Recebido: 27/08/2021
Aprovado: 23/02/2022

Editor Responsável: Prof. Dr. Hermes Moretti Ribeiro da Silva

Evaluation of Lean Manufacturing Practices in an Automotive Component Manufacturer

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RESUMO

Objetivo: este estudo tem como objetivo avaliar as práticas de manufatura enxuta (LM) utilizadas em uma empresa do ramo de componentes automotivos localizada no Pólo Industrial de Manaus (PIM).
Referencial teórico: O referencial de pesquisa adotado neste estudo ocorreu por meio da aplicação do instrumento AME Lean Assessment. Este instrumento foi desenvolvido pela Association for Manufacturing Excellence (AME) para fornecer uma avaliação rápida de em que estágio uma empresa está com a jornada lean.
Desenho/metodologia/abordagem: Um estudo de caso exploratório e devido à necessidade de maior aprofundamento do quadro de investigação. A estrutura da pesquisa foi composta por 14 atributos sobre manufatura enxuta.
Resultados: Os achados apontam para um alto nível de práticas de LM adotadas pela empresa, além de permitir a observação da aplicação prática dos conceitos fundamentais do Sistema Toyota de Produção (TPS) no Pólo Industrial de Manaus. Os achados aumentaram o conhecimento do comportamento organizacional relacionado ao LM.
Pesquisa, implicações práticas e sociais: a pesquisa contribui para o corpo de conhecimento sobre manufatura enxuta considerando sua aplicação no contexto amazônico. O estudo trouxe uma contribuição substancial para a compreensão da manufatura enxuta no contexto de um importante parque industrial no Brasil.
Originalidade/valor: Originalidade é a adoção de uma estrutura de pesquisa para avaliação das práticas de manufatura enxuta no contexto amazônico possibilitando conhecer as peculiaridades da manufatura enxuta na Amazônia, a partir de um caso aprofundado.
Palavras-chave: Manufatura enxuta; Avaliação Lean; Indústria; Componentes automotivos; Amazonas.

ABSTRACT

Purpose: *This study aims to evaluate lean manufacturing (LM) practices used in a company in the automotive component industry located in Polo Industrial de Manaus (PIM), a manufacturing hub in the city of Manaus.*
Theoretical framework: *The AME Lean Assessment instrument was used as the research framework in this study. This instrument was developed by the Association for Manufacturing Excellence (AME) to benchmark where a company is on its lean journey.*
Design/methodology/approach: *An exploratory case study was carried out, and since a more detailed study was needed, a research framework was used, composed of 14 attributes on lean manufacturing.*
Findings: *The findings point to a high level of LM practices adopted by the company, in addition to allowing the practical application of the fundamental concepts to be observed for the Toyota Production System (TPS) at Polo Industrial de Manaus. The findings have increased the understanding in organizational behavior relating to LM.*
Research, Practical & Social implications: *the study contributes to the body of knowledge on lean manufacturing considering its application in the Amazonian context. The study has made a substantial contribution to the understanding of lean manufacturing in the context of an important industrial park in Brazil.*
Originality/value: *Originality is the adoption of a research framework for evaluating lean manufacturing practices in an Amazonia context, allowing the specific characteristics of lean manufacturing to be understood in Amazonia, from an in-depth case.*
Keywords: *Lean manufacturing; Lean Assessment; Industry; Automotive components; Amazonas.*

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VERÇOSA, W.R.; COELHO, M.A. Evaluation of Lean Manufacturing Practices in an Automotive Component Manufacturer. **GEPROS. Gestão da Produção, Operações e Sistemas**, v.17, nº 2, p. 29 - 56, 2022.

DOI: http://dx.doi.org/10.15675/gepros.v17i2.2853

1. INTRODUCTION

The origins of the Toyota Production System (TPS) are related to Japanese cultural, geographic, and economic aspects. The limitations of resources and spaces, in addition to the oriental culture-oriented more to the systems than the western culture, as well as the more concentrated location of the industries are pointed out as factors of the Japanese success (HOPP; SPEARMAN, 2013).

The basic idea of the TPS is to maintain a continuous flow of the products that are being sought to obtain flexibility to the changes in demand. The implementation of this flow is called production at the exact moment and means producing only the items added in the necessary quantity and in the necessary time (MONDEN, 1984). It is based on the complete elimination of wastes, with just-in-time (JIT) and autonomation (automation with a human touch) as its two pillars of support (GHINATO, 1995).

Among the main general concepts related to lean production, the following stand out: (1) development of simple techniques for changing molds; (2) small-batch production; (3) company as a community; and (4) workers who are more flexible in their tasks and active in promoting the company's interests. Additionally, demand-driven production, implementation of Kanban, and combating waste were adopted (WOMACK; JONES; ROSS, 1992).

