Criteria of Green for selecting suppliers	Yes	Yes	Yes
The use of *Lean* and *Green* in strategic planning	Yes	No	Yes

Table 1 – "*Cross-Case*" Analysis / The autors (2012)

In the profile of the researched companies was identified that the three are large, based on the classification of Brazilian Institute of Geography and Statistics - IBGE (2012), according to which are well regarded companies that have from 500 employees in its staff. Regarding the scope of their operations, two (Power and Steel) work both in the national and international territories and the other (Industry) is only national.

The diversification of economic sectors where the companies operate was also an evidenced characteristic by the diversity of the respondent's profile who are mostly male, young (about 27 years old) and working in the company for at least six years. These professionals play the roles of managers, engineers, analysts and assistants and mostly have college degrees (50%), with 25% of those taking postgraduate courses and 25% having incomplete higher education.

As for the standard-setting instruments that guide the actions of the researched companies, it can be noticed in Table 1 that even acting in different economic sectors, the three companies seek to develop a well-structured system of quality because, besides ISO 14001, they also have other quality certifications (ISO 14064, ISO 9001, ISO 9002), suggesting thereby that compliance with the minimum requirements of these sectors in the use of these policies are adopted. This fact can be confirmed by the executive advisor of "Steel":

> There is a sector of EMS (Environmental Management System) in each unit of the group that gives support to all areas of the process and in this sector these principles are considered. Every employee was trained in EMS to meet possible demands.

In Lean-Green perspective, the workforce's commitment to processes and the policy of waste reduction is one of the pillars for improving efficiency. This benefit must be respect for all organization to improve result of lean-green performance (ABREU; ALVES; MOREIRA, 2017).

According to the logistics assessor of "Steel", the main objective of its environmental management system is to "ensure all the monitoring process, from the use of raw materials, through manufacturing and distribution of products to the correct destination of products that were created in the process". Reinforcing the arguments of the respondent, the environmental policy of the company values mainly for the protection and preservation of the health and safety of its employees, the environment and quality of products and services (Steel web site, 2012).

In the search to use the differentiation strategy, effective control of productive activities is essential as an indispensable condition for any company to compete on equal terms with its competitors in today's business world. Without this control and without the ability to evaluate the performance of its activities and intervene quickly to correct failures and improve processes, the company will be at a disadvantage in the face of more efficient competition.

Similarly, the annual sustainability report (2010) of the company "Electric Power" identified strategic direction with regard to three main factors: environmental (regarding environmental preservation and responsible consumption), social (standard of living, personal and professional development) and economic development (the commitment to value creation and profitability, based on sustainable growth), as well as the high level of annual investment in social projects and environmental management.

This environmental concern is evidenced by the search company "Electric Power" in raising environmental awareness in its employees and partners, as outlined in its annual sustainability report (2010, p.172).

In the "Industry" environmental policy, the major focus is on the prevention of pollution, reduction of environmental impacts of the manufacturing process, the search for the well-being of the community of employees, the optimization of natural resources and compliance with laws and other requirements apply to its environmental aspects ("Industry" website, 2012).

Another feature that needs to be taken into consideration for comparative analysis is that the three companies already use Lean Production System (SPE) for over five years and agree that the process is the area that is identified more in reducing waste, followed by logistics and supplies, and then by quality management.

These characteristics are in line with the arguments of Gonzáles-Benito and Gonzáles-Benito (2006), who point out that organizations have increasingly applied techniques to minimize the environmental impacts caused by their productive activity as a way to meet customer requirements, which have intensified the search for products that do not degrade the environment, as well as due to regulation which has also been developed in order to increase the control and taxation of companies, in order to raise the level of government control over these operations.

As shown in Table 1, reducing costs and waste is the main reason for the implementation of the Lean Production System by companies "Electric Power" and "Steel", which also make use of performance indicators and mapping of processes to perform benchmarking these systems. On the other hand, even identifying customer demand as the main motivation for the adoption of the SPE, the company "Industry'' uses the tools of this system (Kanban and Pokayoke) in order to improve the operation of their activities.

