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Implementation of the System Handled in a Production Cell: Casa Study in a Metallurgical Company

Análise da Implantação do Sistema Puxado em uma Célula de Produção: Estudo de Caso em uma Empresa Metalúrgica

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ABSTRACT

The industrial landscape has evolved from mass production to demand-driven systems in a competitive market. Companies face constant change, prompting a need for efficiency and flexibility in operations. The Toyota production system, developed in the 1950s, emphasizes waste reduction and pull-based production. This article explores how the Toyota system is applied in a metallurgical company to reduce waste and improve processes through Kaizen. The general objective of this article is to analyze the pulled production system and its contribution to reducing inventories in the production process in a metallurgical company. This study was operationalized through a qualitative analysis, with the aid of the case study research method within a metallurgical production context. The study participants are a specific sector of the company and data collection involves documentary analysis and secondary data. Data analysis includes content analysis, focusing on reducing lead time and inventories in the production process. Through the implementation of the pull system and the value flow, the production process was optimized, reducing stocks, facilitating quality control, and allowing the rapid identification of anomalies. The development of a future state flow map showed how Toyota Production System tools, such as 5S, visual management and Kanban, can be applied to promote continuous improvement in the manufacturing process. The implementation of the pull system in the sector brought improvements such as production on customer demand, reduced and qualified stocks, ensuring timely deliveries in line with the philosophy of the Toyota Production System, which prioritizes production according to the customer's needs.

Keywords: Toyota System. Value Stream. Lean Production.

RESUMO

O cenário industrial evoluiu da produção em massa para sistemas orientados pela procura em um mercado competitivo. As empresas enfrentam mudanças constantes, o que gera uma necessidade de eficiência e flexibilidade nas operações. O Sistema Toyota de Produção, desenvolvido na década de 1950, enfatiza a redução de desperdícios e a produção puxada. Este artigo explora como o sistema Toyota é aplicado em uma empresa metalúrgica para reduzir desperdícios e melhorar processos através do Kaizen. O objetivo geral deste artigo é analisar o sistema de produção puxado e sua contribuição para a redução de estoques no processo produtivo em uma empresa metalúrgica. Este estudo foi operacionalizado por meio de uma análise qualitativa, com auxílio do método de pesquisa do estudo de caso dentro de um contexto de produção metalúrgica. O participante do estudo é um setor específico da empresa e a coleta de dados envolve análise documental e dados secundários. A análise de dados inclui análise de conteúdo, com foco na redução de lead time e estoques no processo produtivo. Através da implementação do sistema puxado e do fluxo de valor, o processo produtivo foi otimizado, reduzindo estoques, facilitando o controle de qualidade e permitindo a identificação rápida de anomalias. A elaboração de um mapa de fluxo do estado futuro mostrou como as ferramentas do Sistema Toyota de Produção, como 5S, gestão visual e Kanban podem ser aplicadas para promover a melhoria contínua no processo fabril. A implementação do sistema puxado no setor trouxe melhorias, como produção sob demanda do cliente, estoques reduzidos e qualificados, assegurando entregas oportunas em consonância com a filosofia do Sistema Toyota de Produção, que prioriza a produção conforme a necessidade do cliente.

Palavras-chave: Sistema Toyota. Fluxo de Valor. Produção Enxuta.

1 INTRODUCTION

Since the beginning of the industrial era, the market has been undergoing constant changes, having evolved from a system of mass production to modern production systems on demand, in an increasingly aggressive and competitive scenario. The industry has been experiencing, for some time, a process of revolution in the parameters that define the environment in which it runs (Zambon, Cecchini, Egidi, Saporito, & Colantoni, 2019).

In the current context, the new form of competition supplies an increasingly turbulent environment. The intensification of competition gives rise to a “competitive pressure” that motivated companies to direct their forces towards the search for more efficiency in their operations and management processes. Companies need to compete in several dimensions, such as costs, quality, time, flexibility and innovation. Since then, companies have discovered the need to implement, in a continuous and systematic way, increasingly flexible and integrated production systems, aiming to meet the needs posed by the market in the contemporary competitive environment (Millstein & Martinich, 2014). In this environment, changes are constant and compel companies to become flexible and promptly return to market responses.