In the case of the evaluation of LM practices, numerous authors have expressed interest in LM, since studies that consider leanness (RAY *et al*., 2006; BAYOU; KORVIN, 2008; SINGH; GARG; SHARMA, 2010; VINODH; CHINTHA, 2011), readiness (AL-NAJEM; DHAKAL; BENNETT, 2013; GARZA-REYES; ATES; KUMAR, 2015; GARZA-REYES *et al*., 2018) or developed their approaches to measuring lean manufacturing in the macro and microeconomic context (KARLSSON; AHLSTROM, 1996; SÁNCHEZ; PÉREZ, 2001; GOODSON, 2002; SORIANO-MEIER; FORRESTER, 2002). There are several researches that deal with the lean manufacturing evaluation in Brazil and in the world (mentioned above), however, a research gap was observed regarding the lean evaluation in the PIM. Considering that PIM is one of the most important industrial parks in Brazil.

The Industrial Pole of Manaus (PIM) recorded revenues of R$ 145.5 billion in 2021 (until November 2021), which is equivalent to a nominal growth of 32.13% about the amount obtained in 2020 (R$ 110.18 billion). The evolution of revenue represents a gradual recovery in the performance of PIM companies that had been observed since 2014 when PIM had revenues of R$ 87.4 billion (MANAUS FREE TRADE ZONE SUPERINTENDENCE, 2022).

Thus, considering the importance that the LM theme has assumed in recent decades for companies, added to the increase in the number of works produced in the area and having PIM as an important industrial center not only for Amazonas but among the main industrial areas of Brazil, the following research questions were developed for the study:

RQ1. Does the company adopt consistent lean manufacturing practices within its production processes aiming at quality, cost reduction, waste elimination, lead time reduction, and safety?

RQ2. Does the research framework used in the study make it possible to properly evaluate lean manufacturing practices in companies?

This study aims to evaluate the lean manufacturing practices used in an automotive components industry company located in the Industrial Pole of Manaus (PIM) considering fourteen aspects related to lean philosophy. The second section deals with the literature background on the concepts of lean manufacturing and the various approaches to lean assessment developed over the last few years in the literature. Section three presents the study's methodology and its research framework; sections four and five deal with the results and the discussion carried out throughout the study. Finally, the last section presents the conclusion with the final position of the study.

2. THEORETICAL FOUNDATION

2. 1 Lean manufacturing – concepts and lean assessment

From the 1990s onwards, the term JIT was gradually replaced by lean manufacturing. Thus, in a retrospective view, lean production provided a better set than several JIT techniques, the focus was on the flow, the value chain, and the elimination of Muda (waste), through Kaizen events (HOPP; SPEARMAN, 2013).

Schonberger's (1982) work indicated four approaches that companies should adopt to become lean: (1) reallocating floor space, (2) cutting setup time/lot sizes; (3) drawing down buffer stocks; and (4) reducing the number of suppliers.

The TPS is formed by a set of fundamental concepts that can be represented using the diagram "TPS House". It starts with the goals of better quality, lower cost, less lead time, greater safety, and high morale on the roof. It has two external columns, one representing just-in-time (right piece, right quantity, and right time) and the other column autonomation (automation with a human touch guaranteeing quality in the sector). At the center of the system are people (organizational culture) and at its base are various processes (visual management, the Toyota Way Philosophy, and leveled production - heijunka), both in volume and variety (LIKER; MEIER, 2007).

JIT differs from traditional philosophy (just-in-case), as it seeks to dynamically and instantly meet the varied market demand, normally producing in small batches and inventories (both raw materials and finished products) are being viewed as wastes (ANTUNES JÚNIOR; KLIEMANN; FENSTERSEIFER, 1989). The Just-in-time thinking was present in the manuals that Kiichiro Toyoda produced for each process and distributed to strategic collaborators (HINO, 2009).

Autonomation (jidoka) relates to delegating the autonomy to the operator or the machine to stop the process whenever any problem in the processing is detected (GHINATO, 1995) and heijunka is the process of smoothing the production flow, which in together with the reduction of setups, functional training and the factory layout (U cells) are essential for shorter cycle time and a faster response in serving customers (HOPP; SPEARMAN, 2013).

Kanban is the TPS' method of operation, totally preventing overproduction (OHNO, 1997). Kanban represents the first system to use the term “pull”. The kanban in its classic version had its origin in Toyota called the “two-card kanban” system, which had the function of starting the production of the parts, in addition to providing the necessary quantity that should be produced. Unlike the pull production system, in the pushed production system the work starts from the subtraction of established lead time from the date the material is needed, either for shipping or for assembly. Therefore, the pull production system has the following benefits: (1) reduction of WIP and cycle time; (2) smoother production flow; (3) improved quality; and (4) reduced cost (SPEARMAN; ZAZANIS, 1992; HOOP; SPEARMAN, 2004).

Concerning the supplier network, there have been substantial changes in the Ford model, the Toyota Company organized suppliers at functional levels, making them participate in the product development process and sharing human resources. Finally, it encompassed industrial and process engineering and promoted a close relationship between the automaker, dealers, and consumers, with the dealer being the first step for Kanban (WOMACK; JONES; ROSS, 1992).

Other important concepts related to TPS are the five whys (help to discover the root of the problem and correct), Muda (waste), andon (line stop indication board), visual control, teamwork, and Kanban (OHNO, 1997).

