

Operational impacts of lean manufacturing: the case of a consumer goods industrial company

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ABSTRACT

This study aims to verify the effect of implementing a lean manufacturing (LM) system on operational performance in an industrial company's production line. There are few studies that seek to quantitatively verify the effect of implementing an LM system on the operational performance of a company, and that is the main objective of this research. In this case-based study, the LM implementation in the company studied is compared with best practices and reference models, ascertaining the degree of adherence of the company's program. The operational performance, in terms of three key dimensions of cost, quality and lead time, is compared before and after the implementation of the LM program. By comparing the means of quantitative indicators related to the three performance dimensions, evidence was found of significant gains in the operational performance, and it was demonstrated that the company followed many of the best practices of LM implementation found in the literature. This study contributes to managers and to the literature on LM by measuring its apparent impacts on operational performance.

Keywords: Operational performance. Value chain. Lean manufacturing. Best practices.

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1. INTRODUÇÃO

In the early 1960s, consumer demand and the growth of competitors forced companies to pursue new manufacturing practices. This dynamic led Japanese companies in the automotive sector, particularly the Toyota Motor Company, to develop a different method, which was later called the Toyota Production System (TPS) (OHNO, 1997; WOMACK; JONES, 1990; CUSUMANO, 1998).

Lean manufacturing (LM), derived from the TPS, emerged as a management philosophy focused on prioritizing improvements in production through systematic and continuous elimination of losses in a productive system; its central objective is to deliver the maximum value using the least amount of resources possible. When this production system is properly adapted and applied to a company, it provides excellent results, as there are numerous opportunities to reduce or eliminate waste (OHNO, 1997).

Companies that adopt the LM system, using its management tools, discover that the implementation of this system should not only be based on teaching techniques to their employees; attention must also be paid to the human side of LM in order to have successful implementation (SHAH; WARD 2003).

Failures in the implementation processes of lean philosophy and practices in productive environments are largely due to the inadequacy of theories derived from the TPS or a lack of understanding thereof. The TPS is a system whose functioning depends on a correct interrelationship between all its elements, not a partial application of its tools. Before its implementation can begin, it is thus necessary to establish a holistic vision, in order to accurately understand TPS concepts and principles (PASA 2004; LIKER, 2007; PASCALE; ATHOS, 1982; BOZDOGAN *et al.*, 2000). A shallow understanding of how the TPS functions causes leaders to confuse lean tools with the principles that underpin them. This leads to failures in attempts to replicate it (BOWEN; SPEAR ,1999; LIKER, 2007; NONAKA; TAKEUCHI, 2004).

Shah and Ward (2003) found that LM practices contribute substantially to improving the operational performance of factories, although implementation requires increasingly tailored solutions. For this reason, implementing LM management in a productive system is a

complex task. Even so, different authors have published studies regarding best practices for implementing LM.

The need to use indicators that can assess the LM implementation process is important, as, according to Karlsson and Ahlstrom (1997), it is common for decreases in productivity and discouragement with the system's adoption to occur during the initial periods of implementation; these aspects are usually detected by traditional accounting systems. According to Battaglia (2006), most companies' indicators are traditionally linked to financial results, production volume and the efficiency of manpower and machinery. Traditional performance measurement indicators, in particular, do not adequately assess the performance of value streams that are relevant to the company, focusing only on evaluating process and individual operations (MASKELL; BAGGALEY, 2011). Generally, this performance data does not constitute complete relevant information, and when this happens, the organization faces difficulties in promoting the intended improvements. It is therefore necessary to be able to correctly analyze the data and use it for good decision making, which is the essence of performance management (MARTINS, 2002).

This paper presents an attempt to ascertain the operational impact of implementing LM in production lines. To this end, it verified the adoption of practices prescribed for implementing LM in the company studied and sought to relate the adoption of these practices with the subsequent impact on operational performance. It is thus a case study (YIN, 1994), restricted to the environment of a production unit.

Based on the previous reflection, the following research question emerges: “what is the operational impact of implementing an LM program in a non-durable consumer goods company, measured in a specific *ex post* period?”. This study's objective is thus to verify the effect of implementing an LM system on that company's operational performance.

Although LM is widely recognized for its effectiveness in continually improving productivity, product quality and on-time delivery to customers, only 10% or less of companies globally are able to implement LM with the expected success, using lean tools, techniques and technologies to improve their operational performance (VIENAZINDIENE; CIARNIENE, 2013). Therefore, to contribute to increasing knowledge and experience in this area, it is interesting to show—even in a single case study—another example of the results of adopting LM practices in terms of improving operational performance.

2. LITERATURE REVIEW

This chapter presents and discusses theoretical postulates of LM, focused on concepts and processes for its implementation, and highlights the best LM practices that have already been validated in the literature. It also includes arguments that establish associations between LM implementation/use and operational performance.

2.1. LM Implementation

Karlsson and Ahlstrom (1997) proposed measuring the progress made in a company's efforts to become lean by measuring determinants that characterize the application of LM principles in industrial companies. Nine determinants were identified: waste elimination, continuous improvement, zero defects, just-in-time deliveries, existence of pull production, use of multifunctional teams, decentralization, integration of functions and existence of vertical information systems. For each determinant, the authors selected several variables that could adequately characterize it. Measuring the evolution of these variables over time would define the progress achieved in the implementation of the respective LM practices. However, this model has two practical limitations: (1) it does not establish a single quantity to measure the degree of implementation of all LM practices in a company in an integrated manner, and (2) its use is conditioned on the adoption of the same set of determinants and variables, such that the results produced by the model could provide relative comparisons between different companies.