The Toyota production system originated in the 1950s in Japan, with Mr. Taiichi Ohno as its precursor. Its premise was to increase productivity by continuously improving processes by reducing or cutting waste. This multi-step production system, characteristic of many production systems, contemplates the methods of pushing and pulling, the former, widely used by industries, is called as the planned quantity of production, decided by demand forecasts and available stocks (Yamamoto, Milstead, & LIoyd, 2019). In this method, production is carried out according to demand and stock, and the entire process is carried out in a sequential and orderly manner. When a pushed production system is used, inventories suffer a very significant increase and with fixed assets stopped, problems appear, and individual efficiencies create an illusion of control.

In the pulled system, on the other hand, the final process removes the necessary quantities from the previous process at a given time, and this procedure is repeated in the reverse order, passing through all previous processes (Yamamoto et al., 2019). In a pulled production system, a programming logic is created, that is, when it is not possible to cut stocks through a continuous flow of parts, supermarkets must be created with controlled volumes of materials, which serve as points of information generation. previous processes.

Therefore, based on the Toyota production system (TPS), and its contribution to the production process, which promotes the reduction of inventories and reduces waste in the production process, with the analysis of the value flow map (VSM) , this article was developed through an analysis of the production system pulled in a production cell of a metallurgical company, in order to combine the concepts seen in theory with the effective operation in the pulled system present in the company sector, to promote improvement ideas for a future state map by performing Kaizen.

In this case, the general objective of this article is to analyze the pulled production system and its contribution to reducing inventories in the production process in a metallurgical company, based on the following specific objectives: (i) implementing improvements to improve the results of the production system ; (ii) present the results obtained after the first improvement in the value flow; and (iii) relate the benefits obtained by the company by comparing them from the perspective of the pull system.

2 THEORETICAL FRAMEWORK

In this section, the following topics will be covered that relate to the analysis of the implementation of the pull system in a metallurgy production cell, namely: Toyota Production System (TPS), Value Stream Map, basic principles of Lean, Kaizen, Just in Time (JIT), Lead Time, Takt Time and stocks and types of stocks.

2.1 Toyota Production System (TPS)

Toyota Production System (TPS), Lean Production, Just in Time (JIT), Lean Manufacturing, or even Lean Production, are equivalent terms used to name the logic of managing, planning and controlling production, originally developed by Toyota Motor Company in 1945 in Japan, after the defeat of this country in the second world war. From the conceptual foundations developed by this company, other Japanese automobile industries, and later, some Western manufacturing sectors and even the North American automotive sector, over time they have evolved into a concept considered as a production system mix and work philosophy (Piccarozzi, Aquilani, & Gatti, 2018).

The problem at the time was, at the same time, how to cut costs and produce small quantities of many types of cars. The author assures that the fundamental principles of Lean Production were developed from these needs. The “lean” concept became popularly known, following the publication of the work “The Machine that Changed the World”, by Womack, Jones and Ross in 1990, where the authors popularized the usual lean production principles and practices starting from the System Toyota de Produção, which in its philosophy, aims essentially to increase production capacity through the use of fewer resources and the reduction of waste (Pereira, Bonato, Pereira Junior, Czarneski, & D'Ávila, 2019).

2.2 Value Stream Map

It is very important to have the product value flow well defined, as it allows an overview of the processes that add value, since, for a given product the value has been precisely specified, the value flow mapped, the steps that do not add value eliminated value, it is essential that the value in process flows, smoothly and continuously, within the three critical managerial tasks: problem solving, information management and physical transformation (Rahman, Mohamad, Rahman, Hamdala, Larasati, & Ito, 2020).

After identifying the value according to the first principle, mapping the product value chain and eliminating waste according to the second principle, the next step of lean thinking is to make the optimized flow of value flow harmoniously until the arrival of the product to the final customer, redefining the functions and departments, allowing them to contribute to the creation of value for the customer.

The Value Stream Map (VSM) is a procedure for finding all specific activities that occur along the value stream for a product or family of products. It is a particularly interesting tool for the continuous reduction of waste. The idea is to obtain with it a clear visualization of the manufacturing processes and some of their wastes, as well as effective analysis guidelines that aid in the project to optimize the flow and cut these wastes. The VSM is a tool capable of looking at the processes of adding value horizontally, emphasizing activities, actions and connections in the sense of creating value and making it flow from suppliers to final customers (Rahman et al., 2020).