TPS also promotes 5S (Seiri, Seiton, Seiri, Seiketsu, and Shitsuke), being organizational and housekeeping techniques that aim to achieve autonomy and visual control (HOOP; SPEARMAN, 2004). Total Productive Maintenance (TPM) has among its characteristics that everyone learns to clean, inspect, and maintain the equipment (LIKER; MEIER, 2007).

The SMED (Single Minute Exchange of Die) was developed by Shigeo Shingo and deals with a methodology for reducing machine setup time, being designed over 19 years. The author identifies as the internal setup, the set of activities performed with the machine stopped, and the external setup, as the set of activities with the machine running (SHINGO, 2000).

Value Stream Mapping (VSM) is a tool that helps you visualize and understand the flow of materials and information for a given product through the value stream. The value flow is all the actions (with added value or without added value) necessary to deliver products through the main flow of each product, that is, through VSM it is possible to visualize not only the process flow but observe the sources of waste, making possible the connection between the flow of information and material (ROTHER; SHOOK, 1998).

The takt-time is defined based on the market demand and the time available for production, therefore, it is the production pace necessary to meet the demand, resulting from the ratio between the time available for production and the number of units to be produced. Takt-time is the production pace necessary to meet a determined level of demand, it is the time that governs the flow of materials in a line or cell (ALVAREZ; ANTUNES JÚNIOR, 2001).

Numerous authors have expressed interest in the topic of lean assessment, developing models to assess the challenges for the introduction of lean production (Karlsson & Ahlstrom, 1996). Soriano-Meier and Forrester (2002) examined the relationship between the main components of the work of Karlsson and Ahlstrom (1996) and managerial commitment (BOYER, 1996) for the implementation of lean manufacturing. Others developed and tested an integrated checklist to assess changes in manufacturing towards lean manufacturing (SANCHEZ; PEREZ, 2001).

Goodson (2002) described a lean assessment technique called the Rapid Plant Assessment (RPA) process; Nightingale and Mize (2002) presented the Lean Enterprise Self-Assessment Tool (LESAT), which aims to guide companies to implement lean thinking by assessing their current status; Pavnaskar, Gerhenson and Jambekar (2003) used a classification scheme that serves as a link between problems with wastes in production and the tools of lean manufacturing and Kojima and Kaplinski (2004) presented the construction of a lean production index and the analysis of factors determinants of its adoption in the auto components sector in South Africa.

Cardoza and Carpinetti (2005) discuss the process of developing and implementing performance indicators in the lean production system, while Doolen and Hacker (2005) developed an instrument to assess the implementation of lean practices within an organization based on an exploratory study in electronic industries; Wilson (2010) presented eight steps for the implementation of lean manufacturing, starting with cultural change, going through the assessment of the current state and ending with the implementation of kaizen activities and evaluation of the implementation in the company and Kumar and Thomas (2002) presented the software lean that evaluates clean manufacturing practices used in an organization. The software analyzes manufacturing practices considering four aspects: (1) materials and inventory, (2) training, (3) preventive maintenance, and (4) quality. The Massachusetts Institute of Technology (MIT) developed the Lean Enterprise Self-Assessment Tool (LESAT). The tool is organized into three assessment sections: (1) lean transformation/leadership, (2) life cycle processes, and (3) enabling infrastructure (LAI, 2001). LESAT was applied in Brazil in the area of information technology (CANTANHEDE, 2014).

Other examples of studies that evaluated lean manufacturing include Bonavia and Marin (2006) that determined the degree of use of the most representative lean manufacturing practices in Spanish ceramic companies; Gurumurthy and Kodali (2009) sought to determine the current status of benchmarking in the field of LM of a company that is implementing or has already implemented lean thinking; Cumbo, Kline and Bumgardner (2006) investigated the implementation of lean manufacturing in the rough mill, as well as the measurement and performance metrics used in the company; Matsui (2007) worked with nine measurement scales related to JIT production practices in Japanese companies; Srinivasaraghavan and Allada (2006) proposed a complementary methodology to assist lean assessment tools that will provide a quantitative measure of leanness compared to other lean industries, using Mahalanobis distance and five variables; and Taj (2005; 2008) assessed the current state of companies in China in nine manufacturing areas: inventory, team approach, processes, maintenance, layout/handling, suppliers, setups, quality, and scheduling/control.

Other evidence from research in the area points to Shah and Ward (2003) who examined the effect of three contextual factors, plant size, plant age and unionization status on the likelihood of implementing 22 manufacturing practices that are key facets of lean production systems; Shah and Ward (2007) identified a set of measurement items, proposing a set of 10 factors and 48 items to measure SC and its practices; Al-Najem, Dhakal and Bennett (2013) developed a measurement framework to assess lean readiness level (LRL) and lean systems (LS) within small and medium-sized industries in Kuwaiti; Garza-Reyes, Ates and Kumar (2015) assessed the readiness level of the Turkish automotive supply industry to provide a basis for implementing lean practices; and Maasouman and Demirli (2016) developed the visual, data-driven operational level lean maturity model to assess the level of lean maturity and compare them to the performance results in different axes of the manufacturing cells in order to assess lean effectiveness.