Without the force of an established norm or standard for LM implementation, it will be very difficult to obtain the consensus mentioned above. Soriano-Meier and Forrester (2002), in turn, relied upon the model proposed by Karlsson and Ahlstrom (1997) and the extent of managerial commitment to implementing LM practices to propose a quantity, called degree of leanness (DOL), which should be used to measure the degree of implementation of LM practices in industrial companies. According to the authors, the DOL is defined as "the mean of the changes that occurred in a given period, measured by the nine determinants of lean production as defined by Karlsson and Ahlstrom (1997)". As seen, although the definition proposed by Soriano-Meier and Forrester (2002) suggests adopting a single quantity to measure the implementation of LM practices, it implies a temporal limitation that precludes its use for other periods of time. As a means to circumvent some of the limitations

discussed and to help corporate managers implement the concepts of lean operation in their organizations, the Society of Automotive Engineers (SAE) developed two standards, called (1) SAE J4000 – Identification and Measurement of Best Practices in the Implementation of Lean Operations and (2) J4001 – Implementation of the Lean Operation User Manual. An explanation of their contents and details regarding their application are presented below.

The implementation of LM depends upon beginning a process of cultural change in organizations, which will be followed by employee training and the implementation of principles and techniques to sustain it, making it possible to efficiently combat losses in the productive system (WOMACK; JONES, 1990).

The implementation of LM philosophy and principles can be described as performing a set of actions and processes that begins with planning the change, continues with defining the success factors, and ends with implementing practices and measuring progress and barriers.

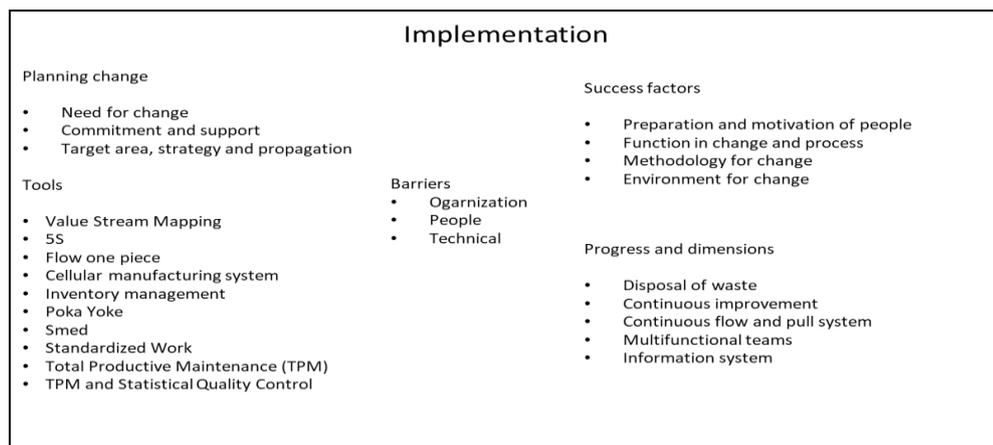
Although many variables can affect the success of implementation, Alavi (2003), Bamber and Dale (2000), Boyer and Sovilla (2003), Parks (2002), and Womack and Jones (1990) agree that management is crucial. According to Boyer and Sovilla (2003), top management should not only demonstrate commitment and leadership but should also work to build interest in the implementation and communicate the change to everyone within the organization. Alavi (2003), Boyer and Sovilla (2003) and Emiliani (2001) argue that management should be visibly linked to the project and participate in LM events. Worly and Doolen (2006) argue that management's lack of investment in the LM implementation can also affect the implementation's success in a less visible manner. If employees feel that the executive team does not respect their efforts, they may become discouraged. Boyer and Sovilla (2003) suggest that although it is often desirable to lead the change from the factory floor, it is important that a transition is performed. Investments in manufacturing support infrastructure are important (SORIANO-MEIER; FORRESTER, 2002), as is the existence of incentive systems for managers and operators (KOH; SIM; KILLOUGH, 2004). On the other hand, Shah and Ward (2003) concluded that factors with little influence are the age of the plant and the degree of the operators' unionization.

Based on these studies, it is clear that the success of an LM implementation depends on the particularities of each company, according to the interrelationships between the different factors mentioned above. Lewis (2000) makes the caveat that companies' trajectories

for implementing LM are unique in most cases, and it is therefore necessary to make adaptations for each organizational, technological and environmental context external to the organization.

Summarizing the conclusions of different studies, such as Martinez and Perez (2001), Radnor and Walley (2008), Duque and Cadavid (2007), Upadhye, Bollbach (2012) and Ciarniene and Vienazindiene (2012), the authors Vienazindiene and Ciarniene (2013) present a diagram of what would, in their opinion, be a model for successful “lean” implementation. (Figure 1).

Figure 1 – Model for Lean implementation



Source: Adapted from Vienazindiene and Ciarniene (2013).

To successfully implement the LM concept, many researchers emphasize some behavioral qualities, such as top management commitment, leadership ability, and management style (SUNDA; BALAJI; KUMAR, 2014). In essence, these qualities would facilitate the integration of the entire organizational infrastructure through strong leadership and a strategic management vision (TALEGHANI; MOUSAVIAN, 2013). The fact is that some organizations that implemented LM reported enormous benefits, whereas others did not achieve the desired results. Some companies that reported initial gains following implementation were able to continually improve while others failed to continually improve. Anand and Kodali (2009) believe that companies, or individual managers, have adopted the lean approach with an incomplete understanding of LM and, as a result, the company has not been able to reap all the benefits that the Toyota paradigm enjoys. According to Sundar *et al.*

(2014), most research on lean systems focuses on only one or two elements, or a combination of two or three elements. To implement LM successfully, there is a need to incorporate all the lean elements and arrange them in a sequence.

2.2. Implementations guidelines

This subsection's objective is to present some authors' guidelines for implementing LM, which provide guides for lean transformation processes because they have a certain degree of structure and detail. These implementation guides serve to stimulate a systemic understanding of the operating mechanisms of the new concept or paradigm, guiding leaders toward an understanding of LM principles and enablers.

Guide models proposed by entities recognized as important in the scientific and business circles, which have a great deal of control over the topic of LM, will be presented succinctly below, following the brevity imposed on this text. Three guide models are referred to here: that of the Lean Enterprise Institute (LEI), that of Productivity Inc., and that of the Massachusetts Institute of Technology (MIT).