Besides that, the company "Electric Power" uses performance indicators to measure the reduction of air emissions through a monitoring sample, as shown by its annual sustainability report (2010, p 172.): "In its environmental monitoring plan, the company sets the systematic control and performance indicators in order to ensure compliance with the conditions of licensing and legal requirements".

Meeting the pressures imposed by environmental legislation and customer requirements and the need to improve the image of the company are the motivating factors that led the three firms to adopt EMS, being characterized that all the companies adopt environmental criteria for the selection of their suppliers, which shows an alignment to the principles of Green Supply Chain Management as a way to ensure the minimization of environmental impacts in the supply chain. These findings correspond to the arguments put forward by Nascimento, Lemos & Mello (2008) on sustainable supply chain.

Concerning the relationship with suppliers, the company "Electric Power" wants to select this segment prioritizing those that are aligned to its social and environmental objectives, still concentrating its purchases of materials in local suppliers, thus having possibility to develop and monitor way more effective these partners, and thus obtain a differentiation of price and quality in their products. As described in its annual sustainability report (2010, p 110.): "The company seeks to extend the positive impact intended for their domestic audience, as care involving ergonomics, training, education, and healthy work environment for all its business chain".

In the company "Industry", the quality objectives and the development of new processes to seek continuous improvement, innovation and development of new technologies, such as machinery and management systems. And the use of various inspection points in the supply chain (storage, furnaces, molding, blasting, machining and shipping), as a way to reduce the rate of process failures , the incidence of defective parts and waste materials with the incidence of rework ("Industry" web site, 2012).

Still in "Industry", it was found that its quality policy is the provision of security products and services are responsible to ensure customer satisfaction and integrity of the user at the lowest possible price, in the development of its employees through an ongoing process of awareness, recovery and training, and improving the integrated management system through continuous improvement (''Industry'' website, 2012).

Environmental management strategies that have their objectives aligned with those develop by lean production and seek the joint use of methods and techniques of different environmental strategies can contribute to raise the level of effectiveness of lean production. This is done through the systemic vision that the organizations have, thus contributing to the reduction of waste and the increase of productivity (COELHO et al., 2008).

Regarding the contribution of Lean Production practices to reduce environmental impacts caused by the production process, the majority of the researched respondents in the three companies (about 75%) identified a positive contribution of these practices. It was also considered that the principles of environmental management are applied to the activities of the Lean Production System (about 60%). According to the analyst of the company "Electric Power": "with the implementation of Lean Production technologies, it automatically reduces all indicators of environmental impacts and the environmental management becomes cheaper and more efficient".

Reverse logistics is recognized by all companies as a tool of lean production that contributes significantly to the reduction of environmental impacts and reducing operating costs. These findings suggest that reverse logistics also contributes to Lean and Green, as a part of the reduction of industrial waste is being held in these companies through the reuse of surplus production (scrap). In the companies "Industry" and "Steel", this activity is directly linked to the production process and operation of supply of materials from suppliers, while in the company "Electric Power", reverse logistics is applied to the maintenance of equipment in production, in power distribution to customers and in the promotion of environmental projects for recycling and reuse of materials in the community.

Reverse logistics is still treated as a logistics area that plans, operates and controls the flow and corresponding logistics information, acting in the area of the return of post-sale and post-consumer goods to the business cycle or the production cycle. This process takes place through the reverse distribution channels, adding them values of diverse natures: economic, service provision, ecological, legal, logistic, corporate image, among others (LEITE, 2010).

Reverse logistics is recognized by all companies as a lean production tool that contributes significantly to reducing environmental impacts and reducing operating costs. These findings suggest that reverse logistics also contributes to lean and green.