In recent years, Thanki and Thakkar (2018) proposed a balanced scorecard (BSC) and strategy map based on a quantitative framework for assessing lean and green performance in the supply chain (SC); Hussain, Al-Aomar and Melhem, (2019) evaluated the impact of integrated lean and green practices on the sustainable performance (environmental, economic and social) of a hotel supply chain; Tortorella *et al.* (2019a) proposed a methodology for assessing lean practices in health organization in Brazil; Tortorella *et al*. (2019b) investigated the level of implementation of lean supply chain (LSC) practices in hotel supply chains, and Shafiq and Soratana, (2020) presented the Lean Readiness Assessment Model (LRAM) to assess the readiness of a humanitarian organization for the adoption of lean manufacturing practices.

Regarding the leanness measure, Singh, Garg and Sharma (2010) developed a method to measure leanness in the automobile component industry, Ray *et al.* (2006) sought to develop a methodology for quantitative and objective assessment of the leanness of any wood products operation using the factor analysis technique considering ten variables, Bayou and Korvin (2008) presented the systematic measure of leanness from the selection of just-in-time (JIT), Kaizen and quality control as lean attributes, Vinodh and Chintha (2011) evaluate the leanness of an organization using the multi-grade fuzzy approach, developing a leanness measurement model incorporated with the proposed approach and Vinodh, Prakash and Selvan (2011) presented a study in which the fuzzy association rules mining approach was used to assess an Indian organization. The attributes used are based on quantitative and qualitative decision units.

Other studies in leanness propose a unit-invariant leanness measure (WAN; CHEN, 2008) to quantify the leanness level of production systems using the concept of data envelopment analysis (DEA), while Bezuidenhout (2016) proposes a simple and universal methodology for quantifying the degree of leanness and agility at any point within a supply chain and Matawale, Datta and Mahapatra (2014) discuss leanness as a way to help companies assess their level of leanness and be able to compare with other industries that are adopting lean concepts. Matawale, Datta and Mahapatra (2015a) researched an Indian automobile sector in which the supply chain performance index was measured considering the point of view of leanness, agility, and flexibility.

Matawale, Datta and Mahapatra (2015b) provided an efficient index system for evaluating the leanness extent of the organizational supply chain, Narayanamurthy and Gurumurthy (2016) describe a leanness assessment methodology that considers interactions between lean elements to calculate systematic leanness, assisting in continuous improvement of lean implementation, Saleeshya and Veda Vyass (2017) researched the ability of a multilevel model to calculate the leanness of a system based on studies conducted in various manufacturing industries and Pakdil and Leonard (2014) developed the leanness assessment tool (LAT) using qualitative (individuals' perceptions) and quantitative (directly measurable and objective) approach to assess lean implementation.

Finally, more recent studies in leanness, such as Pakdil, Toktaş and Leonard (2018), tested the reliability and validity of the qualitative section of the Lean Assessment Tool (LAT) proposed by Pakdil and Leonard (2014) in manufacturing companies in Turkey and the USA. Rehman, Alkhatani and Umer (2018) describe the implementation of lean principles to improvise waste in a manufacturing organization in Saudi Arabia, while Yadav *et al*. (2019) discusses the concept of leanness and provides an effective assessment tool to measure leanness in small and medium-sized enterprises (SMEs) and Silvério, Trabasso and Pereira Pessôa (2020) present a method based on a lean self-assessment approach, consisting of a qualitative method of self-assessment based on lean elements that guide an index definition associated with a roadmap.

3. METHODOLOGICAL PROCEDURES

This research used a qualitative and quantitative approach to analyze the problem. This approach enables a better understanding of the research problems that each of the approaches (quantitative and qualitative) would allow separately. The combined methods make it possible to expand the understanding of research problems (MIGUEL, 2012; CRESWELL, 2009).

The proposal provided for the conduct of an exploratory case study (McCutcheon & Meredith, 1993) where the conclusions obtained through the analysis of the data were based on empirical evidence. Due to the need for greater depth in the research framework, the choice for a simple case study was justified (VOSS; TSIKRIKTSIS; FROHLICH, 2002).

The case study allows dealing with complex situations in a simple way considering that a phenomenon is influenced by the context in which it is inserted (BAXTER; JACK, 2008), also, in the case of operations management and related areas, evidence demonstrates the contribution of cases in terms of building theories in new areas and by integrating applied theory in new contexts (BARRAT; CHOI; LI, 2011). The case study is suitable for analyzing processes of longitudinal change (EISENHARDT, 1989), to gain a holistic perspective as opposed to a reductionist phenomenon (GUMMESSON, 1991) and explains causal relationships that are so complex for research using surveys or experiments, that is, they describe the real context in which an event or intervention occurs (YIN, 1994).

The research framework adopted in this study occurred through the application of the AME Lean Assessment instrument. This instrument was developed by the Association for Manufacturing Excellence (AME) to provide a quick assessment of what stage a company is at with the lean journey. The assessment was based on Iwao Kobayashi's 20 key factors for improving the workplace.