LEI (2005) established a lean roadmap that can assist in the selection of the best training sequence for those interested in their training courses. This guide is not rigid and allows for customization of the lean preparation program, according to the application environment, the trainee's role and the company's stage in the lean transformation. It should be emphasized that all training processes must begin with value stream mapping in order to avoid the common mistake of applying isolated techniques, rather than creating a system that constructs a lean value stream. The guide defines 6 phases in the implementation process: value stream mapping; modifying the skill of change agents, managing policies, achieving process stability, creating a continuous flow of operations and materials, and creating pull production.

Productivity Inc. (2007) presents a guide model for implementing LM, divided into 5 phases: planning, application on a pilot scale, deployment to the entire plan, integration, and continuous excellence.

The guide model for LM implementation from MIT, according to Crabill *et al.* (2000), was established based on practical experiences with implementing lean production in the operations of several US aerospace plants. The Lean Aerospace Initiative (LAI) consortium, mediated by MIT, conducted a study to validate this model. This guide proposes six steps:

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focusing on the value stream, developing lean structure and behavior, creating and refining the implementation plan, implementing lean activities, and focusing on continuous improvement.

2.3. Expected results of LM

The literature regarding the benefits of LM is vast, but there have been few studies that quantify these benefits. Patel and Patange (2017) reviewed the literature on this topic and concluded that having a LM system is now becoming a part of any type of organization. Additionally, LM are broadly used for eliminating different types of waste and increasing profits by making processes more efficient. Basu, Gosh and Dan (2018) created a list of empirically demonstrated benefits of LM. Singh, Singh and Singh (2018) confirmed an improvement in productivity due to LM implementation, in a case study. Similarly, Vinayagasundaram and Kannan (2015) discovered that foundries in India that implemented LM had an increase of 15 to 20% in their output. Kumar and Kumar (2015) proposed and empirically tested a list of benefits and drawbacks of LM implementation, concluding that the benefits outweigh the obstacles. Nallusamy (2016) found a significant relationship between the practice of LM activities and defect rate and turnover rate. Zawislak (2015) found that LM leads to a reduction in costs. Abdulmalek and Rajgopal (2007) demonstrate reductions in lead time and a lower inventory level of in-process raw material. Melton (2005) points to advantages such as a lower lead time for customers, lower inventory levels for the manufacturer, better knowledge management, and more robust processes (meaning fewer errors and therefore less reworking). Detty and Yingling (2000), in a simulation-based study, found reductions in all of these performance variables: inventory, space occupation, transport, labor and equipment required, order lead time, setup time, production lead time, and variation in supplier demand. Shah and Ward (2003), in a regression study using a large sample, concluded that 23% of the operational performance variation in the companies studied was explained by lean practices. In other words, these practices have yielded important positive results.

On the other hand, there are several reports of difficulties and obstacles to implementing LM. Although the benefits of LM are widely known, many companies have yet to implement it. Some reasons for this lack of implementation can be noted: companies have

not heard about this organizational model; they do not know how to implement it; they do not understand Lean principles; they do not have the support of top management; they are unaware of the benefits brought by this model or do not know how to quantify them; or they consider there to be investment costs. These issues were identified by companies as obstacles to implementing LM in Kumar and Kumar (2015). It is also important to point out that different configurations of the manufacturing environment can make it difficult to implement LM, or even worsen the results of LM implementation. For instance, having a flexible production-mix and high fluctuation of the demand for customized products might compromise the benefits of LM implementation (TAJ; MOROSAN, 2011; SAHIN, 2000).

According to Maskell and Baggaley (2011), even without a precise definition of what lean companies are, at least three characteristics are essential: lean methods, culture, and relationships. These authors consider that when companies adopt lean methods, they obtain operational improvements on the factory floor, which spread throughout the organization and end up creating a new organizational culture that strengthens lean thinking. Lean practices should be a set of actions that are planned, implemented and evaluated in order to achieve strategies (NOGUEIRA, 2007).

3. RESEARCH METHODS AND TECHNIQUES

This case study (YIN, 1994) was performed by collecting secondary data from reports, complemented by primary data obtained in semi-structured interviews using a questionnaire, applied to managers and employees in the engineering and operation areas, in order to gather information about the LM model implemented. The questionnaire was developed in a way as to allow comparisons among LM implementation models (the LEI, Productivity Inc. (PROD) and MIT guides), with an extensive checklist that was devised to identify the use of different practices and tools prescribed by these models.

The model of the company studied was compared with existing theoretical postulates regarding LM implementation, according to bibliographic research on the subject. Quantitative aspects were analyzed to compare the mean indicators of the company's operational performance after LM implementation, with the same indicators obtained in the past, before the implementation. To this end, the non-parametric Mann-Whitney test was used, which is suitable for independent samples of smaller sizes. The most common criteria for measuring operational performance brought about by a philosophy such as LM are

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efficiency (cost and capital), reliability (products, delivery and cost), quality, delivery speed and flexibility (product mix) (WHEELWRIGHT, 1978). The indicators used in the present study are based on these criteria.

The company that is the focus of this study is multinational in the non-durable consumer goods sector, ranked among the three largest companies in the non-durable products segment in Brazil. Further details about the company cannot be provided for reasons of confidentiality.

3.1. Development of the survey tools

The questionnaire was divided into two sections. The first section, which had 15 questions, sought information about practices in LM implementation, such as application of tools, personnel involved, team roles and responsibilities and managerial preparation of leadership. This questionnaire made it possible to analyze the company's adherence to best practices in LM implementation. The second section of the instrument, which had 13 questions, focused on difficulties and opportunities, communication during the implementation, the motivational process, conflict resolution and improvements related to LM implementation, but with an operational bias.

A pre-test of the questionnaire was carried out with 12 students from a university center located in the city of Salvador in order to verify if the questions were easy to understand, if they measured what they intended to measure, and the average response time. Adaptations and improvements were made.