The information flow is the movement of information from customers' requirements to the points where the information is needed to guide each stage of the process. Companies based on the principles of mass production usually have parallel information flow: forecasts, schedules, delivery orders, etc. In general, these are sent at each stage of the process. The concept of lean production also aims to simplify the flow of information, looking to set up unique points of programming for production and define loops pulled from information.

The material flow is the physical movement of items along the complete value flow. In mass production, products range from large batches to centralized processes, through pushed programming. The use of VSM, must be made from the drawing of the current state, which is obtained from the collection of information on the shop floor, for each family of products. Based on the information contained in the current VSM, a drawing of the future state is developed. However, the design of the current and future state does not occur in a completely separate and sequential manner. Finally, a work plan must be drawn up and its consequent implementation results in the achievement of the projected future situation (Huang, Kim, Sadri, Dowey, & Dargusch, 2019).

2.3 *Kaizen*

The main key to the success of Japanese production methods is called Kaizen (continuous improvement). The Japanese production system is designed to encourage constant change and improvement as part of daily operations. To achieve Kaizen, management uses the collective experience of all its employees and values joint problem solving. The involvement of everyone, including managers and workers, is fundamental for the Kaizen concept to work. There is always something to improve, whether at work or in any other activity (Rossini, Audino, Costa, Cifone, Kundu, & Portioli-Staudacher, 2019).

Lean production appeared as a manufacturing system whose focus is to improve processes and procedures through continuous waste reduction, such as: excess inventory between workstations, as well as long waiting times.

All of the above objectives were established in order to expand a company's production capacity so that it can compete in this globalized scenario. The goals set by lean production in relation to the various production problems are: zero defects; zero preparation time (setup); zero stock; zero movement; break zero-unit lot (one piece) and zero lead time (Yamamoto et al., 2019).

2.4 *Just in Time* (JIT)

One of the most important concepts of lean production is known by the name Just in Time (JIT). Supplying products to a production line, warehouse, or customer, only when they are needed, is the idea of just in time. JIT is helpful when there is certainty of needs and demands, replacement times, small and known, products of great unitary value and which require a high level of control (Duran & Mertol, 2020)

For the Japanese, JIT means "at the right time", "opportune". In English it means “in time”, that is, “not exactly at the established moment, but a little earlier, with a certain amount of time”. In the Toyota System, production is based on zero stock, so it is equivalent to say that the processes must be replenished with the right items, in the right quantity and at the right time, according to the concept of just in time. Basically, producing goods and services at exactly the right time, not before, so that it does not become stock, and not after, so that there is no waiting on the part of customers, is the concept of JIT (Duran & Mertol, 2020).

2.5 *Lead Time*

The time taken to transform raw materials into finished products is called Lead Time and is related to the flexibility of the production system in meeting a customer's request. So, the shorter the time taken to transform raw materials into finished products, the lower the costs of the production system with regard to customer needs (Dhiravidamani, Ramkumar, Ponnambalam, & Subramanian, 2018).

The lead time basically has five elements: (i) time in the queue - time that the job remains in the work center before starting the operation; (ii) preparation time - time to organize the work center for the operation; (iii) operating time - time required to operate the order; (iv) waiting time - the amount of time that work is kept at the work center, until it is taken to the next work center; and (iv) transportation time: transportation time between work centers (Dhiravidamani et al., 2018).

2.6 *Takt Time*

The “takt time” is defined based on market demand and the time available for production. It is the production pace necessary to meet demand. Mathematically, it results from the ratio between the time available for production and the number of units to be produced. The takt time is the production pace of a part or product in a line or cell (Millstein & Martinich, 2014).

The takt team shows when a certain product should be made. Through the takt team you can see the situation in which the production is. In other words, if a product has a one-minute takt time and it is being produced in two, it will be easy to notice that there is a problem in the flow of that product and actions can be taken in this way. cut such a problem (Bonato, Zimmer, & Pereira Junior, 2019).

In process B, there is a continuous unitary flow, that is, a finished product must come out every determined time. This time is the takt time, much less than the delivery time of the batches from the earlier process. During assembly there are only parts that are actually in production, avoiding the accumulation of unnecessary materials throughout production.