The AME Lean Assessment is composed of 14 attributes using a score from 0 to 5; the attributes are (1) management support; (2) culture; (3) 5S; (4) Value Stream Mapping; (5) setup reduction; (6) total productive maintenance; (7) pull systems; (8) production flow; (9)

plant layout; (10) standard work; (11) lean product and process design; (12) accounting support for lean; (13) supply chain; (14) continuous improvement.

The use of the AME Lean Assessment instrument was applied in a company located in the Industrial Pole of Manaus, to verify the stage in which the company is in its lean journey.

The delimitation of the universe was a company of the automotive components industry located in the Industrial Pole of Manaus. The research techniques (MARCONI; LAKATOS, 2002) used in this study were: (1) indirect documentation (company documents and bibliography); (2) intensive direct observation (in loco observation and open structured interview); and (3) extensive direct observation with the application of the form (AME Lean Assessment).

The research was carried out in five moments: (1) happened an open structured interview (VERGARA, 2009) with two heads of the lean sector company based on a script, based on Guérin *et al.* (2001) for a better understanding of the company considering several economic and social aspects of the studied organization, later; (2) the documentary research was carried out to collecting data in the company's written documents and videos; (3) structured observation followed (VERGARA, 2009) in the different sectors of the organization; (4) the instrument was applied with those responsible (after observation and interviews); and (5) the data were analyzed and tabulated.

For the analysis of the quantitative data, a spreadsheet provided by the AME Lean Assessment was used where the information collected in the company was accounted for to allow an adequate characterization and understanding of how these practices occur within the company. The quantitative data obtained from the script responses were tabulated in a summary table, grouped according to the content, and stratified according to the structure of the evaluation form.

For qualitative data, discourse analysis (BARDIN, 1977) was used based on the following steps: (1) pre-analysis (systematization and establishment of interpretation indicators), (2) data exploration (coding, classification, and categorization), and (3) treatment of results, inference, and interpretation. A summary of the methodological procedures used is presented in Table 1.

Table 1: Summary of the methodological procedures

Stage	Method	Comments
Approach to the problem	Quali-quantitative	Interpretation of the opinion of the interviewees Use of productive quantitative data
Type of research	Exploratory case study	Automotive supplier company located in the Manaus Industrial Pole
Procedure	Indirect documentation Intensive direct observation Extensive direct observation	Reports, internal reports, and website
Data gathering	Single case study In loco observation = two weeks Open structured interview = 10 hours of interview Form application = two weeks	Lean manufacturing department Observation in the productive area Interviews with company managers and employees Application form with company managers and employees
Analysis of data	Content Analysis (Bardin, 1977)	Description, understanding, and explanation of research framework (lean assessment from the following steps: (1) pre-analysis, (2) data exploration, and (3) treatment of results, inference, and interpretation.

Source: Authors.

3.1 Company

The studied company operates in the automotive components industry by supplying radios and clusters to several customers (*Volkswagen, Ford, Renault, Peugeot, Fiat, GM*, among others). The company is among the three main suppliers in this segment and supplies direct to factories in Brazil. It has an average daily production capacity of six thousand products and its main production process is the electronic plate line, composed of four production lines.

It has 320 employees. The company has a department focused on lean manufacturing issues, thus organizing training, analyzing its processes, holding meetings periodically, seeking that the entire company knows, and participates in the Lean philosophy.

Within its production process, it has five SMD (Surface Mounting Device) production lines with a “U” layout, where each machine has its digital visual reader along with the respective standard procedures. In the production process, it also counts with digital PSA (monitor) which shows the total production per hour, graphs and percentages, tables for each production process, actual production with estimated production.

Among the productive indicators are:

1. FTT (First Time Through): percentage of units that complete a process and reach the quality standard without being scrapped;
2. BTS (Build to Schedule): manufactured according to the schedule, that is, to analyze the monitoring of production against the schedule carried out;
3. SCRAPY: related to safety, quality, and delivery.

4. RESULTS

The results describe the application of the AME Lean Assessment form in the studied company considering each of the 14 attributes, together with information from in loco observation and interviews.

Management support

The company has had Lean implemented since July 2017 and since then it has been improving in this thinking, it knows concepts such as kaizen and kanban and implements these concepts in the production process, presenting the periodic monitoring of production in periodic meetings. The company has a department to deal with lean manufacturing, where continuous improvement projects and other actions are managed, including the planning of training related to lean thinking.

Training and projects are done periodically by everyone in the company. The organization has a zero-defects program to encourage employees to eliminate waste. There are professionals trained in white, yellow, green, and black belts. Employees who reach the black belt level become internal training multipliers, fostering a lean culture in the company. There is the META program (Manaus Autonomous Work Team) aimed at rewards for employees in partnership with the Zero Defect Program. In 2018, more than 170 training sessions were held on the subject.

Culture

The company fosters values related to lean thinking throughout the plant. Several points of the plant have tables that pass on values, mission, goals, and other aspects related to lean manufacturing and organizational culture.

The organization has an annual training plan (PAT) for employees, including outsourced employees. Company employees are encouraged to suggest improvements across the company, not just their jobs. For this, some tablets are spread throughout the company and the suggestions go through a committee responsible for their implementation and awards.