After development and pre-test of the questionnaire, semi-structured interviews were performed. All the interviews were recorded in full. The target population totaled 20 company employees: 10 production operators, 3 managers and 7 engineers. The respondents were chosen as follows: the operators were selected randomly, without considering any aspect such as age, gender, employment time or hierarchical level; the only condition was having participated in the entire implementation process. The managers and engineers were chosen because they had participated in and guided the process. All of them were mid-level managers, however we can affirm that the perception of the top-level managers regarding the strategic objectives and systemic view of the LM implementation process were shared with these mid-level managers and with the collaborators, since this shared vision was an important part of the process and an effort to divulge and generate commitment at all levels

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was an important part of the plan.

The quantitative data regarding operational performance in the two periods chosen were collected directly in the company's system. Performance data were collected for two 7-month periods, one before and one after the implementation, with a time period of 4 months between the two periods, which corresponded to the time when LM was effectively implemented in the company. The periods were chosen based on the limitations that were found: The implementation of LM in the company was made recently, so the period of data collection was restricted to the time period available for analysis. A longer period of time for the collection would have been better, however the authors are convinced that the periods are representative, based on the opinion of the three managers that were interviewed.

4. RESULTS AND DISCUSSION

This chapter will present (a) a measurement of the LM implementation process in the company studied and its respective critical analysis, in comparison with the analysis model defined for this, and (b) a comparison between the operational performance results before and after the LM implementation.

The company is one of the three largest companies in the specific market in which it operates, and it decided to implement LM in order to maintain competitiveness and improve the performance of its production line, which uses comparatively old but non-obsolete machinery. With the new production system, the company hoped to make significant gains in terms of time, quality and cost.

The company studied has 2 (two) production lines; lean production was implemented in only one of them. It produces two types of products (one in each line), using five different kinds of packaging. It is important to point out that the time required to change tools is significant and represents about 5% of operating time. The production line is only partially automated, and is labor-intensive. The company manufactures products in both made-to-order and made-to-stock modes. The cost of products, as presented in this study, represents the unitary value of cost accrued for accounting purposes, following Brazilian legislation (MARTINS *et al.* 2000).

In the 18-month period during implementation, no internal factors—such as technology or the makeup of the team—or external factors—such as raw material price or market oscillations or seasonality—were significant enough to change the expected result of

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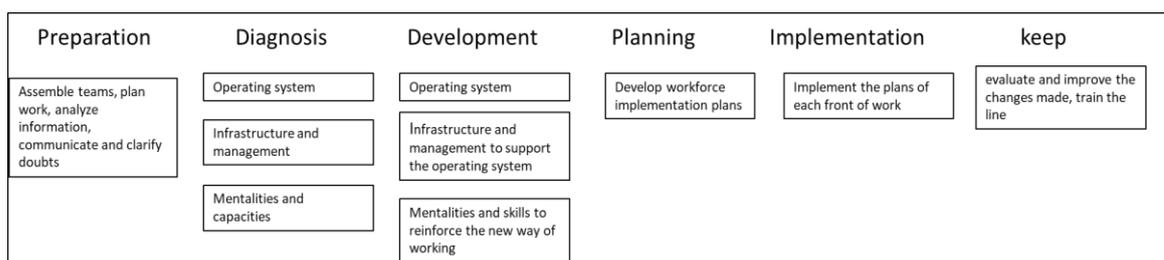
the line's transformation. The LM tools that were applied were therefore essential to the results obtained.

4.1. Implementation guide of the company studied

LM implementation took place in the company studied in stages (preparation, diagnosis, design and implementation), in which people who actively participated in the implementation were selected. These people were the change agents and were divided into work fronts (Figure 2). It focused on a sanitary napkin production line in Camaçari, with a current production of 37,000 boxes and a sale of 50,000 boxes in the northeast region; the current contribution margin is 8%, which can reach a maximum of 45% on the curve of the plant's development and maturity. The implementation lasted a total of 14 weeks, divided as follows:

- a. Preparation (1 week)
- b. Diagnosis (2 weeks)
- c. Design (1 week)
- d. Implementation (10 weeks)

Figure 2 – Implementation phases carried out at the Company



Source: The authors (2019).

a. **Preparation:** In this stage, the teams are assembled, the work is planned, the information is analyzed, communications are sent and doubts about the implementation are cleared up.

b. **Diagnosis:** In this stage, the flow of materials and information is analyzed, observations on the operation are taken into account, and the roles and responsibilities are

presented, discussing incentives and performance management. Differences in the mindset and skill of each employee directly involved at all levels are identified through discussions, surveys and interviews. The current results are compared with the objectives, and milestones are identified to measure and record the impacts.

c. **Design:** In this stage, the system is technically verified to meet future customer needs, process efficiency, cost, quality and safety, workload and support structure, and actions to improve the new method of working are identified.

d. **Implementation:** In this stage, the actions that were suggested during the diagnosis and design phase are performed. Implementation plans are developed for each work front, the actions are implemented, and the changes that were made are evaluated and improved, in addition to operators on the production line being trained.

Some tools and tasks related to the LM methodology were implemented in this stage. They were the following: 5S, TPM, Kanban, visual management, Kaizen, Gemba, SMED, pull system, standardized work, quality at the source and communication. Figure 3 shows the timeline of the phases of the implementation process.

Figure 3 – Timeline of implementation phases

Phase	weeks													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Preparation														
Diagnosis														
Drawing														
Implementation														

Source: the authors (2019).

4.2. Comparison between benchmarks of LM implementation and practices used the company

The evidence gathered here aims to contribute to the literature that establishes operational performance advantages for companies that adopt LM. The objective is to determine the company’s degree of adherence to best practices, in the process of implementing LM in the production line. The premise is that a high degree of adherence can bring benefits to the company, in the dimensions indicated in the literature review.

Table 1 shows a breakdown of the phases in all three implementation guides and compares the guides' practices, activities or recommendations with what was done at the company studied. This table unifies the main and most relevant approaches to LM concepts taken from the three guides. An "X" in the table signifies the presence of the practice in a guide or at the company. The LM implementation stages, as show on table 1 below, were defined in a discretionary way. The company did not follow a single model of LM implementation. However, all three models (LEI, PROD and MIT) were used as benchmark and were consulted during the planning stage. Table 1 thus presents the main concepts from the LEI, Productivity Inc. (PROD) and MIT guides, as well as the concepts uses or applied at the company studied (Company A).