3 RESEARCH METHOD

This chapter presents the methodological structure adopted to carry out this research. Research can be defined as a rational and systematic procedure that aims to find solutions to the proposed problems. Research is necessary when there are not enough arguments and information to solve the problems, or when the available information is dispersed. It develops in a process with several stages that range from the formulation of the problem to the presentation of the results, carefully using methods, techniques and other scientific procedures (Gil, 2018)

In this study, we chose to use the qualitative method through a case study. Qualitative research is understood as the formative evaluation of information with the purpose of improving the effectiveness of a program, and document analysis is one of the most used sources in research, as it presents data from different periods of the studied company (Roesch, Becker, & Mello, 2015). About the case study approach, it entails a thorough analysis of a singular situation, whether that of an individual or an organization, with the purpose of examining the particular circumstances surrounding it (Roesch et al., 2015).

The case study is a modality that consists of a deep and exhaustive study of one or a few aims and seeks to explore a contemporary phenomenon in its context and can be used in an exploratory and descriptive way, including these as case exploration and description. Case study is a method that contributes to the knowledge of individual, group and organizational, social phenomena. It allows researchers to learn about the holistic and significant characteristics of real-life events, such as group behavior, maturation of industries, organizational processes, among others (Yin, 2015). In this research the focus of the case study is the organizational process of production of a metallurgy.

As for the target population that characterizes the universe of this research, it consists of a sector of a metallurgical company, in which its production model is analyzed. The universe forms a group of elements (companies, products, individuals) that show the characteristics to be investigated. The sample population or simply the sample is chosen from this universe, based on representativeness criteria. In the context of the study, the target sample population corresponded to the sector that was the object of analysis (Roesch et al., 2015).

Regarding the instruments of data collection, it corresponds to a document that makes it possible to present questions and inquiries to the respondents, providing the acquisition of the answers that will contribute to the solution of the problem, it was decided to observe and collect secondary data (Roesch et al., 2015). Observation is a fundamental element for research, since it is from this that the researcher can outline steps, formulate problems, build hypotheses, define variables and collect data (Gil, 2018). Secondary data collection was also used, which consists of collecting existing data and made available by the company in reports, indexes, files and databases, through their analysis (Roesch et al., 2015).

As for the data analysis, in the present study the data are analyzed by coding the answers obtained in the interpretation of the same through their relationship with the studied theory. The treatment of the data is how it is intended to treat the data to be collected, justifying why such treatment is adequate for the purposes of the Project (Roesch et al., 2015). From the data obtained in the collection, it is intended to evaluate, explain and understand the problematic issue and meet the research objectives. It is used in the analysis of results, the content analysis that consists of extracting meaning from the text and image data and transferring them into information for the research carried out (Roesch et al., 2015).

Therefore, the method used in this research was developed in four stages. The first step was the bibliographic survey with the aim of seeking to add knowledge about the mapping of the value flow, lead time and the reduction of stocks. The second step consisted of conducting a data collection in the company of this study, using the value flow maps and the lead time with data collected in the company's system. The third step consisted of analyzing and evaluating the data collected in the data collection. The fourth step was to develop possible improvements in the production flow process to reduce the takt team's lead time and inventories in the sector. The use of the must be made from the drawing of the current state, obtained from the collection of information on the shop floor, for each family of products. Based on the information contained in the current VSM, a drawing of the future state was developed (Huang et al., 2019).