5S

The materials, parts, and tools are organized in suitable places, identified, organized, and clean. There is the 5S trophy aimed at adopting practices, as well as the Pit Stop 5S in which a checklist is applied monthly in the company's areas.

Considering the nature of the business, the environment is extremely clean, with several air curtains throughout the production process. Both the production and the administrative part show clear signs of application of the 5S program.

Value stream mapping

Regarding the Value Stream Mapping (VSM), the company has periodically prepared and revised the value flow mapping of its processes, looking for opportunities to improve processes, in addition to eliminating waste. Value stream mapping is aligned with the company's business objectives.

Setup reduction

The setup time of equipment and processes is monitored daily. There are programs to reduce the setup, through SMED, besides, there is a checklist in the setup of the machines and training for employees on the process of reducing the setup. The company fixes identified tags with information on the critical workstation to help with the setup. Finally, specific cabinets located in the sectors assist in exchanges.

Total productive maintenance

The company is aware of total productive maintenance (TPM) and is in the process of implementing it internally. It works with corrective maintenance when necessary on the machines, but works more with preventive maintenance periodically from a maintenance plan. All employees are involved in autonomous maintenance.

Pull systems

The production planning is based on the sales forecast for the respective month considering the information passed on by each customer. From there, the company prepares the master production plan which is passed on to each of its lines, using the kanban to pull production. Several machines and equipment have signage (Andon) that helps in managing the shop floor.

The flags are spread throughout each production process of the company. Employees receive training to understand the tools (kanban and andon) and how they can make adjustments. Suppliers also receive training to support internal kaizen events. Customers, suppliers, and production work within the Kanban system as well as other lean tools.

Production flow

The production flow is defined every week by meetings on weekly production. Daily goals are defined on what and how much will be produced, aiming at monitoring production in real-time, through screens scattered on the production lines. The company monitors the production flow through flowcharts and VSMs in real-time; this information is passed on at Supply Status Board meetings. Among the productive indicators are:

1. FTT (First Time Through): percentage of units that complete a process and reach the quality standard without being scrapped;
2. BTS (Build to Schedule): manufactured according to the schedule, that is, to analyze the monitoring of production against the schedule carried out;
3. SCRAPY: related to safety, quality, and delivery.

Plant layout

The company's layout is U-shaped in its production line. Each line has visual indicators (visual management) that present the production indicators updated periodically. The productive indicators involve data on productivity, quality, costs, delivery, safety, and motivation.

Standard work

All standard work procedures are documented, passed on to each employee through internal or external training. All material flows and administrative processes are also documented. Periodic training takes place to update employees when a new version of a certain standard work procedure appears. The company is certified in its quality management system. In conclusion, the company uses FMEA (Failure Mode and Effect Analysis) to prevent failures and analyze the risks of processes, mainly by engineering and quality departments.

Lean product and process design

The organization does not carry out product development at the Manaus plant, it only assembles the products and then distributes the final product. The product development process takes place at other plants located in the United States and Mexico.

The product development process happens through the elaboration of an initial sketch by the customer, going through its conception in the USA and Mexico, and adapting to the local reality in Brazil from the department of new models (considering the production and market peculiarities).

Accounting support for lean

The company uses the concept of cost centers; however, it does not implement lean accounting concepts.

Supply Chain

The organization has more than 400 suppliers that are spread around the world. The company monitors the main vessels, which have the most critical materials, with technology that helps to locate the ship in real-time. In the case of Amazon, adequate supply planning is necessary considering that there are raw materials that take up to three months to arrive.

In supply chain management, the company uses MPAL (Material Planning and Logistic) to better manage the process. The demand for materials is based on the sales forecast, which is established month by month. The company also serves European, Asian and American customers. The main modal used is the air for the production flow.

Continuous improvement

The Zero Defect Program stands out, by encouraging employees to participate in daily activities that eliminate waste. The company is in the process of updating to industry 4.0, with four implementation projects, in addition to having a project that deals with an application to identify a problem in a product or process and the system indicates possible solutions with just one beep. The system is exclusive to the Manaus plant.

The main tools related to lean manufacturing are adopted by the organization to eliminate waste and continuously improve processes. The results are shared between sectors, through kaizen events that encourage cooperation between sectors and different hierarchical levels.

In conclusion, the company adopts DMAICR (define - measure - analyze - improve - control - replicated) where R deals with the process of replicating to other employees. The company also uses the A3 Report as a tool for improving processes.

5. DISCUSSION

RQ1. Does the company adopt consistent lean manufacturing practices within its production processes aiming at quality, cost reduction, waste elimination, lead time reduction, and safety?

Concerning management support, although the company started the lean manufacturing implementation process a short time ago, there was full support from senior management, encouraging employees to participate in lean production, aiming at improvements for the company. Top management is encouraging the training of employees in the six sigma philosophy. The results indicate alignment with the literature that emphasizes the importance of top management in lean manufacturing (HINO, 2009; ANTUNES JÚNIOR; KLIEMANN; FENSTERSEIFER, 1989; LIKER; MEIER, 2007; GHINATO, 1995).