The company "Steel" develops, in its operation, a set of "best practices" that aims to meet environmental requirements, which are defined by the law or by its environmental management system ("Steel" web site, 2012), expansion and maintenance of green areas with native species, water reuse, waste, recycling of ferrous materials among others. According to the executive advisor of "Steel", recycling is an important process to the waste management of the company in which almost 80% of the waste generated by the business process is reuse, with a strict control over its implementation.

Another important discovery identified by most respondents (75%) was that the three companies make use of criteria and standards (ISO 14001 and OHSAS 18001) of Environmental sustainability in selecting their suppliers, in order to guarantee a reduction of the environmental impacts of all their supply chains (green supply chain management).

Gavronski, Balbinotti e Ferrer (2005) defend the importance of implementing the ISO 14001 standard and also point out the need to meet the requirements of stakeholders; improving the company image; legal requirements and the improvement of operational performance, as the main motivational factors that lead Brazilian organizations to adopt this certification.

When verifying how the practices of Lean and Green are considered in the strategic planning of the companies, it was found out that two, "Electric Power" and "Steel", consider the

results obtained with the application of lean production and environmental management system within their annual strategic planning. They also define targets and indicators to measure these outcomes and evaluate the contribution of these tools for improving organizational productivity.

In a comprehensive overview of the sample, the respondents of the company "Industry" asserted that they realize the complementary concepts of "Lean" and "Green" and the benefits brought about by the reduction of waste. However, these results aren't used in defining their strategic planning. They understand that the driver factor of their organizational strategies is identifying and meeting the requirements set by customers.

Most respondents agree that the implementation of Lean Production System contributes to the reduction of waste and to the minimization of costs and environmental impacts caused by the production process, as well as it uses the main tools (Kanban, Pokayoke, Cell Production and Visual Control) of this model in their operations in order to ensure better operational results and market differentiation.

Even in the "Industry", which reported that the questionnaire does not identify the applicability of lean in its production process, it was found that it uses this philosophy to the process control and waste reduction.

In the company "Industry'', it was only identified environmental projects recycling and selective collection, as well as social projects with a focus on professional development of its employees, financial support for sporting activities and participation in annual profits.

For Godinho Filho and Fernandes (2004, pp. 15-16) "Lean Manufacturing is not a solution to all evils; its application will depend on the strategic objectives of the company in question, "however, it consists of a methodology that assists in the reduction of waste and with this, promotes the reduction of costs and the elevation of quality in the industrial processes. Even so, it needs a "maturation period", that is, the consolidation of the model, so that the cultural and financial results of its implementation can be identified".

According to the results coming from the research and in the management reports of the three companies investigated, it was found that they all have mature and well-developed processes for improving EMS; they seek to improve quality of life of their employees and the community through environmental training programs and professional development; act on reducing environmental impacts, project-selective collection and recycling, and encourage the efficient use of natural resources.

Still, the findings obtained by the research identified the existence of complementarity between the concepts of "Lean" and "Green" though that does not allow systematic way to assess the degree of their contributions in reducing waste. These interactions in productive business environment are perceived by the researched subjects that highlight the benefits arising out of this relationship.

Therefore, the actions in this direction was presented as evidence, that the investigated companies seek to minimize the environmental impacts generated by their production processes in two of the three companies. In addition, companies ("Electric Power" and "Steel") take into consideration the results obtained by this synergy in their annual strategic planning and formulation of productivity goals.

From the results analyzed in the questionnaires applied, and in the managerial reports of the three companies researched, it was verified that all have a mature EMS and with well-developed improvement processes; seek to improve the quality of life of its employees and the community, through programs of environmental training and professional development; reduce the environmental impacts; use selective collection and recycling projects, as well as encouraging the efficient use of natural resources.

Still, the results found by the research identified the existence of complementarity between the concepts of "lean" and "green" although in a non-systematized way that allowed to evaluate the degree of their contributions in the reduction of waste. These interactions in the productive environment of the companies are perceived by the researched individuals that highlight the benefits derived from this relationship.