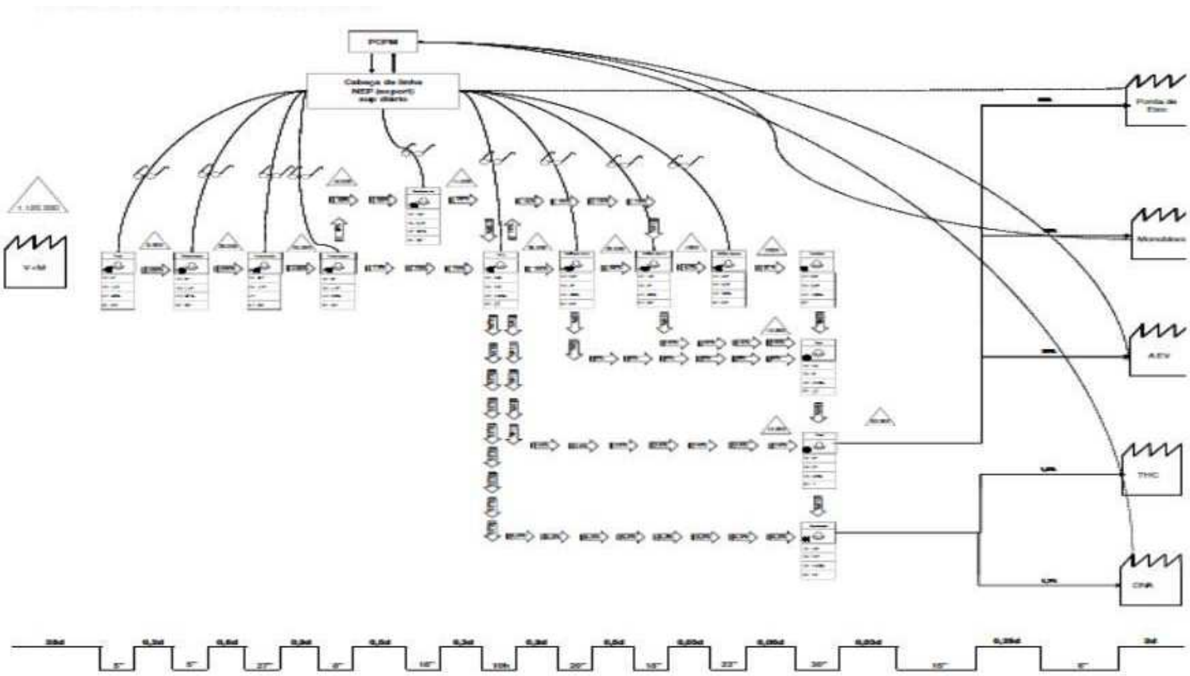
4 ANALYSIS AND DISCUSSION OF RESULTS

From the data obtained in the collection, it is intended to assess, explain and understand the problematic issue in this chapter, meeting the research objectives.

4.1 Implementation of Improvements with the system pulled in the company (pull system)

The process is the flow of materials or products that are at different stages in the production process, which can be observed through the gradual transformation of raw materials into finished products. In this chapter we see the transformation process of the production system pushed into the pulled system with the mapping of the old and current production process of the company sector under the vision of the pulled system philosophy together with Lean Enterprise. The presentation of the results analysis aims to meet the specific goals of the work, supported by the theoretical framework seen. Figure 1 presents the map of the past state of the company's sector.

Figure 1. Map of the past state - Pushed System Flowchart



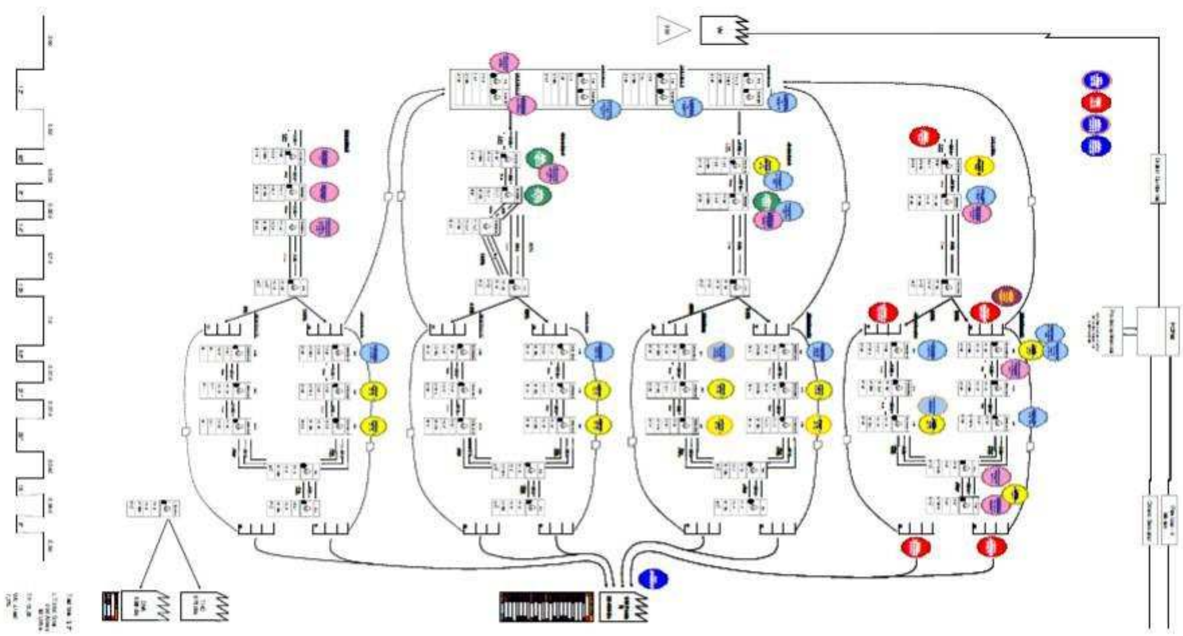
Source: provided by the company.