As for culture, the company has its mission, vision, and well-defined values being disseminated to employees, in addition to having an annual training plan for its employees and third parties, training on a white, green and black belt, in addition to training on lean philosophy. The results point to a company that fosters the culture of continuous improvement (lean manufacturing and six sigma) at all levels as indicated in the literature (HOPP; SPEARMAN, 2013; HINO, 2009; ANTUNES JÚNIOR; KLIEMANN; FENSTERSEIFER, 1989; LIKER; MEIER, 2007; GHINATO, 1995).

About the implementation of 5S, the use of philosophy was observed throughout the company, not only in the production process but also in the top management. The evidence demonstrates standardization and organization in the materials and parts, during the work in process (WIP), with the final product and with the documentation in appropriate places, in addition to activities to encourage and reward the best internal solutions in line with the literature (LIKER; MEIER, 2007; HOOP; SPEARMAN, 2004)

To the value flow mapping, it was observed that it uses VSM in several processes, however, it still needs to expand to all production lines. In general, VSM is used to identify improvements in its production processes following Rother and Shook (1998).

About the reduction of Setup, time is measured for equipment and processes for the reduction of setup, in addition to having programs properly implemented to make this reduction such as "SMED" and the checklist setup, in alignment with Shingo (2000).

Concerning total productive maintenance, the company is in the implementation phase and it was observed that it still works with several corrective actions, despite having effective maintenance planning. Employees begin to become involved with TPM (LIKER; MEIER, 2007; SHINGO, 2000).

About the pull system, the results indicate a company that adopts kanban in most areas, having suppliers delivering components within the concept of just-in-time and adopting level production, takt time, and cycle time for monitoring daily production (OHNO, 1997; ALVAREZ; ANTUNES JÚNIOR, 2001; LIKER; MEIER, 2007; GHINATO, 1995).

To the production flow, the company has robust production planning and management systems that involve daily goals, production indicators, cash management, real-time production.

As for the layout of the plant, the evidence suggests that the company works with the concept of "U" cells, with indicators for each of the lines, both visual and manual of its process from the beginning to the end of the product production process (SPEARMAN; ZAZANIS, 1992; HOOP; SPEARMAN, 2004; HOPP; SPEARMAN, 2013).

As for the standard work procedure, the results indicate that the company has the procedures well organized, documented, and transmitted to each employee, with work procedures in production and administration, by the standardization presented in the literature (WOMACK; JONES; ROSS, 1992).

When it comes to lean product and process design, like many of the companies in the Industrial Pole of Manaus, the company does not carry out the product development process, these projects are done in plants in the USA and Mexico. It just adapts to the productive reality, product assembly, and distribution. This evidence demonstrates a characteristic of the PIMregarding product design, different from that highlighted in Womack, Jones and Ross (1992).

Regarding the supply chain, the findings point to adequate supply chain management considering the number of suppliers (more than 400) around the world and using technology to monitor the most critical materials and logistics to apply the concepts of just-in-time in production, avoiding production losses, according to Schonberger (1982) and Womack, Jones and Ross (1992).

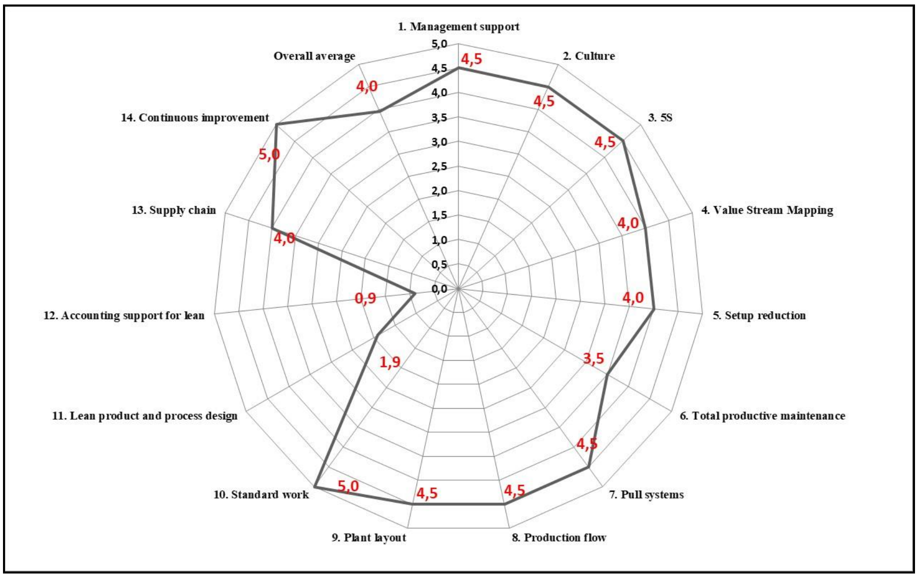
That said, in continuous improvement, the evidence points to a company with a philosophy for constant improvement of its processes, elimination of waste, and quality production. Investing in actions aimed at industry 4.0, having four projects in execution, and aiming at quality production, cost reduction, waste elimination, reduction of lead time, and safety, in alignment with Womack, Jones and Ross (1992), Spearman and Zazanis (1992), Hoop and Spearman (2004) and Hopp and Spearman (2013).