5 FINAL CONSIDERATIONS

Knowing the contribution of Lean Production and Environmental Management to reduce waste in production processes of the researched companies was the focus of this study. From cross-analysis of the information collected in questionnaires and researched reports, it was found that goal was achieved, with the evidence that the companies investigated confirm that the use of Lean Production System associated with Environmental Management in production processes contribute to the reduction of costs (waste). It also indicates that the complementary concepts of lean and green in its production process can help to reduce waste, as it can be seen in detail in Table 1 ("Cross-Case" Analysis).

Some observations demonstrate the identification of the practical use of the Lean philosophy in the production process of the company and the benefits of Lean production as a strategy to minimize the impacts on performance of environmental management, as the benefits of adopting these practices are countersigned by the researched authors in section 2, and now confirmed by this investigation.

Despite the confirmation that all companies are using lean manufacturing processes and environmental management and waste reduction strategy, no evidence that there are systems and evaluation indicators, although there are indications of a process of monitoring results, were found the Lean Production System.

Moreover, it was identified that one of the companies does not recognize the complementarity of these concepts, nor takes into consideration when formulating their strategic planning, but it uses the Lean tools, and implements environmental protection and prevention of the impacts caused by their activities production process, as a requirement for compliance with quality standards and legislation. These findings may indicate that the combination of Lean and Green concepts, because they are relatively new, is not widespread and internalized in the environment of the organization yet.

The implementation of a quality management system, through ISO9001 and ISO14001 certification, provides the researched companies with an efficient management mechanism where processes are management and controlled according to customer's requirements, through a policy of continuous improvement (Kaisen). This has served as a basis for the use of the tools proposed by lean manufacture and with that, intensifying the strategy of reduction of waste. For even if the benefits of the Lean-Green relationship are not widely known to all respondents, joint adoption of these practices provides a significant competitive advantage for organizations that adopt it.

The perceived contributions with the complementarity of Lean and Green in researched companies indicate that the most benefited areas from reduced costs and waste, using the practices of lean production and environmental management, are mainly the areas of production, logistics and supply and quality management. However, the evaluation of the effectiveness of the achieved results still requires the creation or implementation of systems and indicators for this purpose.

Therefore, it was possible identify in the research that Lean contributes positively with Green through a management policy to reduce waste and with this, the reduction of environmental impact.

Even though companies that use lean and green joint practices are better performing in relation to environmental factors, since they share the same strategic objectives to reduce the environmental impact caused by the generation of solid waste, atmospheric emissions and energy consumption.

Another important observation to be highlighted in the final analysis of this study concerns the failure to identify clear that the Lean and Green were implemented within a strategic vision and complementary evidence, although respondents state that they realize this complementarity.

This article sought to contribute to the development of Lean and Green and their relations issues, providing theoretical foundations for the evolution of the debate by identifying the contribution of their applications to achieve better operating results through reduced waste.

Other contributions of this study can be mentioned as the following suggestions:

a. Conduct further research on the subject, including the application of Lean and Green in other companies, including geographical regions or economic sectors of different from the ones studied here;
b. Further study of integrating concepts with the application of a survey in companies that use Environmental Management and Lean Production Systems;
c. Investigate the efficacy of using Lean Production associated with Environmental Management in operational processes based on indicators of outcome assessment;
d. Research the relationship between the Cleaner Production (CP) and Lean Production and its contribution to environmental management;
e. Conduct studies that demonstrate the contribution of the waste reduction proposed by lean methodology for Economy Circular.

These studies did not aim to exhaust the possibilities of further development of these themes, even narrowing the diversity of scientific approaches used today, but to deepen the discussion about the importance of these concepts for managing better results in the production processes of companies.