Table 1 – Comparative table of implementation guides

PHASE	Description of the Step	LEI	PROD	MIT	Company A
VALUE STREAM MAPPING	Develop an understanding of the key LM concepts	x	x	x	x
	Visualize the stream and locate losses	x	x	x	
	Eliminate the losses	x	x	x	
	Expand the value stream to the entire business process	x	x	x	
	Adapt management methods to the new reality	x	x	x	
MODIFYING THE SKILL OF THE CHANGE AGENTS	Introduce lean production principles and techniques throughout the company	x	x	x	x
	Develop studies and applications that show people the way	x	x	x	x
	Obtain agreements, commitment, cooperation and support	x			x
	React productively to resistance	x			x
	Focus Kaizen activities on the points of greatest gain and impact	x	x	x	x
MANAGING POLICIES	Define the company's current needs and priorities	x	x	x	x
	Deploy strategic guidelines (Hoshim Kamri)	x	x		
	Develop a master plan	x	x	x	
	Share understanding and commitment	x			x
	Establish a lean mindset	x		x	x
	Sustain a lean transformation	x	x	x	x
ACHIEVING BASIC STABILITY	Identify losses that cause production line stability problems	x			x
	Implement TPM	x	x	x	x
	Determine the annual capacity level	x			
	Increase the stability of the value flow	x			

PHASE	Description of the Step	LEI	PROD	MIT	Company A
CREATING PULL PRODUCTION	Create a continuous flow in the timing process of the work elements	x	x		x
	Create a continuous flow of materials	x	x		
CREATING A CONTINUOUS FLOW OF BASIC OPERATIONS AND MATERIALS	Create a continuous flow in the rest of the process	x			
	Create a single flow or small batches	x	x	x	
	Implement the pull production logic	x		x	x
	Sustain the changes	x			
	Carry out an initial evaluation		x		
PLANNING	Define objectives and goals, measurements and milestones	x	x	x	x
	Establish a lean organization		x		
	Research the current conditions	x	x	x	x
	Establish a deployment policy	x	x	x	
	Disseminate the lean production policy	x	x		x
PILOT APPLICATION	Prepare and focus		x		
	Apply 5S	x	x	x	x
	Develop a standard worksheet and inventory	x	x	x	x
	Establish a single stream/ implement specific methods	x	x	x	
	Apply quick tool change (QTC)	x	x	x	x
	Apply autonomous maintenance	x	x	x	
	Apply visual production controls	x	x	x	x
	Apply poka-yoke systems	x	x	x	
	Analyze the results		x		
	Reapply 5S		x		
DEPLOYMENT TO THE ENTIRE PLANT, EXPANSION TO OTHER AREAS AND STANDARDIZATION OF ACTIVITIES	Develop plan to implement the improvements tested in the pilot area		x		x
	Repeat application in other areas	x	x		
	Apply advanced single stream	x	x	x	
	Implement automation (Jidoka)	x	x	x	
	Implement the production flow in leaps		x		
	Analyze the results		x		
	Apply Kanban	x	x	x	x
	Analyze the results		x		
INTEGRATION	Establish an interface with MRPII		x		
	Deploy lean understanding in the value chain	x	x	x	
	Educate and involve all the employees	x	x		x
	Analyze the results		x		
	Apply Simultaneous Engineering		x		
	Analyze the results		x		
	Begin a supplier development program	x	x	x	
	Analyze the results		x		
Apply QFD	x	x			

PHASE	Description of the Step	LEI	PROD	MIT	Company A
	Analyze the results		x		
	Study the results and revise the strategies		x		
EXCELLENCE	Break paradigms		x	x	x
	Invest in R&D to find new methods and technologies	x	x		
	Publish results	x	x	x	x
	Celebrate success		x		x

SOURCE: Adapted from Productivity Inc. (2007); Massachusetts Institute of Technology (MIT), according to Crabill *et al.* (2000); Lean Enterprise Institute (LEI) (2005).

The conditions for carrying out LM implementation depend on the particularities of the company adopting this methodology (LEWIS, 2000); although the terminology of the phases or stages are different in all the guides, there are many similarities in the application, as the tools practically do not change.

After examining the comparative table, it can be concluded that the company's adherence to the three implementation guides is partial, but considerable. Of a total of 65 practices found in the three guides, the company followed 25 practices. Individually, the MIT guide advocates 25 practices, the Productivity Inc. guide advocates 40 practices, and the LEI guide advocates 55 practices. However, an analysis based only on the number of practices adopted may not be very enlightening without some additional comments.

According to the implementation phases proposed by the guides and the company's model for implementing LM, some comparisons should be presented:

1. In all the guides presented, VSM is performed in a clear manner, becoming a premise for implementation. However, the company studied does not show clarity at this stage, which may become a limitation in the implementation.
2. The company studied does not apply any type of deployment of lean understanding in the value stream, meaning that not all areas will be involved in the implementation.
3. There is no supplier development program, resulting in difficulties in replacing or purchasing parts and in developing improvements in conjunction with the company.
4. The guides suggest applying autonomous maintenance; this is one of the fundamental pillars for successful implementation. However, the company studied is still at a basic level on this subject.

5. As positive points, there are similarities between the guides and the company studied in the following topics: application of 5S, TPM, a focus on Kaizen activities, application of visual controls, research on current conditions, Kanban, standard work, a focus on teaching people the means, LM concepts, and sustainability of lean understanding.

It can therefore be concluded that LM implementation in the line studied was in accordance with many of the practices recommended and suggested in the literature. The company's effort is expected to be reflected in operational performance gains (ZAWISLAK, 2015; ABDULMALEK; RAJGOPAL, 2007; MELTON, 2005; SHAH; WARD, 2003; BASU, GOSH; DAN, 2018; SINGH, SINGH; SINGH, 2018; VINAYAGASUNDARAM; KANNAN, 2015; KUMAR; KUMAR, 2015; NALLUSAMY, 2016; ZAWISLAK, 2015). This analysis is performed below.