In conclusion, the company adopts consistent lean manufacturing practices in its production processes. It has a department that studies LM to train and qualify employees, in addition to the support of senior management and established organizational culture, focused on continuous improvement.

RQ2. Does the research framework used in the study make it possible to properly evaluate lean manufacturing practices in companies?

Concerning the result of the application of the research framework (Figure 1), the company presented an overall average of 4.0, demonstrating that it is a world-class company with LM even though it recently started its lean journey. The attributes with the greatest highlights were: standard work and continuous improvement that scored five; six other attributes (management support, culture, 5S, pull systems, production flow, and plant layout) achieved a score of 4.5; the attributes value stream mapping, setup reduction, and supply chain reached grade 4; and only lean product and process design and accounting support for lean attributes scored below two (2.0). The total productive maintenance attribute scored 3.5.

Figure 1: Result of the application of AME Lean Assessment. Source: own elaboration.



Source: Authors.

The instrument deals with 14 attributes that are within the philosophy of lean manufacturing, enabling quick analysis of the company that seeks to assess its stage of evolution in the lean walk. In this way, the instrument achieves its purpose of providing a short-term assessment of your lean journey.

Also, the research was complemented with an open structured interview, structured observation, content analysis, and documentary research. This diversity of sources of information provides the scientific reliability necessary for this case study. All the research techniques used indicate an in-depth case contributing to the literature by deepening the observations in the real context about the application of lean philosophy in a company.

The research framework deals with a quantitative diagnosis in proximity to the work of Doolen and Hacker (2005), Singh and Sharma (2010), Vinodh and Chintha (2011), and Pakdil and Leonard (2014), with the adoption of its evaluation methodology, in agreement with Karlsson and Ahlstrom (1996), Goodson (2002), Kumar and Thomas (2002), Al-Najem, Dhakal and Bennett (2013), Thanki and Thakkar (2018) and Shafiq and Soratana (2020); and acting on a tactical and operational level, similarly to Soriano-Meier and Forrester (2002), Shah and Ward (2003; 2007), Narayanamurthy and Gurumurthy (2016), Hussain, Al-Aomar and Melhem (2019), Tortorella *et al*. (2019a; 2019b).

In conclusion, the research framework made it possible to evaluate lean manufacturing practices in the company by bringing a quick environmental analysis of the status of its lean journey. When associated with other research techniques (open structured interview, structured observation, content analysis, and documentary research) it provided a more comprehensive and deeper understanding of the phenomenon within the company studied. The internal validity of the case study is confirmed by the systematic comparison of the literature about the research framework, while the reliability of the study is justified by the preparation of the database that was organized, integrated, and synthesized of the information obtained from different sources of evidence. resulting from the various research techniques employed (VILLARREAL, 2017; VILLARREAL; CALVO, 2015; VILLARREAL; LANDETTA, 2010).

6. CONCLUSION

This study aimed to evaluate the lean manufacturing practices used in a company in the Industrial Pole of Manaus considering 14 attributes about lean philosophy. The methodology used made it possible to verify the adoption of LM practices in the company, in addition to testing whether the research framework enabled an adequate assessment when compared to the literature and its practicality.

The findings point to a high level of LM practices adopted by the company, classifying it as an organization on a high journey. It was observed that all the fundamental concepts of TPS are employed on a large scale in the company and the methodology adopted in the case study provided the internal validity and reliability required for the research. The findings increased the knowledge of organizational behavior related to LM.

The research framework proved to be adequate for evaluating LM practices considering the 14 main points related to the theme. However, when it was complemented with other research techniques, the amount of information generated about the current status of the company increased.

Concerning theoretical implications, the research contributes to the body of knowledge about lean manufacturing considering its application in the Amazonian context (Industrial Pole of Manaus).

The findings of this research are added to previous research corroborating the existing literature and demonstrating its application in practice. The study made a substantial contribution to the understanding of lean manufacturing in the context of an important industrial park in Brazil.

As for research and social implications, the study contributes to the search for a holistic view of the phenomenon studied in order to capture the understanding of a reality based on the perceptions of local agents (managers and employees). This type of study makes it possible to carry out multiple interpretations of an organizational reality. In the case of this study, a reality was presented.

As for the managerial implications, the study may serve as a basis for the implementation or improvement of lean manufacturing by managers, as well as the results draw attention to productive improvement efforts in the company. The study contributes to the search for a holistic view of the phenomenon studied in order to capture the understanding of a reality based on the perceptions of local agents (managers and employees). This type of study makes it possible to carry out multiple interpretations of an organizational reality. In the case of this study, a reality was presented.

Finally, the results of this research can be compared with similar studies in other industries, Brazilian states, and countries to determine which concepts are most successful or unsuccessful in different industries and countries.

Among the limitations of the research is the limited sample size, considering that the study took place in only one company in the automotive components sector, however, it is worth mentioning that it is an in-depth case that enabled a deep understanding of the phenomenon analyzed (lean manufacturing). For future work, the opportunity to expand or conduct similar research in the same sector or the supply chain is indicated, expanding the sample size.

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