REFERENCES

ABDULMALEK, F.; RAIGOPAL, J. Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. **International Journal of Production Economics**, v. 107, p. 223-236, 2007

ABNT - Associação Brasileira de Normas Técnicas. **NBR ISO 14001: aspectos ambientais.** Rio de Janeiro, 2002

ABREU, F.; ALVES, A.; MOREIRA, F. Lean-Green models for eco-efficient and sustainable production. **Energy**, 2017.

ALMEIDA, J. **Gestão ambiental para o desenvolvimento sustentável.** Rio de Janeiro: Thex, 2009

BARBIERI, J. **Gestão ambiental empresarial: conceitos, modelos e instrumentos.** 2. ed. São Paulo: Saraiva, 2007

BALLESTERO-ALVAREZ, M. **Gestão da qualidade, produção e operações.** São Paulo: Atlas, 2010

BARRY, M.; RONDINELLY, D. Proactive corporate environmental management. **Academy of**

Management Executive, v. 12, n. 2, p. 38-50, 1998.

BARROS NETO, J. Modelo de formulação de estratégias de produção para pequenas empresas. **Alcance**, v. 11, n. 2, p. 259-278, 2004

BERGMILER, G.; MCWRIGHT, P. Lean Manufacturers' Transcendence to Green Manufacturing. **Proceedings of the Industrial Engineering Research Conference**, Miami: FL – USA, 2009

CAMPOMAR, M. Do uso de "estudo de caso" em pesquisas para dissertações e teses em administração. **Revista de Administração**, v. 26, n. 3, p. 95-97, 1991

CERVO, A.; BERVIAN, P. **Metodologia científica.** 5. ed. São Paulo: Prentice Hall, 2002

COELHO, A.; ERDMANN, R.; VAN BELLEN, H.; SCHULZ, A.; COELHO, Cristiano. A Complexidade da Gestão de Produção: um enfoque na gestão ambiental. In: EnANPAD, 32., 2008, Rio de Janeiro. **Anais**... Rio de Janeiro: ANPAD, 2008. 1 CD-ROM.

CORRÊA, H.; CORRÊA. C. **Administração de produção e de operações:** manufatura e serviços: uma abordagem estratégica. São Paulo: Atlas, 2005

DHINGRA, R.; KRESS, R.; UPRETI, G. Does lean mean green? **Journal of Cleaner Production**. v. 85, p. 1-7, 2014

DONAIRE, D. **Gestão ambiental na empresa.** São Paulo: Atlas, 1995

ELIAS, S.; MAGALHÃES, L. Contribuição da produção enxuta para a obtenção da produção mais limpa. **Produção On Line**. v. 3, n. 4, 2003

GAVRONSKI, I.; BALBINOTTI, M.; FERRER, G. ISO 14001 Certification in Brazil: Towards a Taxonomy of Environmental Strategies. In: EnANPAD, 29, 2005, Brasília. **Anais**... Brasília: ANPAD, 2005. 1 CD-ROM.

GODINHO FILHO, M.; FERNANDES, F. Manufatura Enxuta: uma revisão que classifica e analisa os trabalhos apontando perspectivas de pesquisas futuras. **Gestào & Produção**, v. 11, p. 1-19, 2004.

GODOY, A. Pesquisa qualitativa: tipos fundamentais. **RAE**, v. 35, n. 3, p. 20-29, 1995

GONZALEZ-BENITO, J.; GONZALEZ-BENITO, Ó. A Review of Determinant Factors of Environment Proactivity. **Business Strategy and the Environment**, v. 15, p. 87-102, 2006JIMENEZ, J.; LORENTE, J. Environmental performance as an operations objective. **International Journal of Operations & Production Management**, v. 21, n. 12, p. 1553-1572, 2001

JOHANSSON, G.; SUNDIN, E. Lean and green product development: two sides of the same coin? **Journal of Cleaner Production**. v. 85, p. 104-121, 2014

KING, A.; LENOX, M. Lean and Green? Na empirical examination of the relationship between lean production and environmental performance. **Production and Operations Management**. v. 10, n. 3, p. 244-256, 2001