The map in figure 1 shows a pushed system, based on the secondary data presented on the map, it was possible to consult and verify that the pushed system has several programming points in the sector. The information comes from the PCPM, which sends the production orders so that the cell-to-cell programming can be carried out without establishing the maximum and minimum stock within the process. This process, in addition to being time consuming, has a greater chance of errors in programming.

The objective of the pushed system is to keep the cell producing at all times, producing as much as possible, in this process there is no inventory control and the lead time is high, the space to store the finished parts is large and without inventory control, without visual management, and production controls are made through spreadsheets with manual counting of stored items. It is easy to see very high stocks between production operations, with several stock points within the cells increasing the takt time.

With the development of an action plan for a pulled system, a map of the future state was created in which the aim is to reduce lead time, takt time and reduce inventories. Figure 2 presents the map of the future state of the company's sector.

Figure 2. Map of the future state - Flow Chart of the Pulled System



Source: provided by the company.

After checking the flowchart of the system pulled from figure 2 shown above, and currently used by the company sector, the use of a single programming point was verified, thus cutting the various other programming points of the pushed system used in the past. This change in the production system tends to ease and make the production process more efficient.

The data in table 1 shows the numbers of the system pushed, system pulled and the current one after the improvements implemented.

Table 1. Data comparation

Data	Pushed	Pulled	Current
Lead time (days)	4,5	2,7	2
Takt time (hours)	2	50	40
Unfinished stock (pieces)	300.000	185.000	165.000
Finished stock (pieces)	175.000	135.000	110.000

Source: Data research (2023).

Table 1 shows the data collected from the system pushed in the sector of the study company with a lead time of approximately 4.5 days, the takt time of approximately 2 hours and a stock of approximately 300 thousand unfinished pieces and 175 thousand finished and the data raised after implantation of the pulled system in the sector of the study company with a lead time of approximately 2.7 days, the takt time of approximately 50 minutes and a stock of approximately 185 thousand unfinished pieces and 135 thousand finished.

After the improvements in the current pull system implemented in the company's sector of the case study, the lead time was approximately 2 days, the takt time approximately 40 minutes ago and the stock approximately 165 thousand unfinished pieces and 110 thousand finished. The finished parts supermarket has become the programming point of the sector's production cell, being the system's puller, that is, from the moment the customer consumes parts from the supermarket automatically, the system triggers the so-called production process in the “full box x empty box” cell. In the cycle map of the part in the pulled system developed for the production cell, there is the study in which it is called “full box x empty box”, in which there are the three cycles within the production process pulled into this cell, with specific inventory points and only one scheduling point.

In the map of the value flow in the sector of the study company there is the representation of the inventory points within the sector of the company, which are monitored by the supervisor in a quick walk in which he can observe the maximum and minimum points within the production process of the sector, having an overview of the value flow, team and stock.

4.2 Improvements saw after implantation of the pulled system.

This topic presents the advantages of reduced lead time and the system pulled for the company where the study was conducted.

The first aspect addressed refers to the lead time, which consists of the time it takes to transform raw materials into finished products. In the case of the company in question, in the cage sector, the lead time is approximately two days, considering the start when the raw material starts the production process on the first machine in the cage sector until it is finished on the last machine in the process, packaged and sent to the supermarket for ready-made parts.

This process forms the following steps: the lead time in the study sector is estimated on the average time of the machine cycles, the heat treatment time and the necessary movements, so that the part goes through the entire process from the beginning (material until finished product. This lead time can be reduced, through improvements in the process. These types of changes could bring numerous benefits, such as greater agility in meeting customer needs, small-scale production, flexibility and ease of identification of possible losses during the production flow.