4.3. Critical analysis of the implementation

After collecting data through interviews—comprising a total of 20 interviews with 3 managers, 7 engineers and 10 production operators—the most important data regarding LM implementation in the production line studied were compiled. The implementation team was arranged as follows:

1 plant manager, 1 LM manager, 10 engineers (2 process, 4 continuous improvement, 3 maintenance and 1 production engineer), 1 HR analyst, 2 trainees, 1 level III operator and 1 material analyst.

In this context, 20% of respondents admitted that they did not know about or understand the process of implementing LM in the plant as a whole. They did not know the stages, or the start and end dates, or what the implementation activities were. With regard to leadership, six out of ten production operators indicated that they should have had more support, particularly in the application of LM tools. The leader's attitude was also indicated in the sense of the desire for immediate results. Forty percent of all respondents indicated a lack of planning and business sustainability and stated that the result was more important for all aspects, regardless of whether or not there was planning. Although there was no specific LM training for management, the managers demonstrated full knowledge on the use of the tools to be applied during LM implementation.

Regarding the use of LM methodology and tools, knowledge was superficial, and there were many gaps. For example, 100% of respondents did not know how to identify/describe

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the value stream mapping (VSM) that was used during the implementation, which indicates a fundamental failure in LM implementation. According to Rother and Shook (2003), value stream is every action (adding value or not) necessary to bring a product across all the flows essential to each manufactured product, provided it has manufacturing steps.

5S was a positive point, as 100% of respondents had full knowledge on the subject, knew how to apply it and had positive experiences relating 5S to waste reduction.

With regard to the behavioral area, 30% of the operators interviewed admitted that they felt pressure during the implementation to achieve the expected result and stated that any other result was not acceptable.

Regarding safety, this was a positive point because 100% of respondents pointed to the safety issue as their main value within the company. This demonstrated the top management's commitment to the well-being of its employees at work.

4.4. Operational performance

This section will present the operational performance of the production line before and after LM implementation, divided into four (4) large blocks of indicators.

- a) Financial – Cost: considers the value of the product's cost after manufacture.
- b) Productivity – OEE indicator: a known indicator, used by the company, which is calculated by the following expression: fraction of available operating time multiplied by the efficiency index of the equipment and multiplied by the fraction of approved products (Rama and Abraham, 1997).
- c) Waste (expressed as production scrap): considers the quantity of products that were to be produced in a given period divided by what was actually produced and approved.
- d) Safety: measures the number of accidents or incidents at the plant.

Financial Results:

Table 2 shows the financial results, before and after the implementation process took place in the factory.

Table 2 – Financial results before and after implementation

7 months before implementation		7 months after implementation	
Jan/14		Dec/14	
	80.2		65.3
Feb/14		Jan/15	
	59.1		50.2
Mar/14		Feb/15	
	51.8		48.1
Apr/14		Mar/15	
	61.2		49.3
May/14		Apr/15	
	47.7		46.4
Jun/14		May/15	
	50.4		35.1
Jul/14		Jun/15	
	50.1		39.6
Financial (unit cost)			
Mean= 57.2		Mean=47.7	

Unit: Brazilian Real; Source: The authors (2019).

The mean cost of the product seven months before implementation was R\$ 57.2 per 1000 units produced; seven months after implementation, the mean was R\$ 47.7 per 1000 units produced. In other words, after implementation, there was a gain of 19.9% (Table 2). The cost of the product produced was reduced, demonstrating the effectiveness of the implementation.

Figure 4 – Mean Cost of Product: Evolution during the two periods



Source: The authors (2019).

Figure 4 shows the evolution of cost during the two periods. The non-parametric Mann Whitney test revealed that there is a statistically significant difference between the financial results of the line before and after the LM implementation, with 95% confidence (U = 10; p value = 0.03673).

Productivity Results

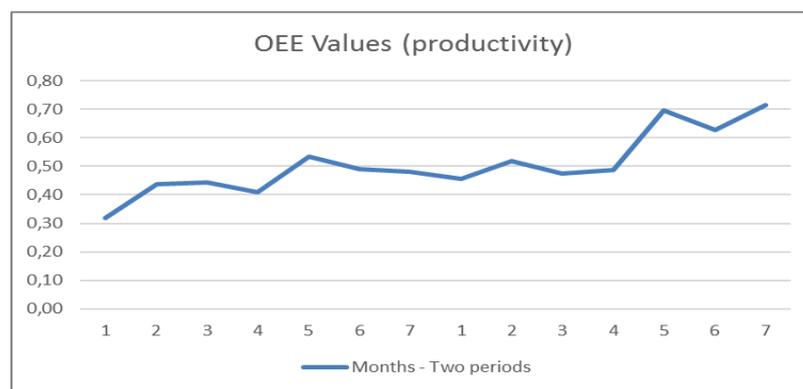
Table 3 – Productivity result before and after implementation (OEE)

7 months before implementation		7 months after implementation	
Jan/14		Dec/14	
	31.8%		45.6%
Feb/14		Jan/15	
	43.6%		51.8%
Mar/14		Feb/15	
	44.4%		47.6%
Apr/14		Mar/15	
	41.0%		48.6%
May/14		Apr/15	
	53.4%		69.7%
Jun/14		May/15	
	48.9%		62.8%
Jul/14		Jun/15	
	48.0%		71.5%
Productivity			
Mean= 44.4		Mean=56.8	

Unit: Percentage; Source: The authors (2019).

The mean OEE values during the seven months before implementation was 44.4%. After seven months of implementation, the mean OEE values increased to 56.8%, resulting in a productivity gain of 27.9% after implementation, proving the effectiveness of the implementation (Table 3).

Figure 5 – Productivity: Evolution during the two periods



Source: The authors (2019).

Figure 5 shows the evolution of OEE values during the two periods. The non-parametric Mann Whitney test revealed that there is a statistically significant difference between the results of the line before and after LM implementation, with 95% confidence (U = 9; p value = 0.02743).