LACERDA, L. **Logística reversa:** uma visão sobre os conceitos básicos e as práticas operacionais. Rio de Janeiro: COPPEAD/UFRJ, 2002

LEE, M. A review of the theories of corporate social responsibility: Its evolutionary path and the

road ahead. **International Journal of Management Reviews**, v. 10, n. 1, p. 53-73, 2008

LEITE, P. **Logística Reversa meio ambiente e competitividade**. 2 ed. São Paulo: Prentice Hall, 2010

LEWIS, M. Lean production and sustainable competitive advantage. **International Journal of Operations & Production Management**, v. 20, n. 8, p. 959-978, 2000

LIKER, J.; MEIER, D. **O Modelo Toyota: manual de aplicação.** Porto Alegre: Bookman, 2007

MELTON, T. The benefits of lean manufacturing: what lean thinking has to offer the process industries? **Chemical Engineering Research and Design**, v. 83, p. 662-673, 2005

MINAYO, M. **Pesquisa social, teoria, método e criatividade**. Rio de Janeiro: Vozes, 2000

NASCIMENTO, L.; LEMOS Â.; MELLO, M. **Gestão socioambiental estratégica**. Porto Alegre: Bookman, 2008

PORTER, M.; LINDE, C. Green and competitive: ending the stalemate. **Harvard Business Review**, v. 73, n. 5, p. 120-134, 1995

REIS, H.; FIGUEIREDO, K. A redução de desperdícios na indústria. **Revista de Administração**, v. 30, n. 2, p. 39-49, 1995

RITZMAN, L.; KRAJEWSKI, L.; MALHOTRA, M. **Administração de produção e operações**. São Paulo: Person Prentice Hall, 2009

ROESCH, S. **Projetos de estágio e de pesquisa em administração**: guia para estágios, trabalhos de conclusão, dissertações e estudos de caso. 3. ed. São Paulo: Atlas, 2006

ROTHENBERG, S., PILL, F.; MAXWELL, J. Lean, Green and the quest for superior environmental performance. **Production and Operations Management**. v. 10, n. 3, p. 228-242, 2001

SALVADOR, R.; PIEKARSKI, C.; FRANCISCO, A. Approach of the two-way influence between lean and green manufacturing and its connection to related organizational areas. **International Journal of Production Management end Engineering**. v. 5, n. 2, p. 73-83, 2017

SANCHES, C. Gestão ambiental proativa. **RAE**, v. 40, n. 1, p. 76-87, 2000

SAURIN, T.; RIBEIRO, J.; MARODIN, G. Identificação de oportunidades de pesquisa a partir de um levantamento da implantação da produção enxuta em empresas do Brasil e do Exterior. **Gestão & Produção**, v. 17, n. 4, p. 829-841, 2010

SEVERINO, A. **Metodologia do trabalho científico**. 23. ed. São Paulo: Cortez, 2007

SIMPSON, D.; POWER, D.; SAMSON, D. Greening the automotive supply chain: a relationship perspective. **International Journal of Operations & Production Management**. v. 27, n. 1, p. 28-48, 2007

SIMONS, D.; MASON, R. Lean and Green: “doing more with less”. **ECR Journal**, v. 3, n. 1, p. 84-91, 2003

SLACK, N.; CHAMBERS, S.; HARLAND, C.; HARRISON, A.; JOHNSTON, R. **Administração da produção**. São Paulo: Atlas, 2010

SRIVASTAVA, S. Green supply-chain management: a state-of-the-art literature review. **International Journal of Management Reviews**. v. 9, n. 1, p. 53-80, 2007

STAKE, R. **Pesquisa qualitativa**: estudando como as coisas funcionam. Porto Alegre: Penso, 2011

YANG, M.; HONG, P.; MODI, S. Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. **International Journal of Production Economics**. v. 129, p. 251-261, 2011

YIN, R. **Estudo de Caso**: planejamento e métodos. Porto Alegre: Bookman, 2010