Having a reduced lead time eases the production of smaller batches and, so, a reduction in inventory costs, in addition to facilitating the identification of possible losses in the process. "Agility in reaction when necessary", that is, flexibility to produce a large mix of parts in a short period of time, according to customer demand. The reduced lead time looks to add value to the production line, through reduced costs, flexibility and agility in meeting demands.

The pulled system can be defined as production carried out according to the customer's request, therefore, when the customer wants it and in the quantity he wants. The company in the present study adopted this tool in order to add value to the business, reducing costs and increasing its competitiveness. This system has the advantage that the production is aligned according to the demand, that is, the production is carried out according to the customer's need, in contrast to the previous one that used large stock to meet the customer's need. It can be said that the production flow of the pull system is ordered, having a beginning, middle and end.

Another crucial point of the pulled system is the attendance to DSA (index that measures the delivery of the right product, in the quantity and at the right time), as simple as it may seem, this procedure requires a production line with efficiency and commitment in delivery. Working with a minimum of inventory between operations and keeping the production line organized are some of the advantages of the pull system. For the company, one of the great advantages of the pulled system is to actually produce what is needed according to demand, in addition to being an agile and flexible system in its responses with respect to variations in demands, facilitating customer service (DSA), and to facilitate parts flow and quality control in the production cell.

4.3 Main aspects for maintenance of the pulled system

As previously exposed, the pull system has numerous advantages, however, discipline and monitoring are necessary for the system to become sustainable. Among several aspects, it is pertinent to highlight people, who are extremely important for the proper functioning of the system, being necessary to receive adequate training, aligned with the new method. Culture also needs to be worked on and gave, as it is necessary for people to understand the functioning and why this system is used in the production line, thus favoring the progress of the process.

It is worth highlighting as a maintenance point of the pulled system, the periodic review of demands. This practice aims to check the reality and market variations; therefore, quarterly reviews are conducted with data provided by the Manufacturing Production Planning and Control (PCPM) department. The reliability of machines is considered a point of attention for the proper development of the system, and for that it is necessary to have employees trained to run them in order to guarantee their smooth operation.

In relation to the pulled system, production is carried out when the customer needs or "pulls". According to the Toyota philosophy, you have to produce what the customer wants, when he wants and, in the quantity, he wants (Yamamoto et al., 2019). In an ideal scenario, it would be to manufacture a single product for the customer's order, resulting in zero stock, so everything that is produced is consumed. In the company's reality, this flow is often flawed, requiring small levels of inventory, thus ensuring the necessary security to carry out production within the established deadline. It is possible to verify that the pulled system has numerous benefits for the company, among them, reduction of inventories, reduction of storage and maintenance costs, promotes organization in the production line and reduces inventory error.

5 CONCLUSIONS

With the implementation of improvements in the production system, which were the implementation of the pulled system and the value flow, it was possible to reduce inventories between operations, as well as perfect and understand the flow of the manufacturing process, which was very complicated and difficult to understand. The process started to use small production batches, easing the flow of parts and the quality control started to be sprayed in several points of the cell. If there is an anomaly in the parts, it is easy to find it, in which case, the number of defective parts is less. The flow map of the future state was drawn and it was identified where it was and where it could be reached using the tools mentioned in the Toyota production system, understanding why this system is so successful, since the mapping shows where you have to apply the 5s, visual management, Kanban and other tools that need to be added to planning, and especially, training people, making the whole flow work always in search of continuous improvement.

It is possible to affirm that the pulled system brought significant improvements to the sector, such as, production according to the customer's demand, reduction and the qualification of stocks, guaranteeing the fulfillment of deliveries whenever the customer needs, which is in line with the philosophy of Toyota production system, which produces as needed for delivery.

The study did not extend to other sectors of the analyzed company, not taking into account the changes that the introduction of lean thinking may have brought to such areas of the company.

Although it can be considered limited, as it does not offer bases for generalizations, the study supplies opportunities to get to know, in greater depth, a real and complex context, which can supply sufficient information for another future research. It is suggested as future work the application of the tools used here, as the processes can always be improved and, so, new tools may appear, which makes the study a continuous improvement cycle of importance for companies.

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1) concepção e planejamento.	X				
2) análise e interpretação dos dados.	X	X			
3) elaboração do rascunho ou na revisão crítica do conteúdo.	X	X	X		X
4) participação na aprovação da versão final do manuscrito.	X	X	X	X	X