Waste Results

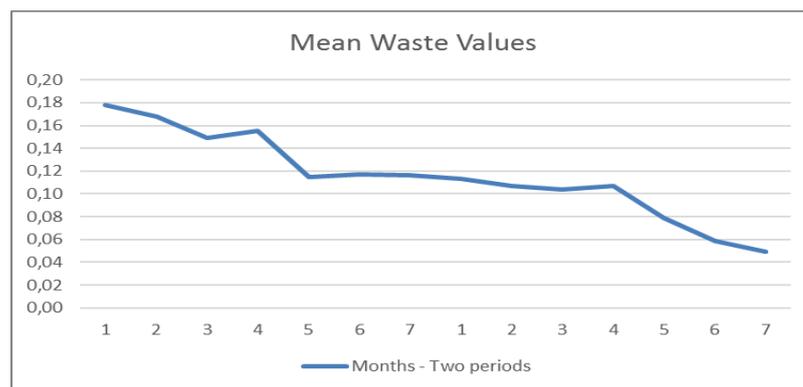
Table 4 – Waste results before and after implementation

7 months before implementation		7 months after implementation	
Jan/14	17.8%	Dec/14	11.3%
Feb/14	16.8%	Jan/15	10.7%
Mar/14	14.9%	Feb/15	10.4%
Apr/14	15.5%	Mar/15	10.7%
May/14	11.5%	Apr/15	7.9%
Jun/14	11.7%	May/15	5.9%
Jul/14	11.6%	Jun/15	4.9%
Waste			
Mean=14.25		Mean= 8.82	

Unit: Percentage; Source: The authors (2019).

Table 4 indicates that the mean waste results seven months before implementation was 14.25%; after (seven) months of implementation, the mean was reduced to 8.82%. There was thus a significant gain; that is, after implementation, the quantity of culled products decreased by 61.2%, indicating the effectiveness of the implementation.

Figure 6 – Mean Waste fractions: Evolution during the two periods



Source: The authors (2019).

Figure 6 shows the evolution of mean waste values during the two periods. The non-parametric Mann Whitney test revealed that there is a statistically significant difference between the results of the line before and after LM implementation, with 95% confidence ($U = 0$; p value = 0.00107).

Safety Level Results (accidents or incidents at the plant)

Table 5 – Accidents and incidents before and after implementation

7 months before implementation		7 months after implementation	
Jan/14	0	Dec/14	0
Feb/14	0	Jan/15	0
Mar/14	0	Feb/15	0
Apr/14	0	Mar/15	0
May/14	0	Apr/15	0
Jun/14	0	May/15	0
Jul/14	0	Jun/15	0
Safety			
Mean=0		Mean= 0	

Unit: Number of events; Source: The authors (2019).

The safety level (accidents and incidents at the plant), shown on table 5, was completely stable after seven months of implementation, with no occurrences. Given the conditions under which the company operates, this result was expected for the line.

6. CONCLUSIONS

This study analyzed and demonstrated the changes that occurred in operational performance after implementing an LM system. The productivity, waste and cost indicators had significant gains between the two periods analyzed, confirming that there were indications of the positive impact of LM on the line investigated.

This work concisely corroborates and confirms the studies cited in the literature review, which establish a direct relationship between LM implementation and operational performance. The company studied follows some of the best practices found/suggested in the literature regarding LM. The opportunities identified serve as a suggestion of future improvements to be implemented in the company

The results of this study may be useful to academics interested in the impacts of LM on operational performance and to managers who seek to understand implementation practices for Lean concepts in industrial companies.

Like any empirical study, this research has limitations. By being based on a single case, it is not possible to generalize results, and the external validity is small. However, it was found relatively strong evidence that the LM implementation had positive impacts on the operational performance of the company. This study was also limited by the short amount of time available for collecting data regarding the LM implementation, with the aim of comparing operational performance before and after the process. One suggestion for future studies is to use a large sample, with an online questionnaire, thus increasing the external validity, which is limited in a case study.

REFERENCES

- ABDULMALEK, F. A., RAJGOPAL, 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, n.1, p. 223-236, 2007.
- ALAVI, S. The right way [lean manufacturing]. **Manufacturing Engineer**, v. 82, n.3, p.32-35, 2003.
- ANAND, G., KODALI, R. Development of a framework for lean manufacturing systems. **International Journal of Services and Operations Management**, v. 5, n.5, p. 687-716, 2009.
- BAMBER, L., DALE, B. G. Lean production: a study of application in a traditional manufacturing environment. **Production planning & control**, v.11, n.3, p.291-298, 2000.
- BASU, P., GHOSH, I., DAN, P. K. Structural equation modelling based empirical analysis of technical issues for lean manufacturing implementation in the Indian context. In: INDUSTRIAL TECHNOLOGY AND MANAGEMENT. 2018. 7th. **Anais...International Conference on** (pp. 57-61). IEEE, 2018.
- BATTAGLIA, F., PICCHI, F., FERRO, J. R. **Desenvolvimento Lean de produtos**. Resumo baseado nos Portugueses, 2006.
- BOYER, M., SOVILLA, L. How to identify and remove the barriers for a successful lean implementation. **Journal of Ship Production**, v.19, n.2, p.116-120, 2003.
- BOWEN, H. K.; SPEAR, S. Decoding the DNA of the Toyota production system. **Harvard Business Review**, 1999.
- BOZDOGAN, K., MILAUSKAS, R., MIZE, J., NIGHTINGALE, D., TANEJA, A., TONASZUCK, D. Transitioning to a lean enterprise: a guide for leaders. **Massachusetts Institute of Technology**, v 1., 2000.

ČIARNIENĖ, R.; VIENAŽINDIENĖ, M. Lean manufacturing: theory and practice. **Economics and management**, v.17, n.2, p.726-732, 2012.

CRABILL, J.; AIR, U. S.; GRUMMAN, N.; MEADOWS, D.; MILLER, C.; PRATT, B. S. Production Operations Level Transition-To-Lean Roadmap. Production **Operations Transition-To-Lean Team**, 2000.

DETTY, R. B.; YINGLING, J. C. Quantifying benefits of conversion to lean manufacturing with discrete event simulation: a case study. **International Journal of Production Research**, v.38, n.2, p. 429-445, 2000.

DUQUE, D. F.; RIVERA CADAVID, L. Lean manufacturing measurement: the relationship between lean activities and lean metrics. **Estudios gerenciales**, v.23, n.105, p. 69-83, 2007.

EMILIANI, M. L. Origins of lean management in America: the role of Connecticut businesses. **Journal of management History**, v.12, n.2, p. 167-184, 2006.

KARLSSON, C.; ÅHLSTRÖM, P. A lean and global smaller firm? **International Journal of Operations & Production Management**, v. 17, n.10, p. 940-952, 1997.

KUMAR, R.; KUMAR, V. Lean manufacturing in Indian context: A survey. **Management Science Letters**, v.5, n.4, p. 321-330, 2015.

LEI - LEAN ENTERPRISE INSTITUTE. 2005. "**Lean Roadmap**." Disponível em: <http://www.lean.org.br/Events/LeanRoadMap.cfm>. Acesso em 12 Set 2017.

LIKER, J.; MEIER, D. **O Modelo Toyota: Campo de Aplicação** [The Toyota Way Fieldbook]. Ed. Bookman, Porto Alegre. Portuguese., 2007.

MARTÍNEZ SÁNCHEZ, A.; PÉREZ PÉREZ, M. Lean indicators and manufacturing strategies. **International Journal of Operations & Production Management**, v. 21, n. 11, p.1433-1452, 2001.

MARTINS, E.; GELBCKE, E. R.; IUDÍCIBUS, S. D. **Manual de contabilidade das sociedades por ações**. São Paulo: Atlas, 2000.

MASKELL, B. H.; BAGGALEY, B.; GRASSO, L. **Practical lean accounting**: a proven system for measuring and managing the lean enterprise. CRC Press, 2011.

MELTON, T. The benefits of lean manufacturing: what lean thinking has to offer the process industries. **Chemical engineering research and design**, v. 83, n.6, p. 662-673, 2005.

NALLUSAMY, S. Frequency analysis of lean manufacturing system by different critical issues in Indian automotive industries. **International Journal of Engineering Research in Africa**, v. 23, p. 181-187, 2016.

- NOGUEIRA, M. D. G. S. **Proposta de método para avaliação de desempenho de práticas da produção enxuta-ADPPE**. 116f. 2007. Dissertação (mestrado em engenharia de produção) – Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, 2007.
- NONAKA, I.; TAKEUCHI, H. **Criação de conhecimento na empresa**. Elsevier Brasil, 2004.
- OHNO, T. **O sistema Toyota de produção além da produção**. Bookman, SP, 1997.
- PARKS, C. M. Instill lean thinking. **Industrial Management**, v.44, n.5, p. 14-14, 2002.
- PASA, G. S. **Uma abordagem para avaliar a consistência teórica de sistemas produtivos**. 188f. 2004. Tese (Doutorado em engenharia de produção) – Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, 2004.
- PATEL, J. S.; PATANGE, G. S. A Review on Benefits of Implementing Lean Manufacturing. **International Journal of Scientific Research in Science and Technology**, v. 3, p. 249-252, 2017.
- PRODUCTIVITY INC. **Lean Production Implementation Roadmap: A Guide for the Lean Journey**. Disponível em: <http://www.advancedmanufacturing.com/January00/pdf/leanroadmap>. Acesso em 02 mar 2017.
- RADNOR, Z.; WALLEY, P. Learning to walk before we try to run: adapting lean for the public sector. **Public money and management**, v.28, n.1, p. 13-20, 2008.
- ROTHER, M.; SHOOK, J. **Aprendendo a enxergar**. São Paulo: Lean Institute Brasil, 2003.
- SAHIN, F. Manufacturing competitiveness: Different systems to achieve the same results. **Production and Inventory Management Journal**, v.41, n.1, p. 56, 2000.
- SHAH, R.; WARD, P. T. Lean manufacturing: context, practice bundles, and performance. **Journal of operations management**, v. 21, n.2, p. 129-149, 2003.
- SINGH, J.; SINGH, H.; SINGH, G. Productivity improvement using lean manufacturing in manufacturing industry of Northern India: A case study. **International Journal of Productivity and Performance Management**, v.67 n. 8, p. 1394-1415, 2018.
- SORIANO-MEIER, H.; FORRESTER, P. L. A model for evaluating the degree of leanness of manufacturing firms. **Integrated Manufacturing Systems**, v. 13, n.2, p. 104-109, 2002.
- SUNDAR, R.; BALAJI, A. N.; KUMAR, R. S. A review on lean manufacturing implementation techniques. **Procedia Engineering**, v. 97, p.1875-1885, 2014.

TALEGHANI, M.; MOUSAVIAN, S. J. The role of total quality management in performance improvement of new enterprises (Case study: Insurance industries of northern Iran). **Journal of Mechanical and Industrial Engineering Research**, v.2, n.2, p.52, 2013.

VIENAZINDIENE, M.; CIARNIENE, R. Lean manufacturing implementation and progress measurement. **Economics and management**, v.18, n. 2, p. 366-373, 2013.

VINAYAGASUNDARAM, M. R.; KANNAN, V. Implementation of Lean manufacturing practices and its impact on productivity in Coimbatore foundries. **International Journal of Modern Engineering Research**, v.5, n.5, 2015.

WHEELWRIGHT, S. C. Reflecting corporate strategy in manufacturing decisions. **Business horizons**, v.21, n.1, p.57-66, 1978.

WOMACK, J. P.; JONES, D. T.; ROOS, D. **Machine that changed the world**. Simon and Schuster, 1990.

YIN, R. K. **Case study research: design and methods**. Thousand Oaks, CA, 1994.

ZAWISLAK, P. A. Apresentação à edição brasileira [Introduction to the Brazilian edition]. IN: Tidd, J.; Bessant, J.; Pavitt, K. **Gestão da inovação** [Innovation management]. Porto Alegre: Bookman, 2015.