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Application of Lean Manufacturing to Reduce Unproductive Times in a Valve Spring Inspection and Packaging Cell

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***Abstract*—*Lean Manufacturing (LM) is a philosophy that allows companies to be elevated using their tools and contribute to the improvement of sectors. Therefore, it is necessary to adopt this system in order to continuously improve it, therefore, the general objective of this research was to analyze the feasibility of implementing the lean manufacturing tool in a valve spring inspection and packaging cell. To do this, specify the following specific objective, determine a method capable of increasing production capacity through LM, in order to increase competitiveness and profitability and evaluate the time results provided by LM. An action research was carried out to understand the benefits of applying this study in an inspection and packaging cell through the use of practical activities in company X. The results show that using tools such as the Ishikawa Diagram it is possible to use the cause root of the problems, thus allowing to develop actions to solve the problems. Thus, it was possible to verify that, when discovering the problems, it can increase by about 15% in area 1 and 9% in area 2.*

I. INTRODUCTION

Globalization is a phenomenon that has occurred frequently in recent decades, with this, there has been a great expansion of the market, as well as the increase in the competitiveness of companies, which required the development of new tools and methodologies to improve production processes. In this scenario, it is worth highlighting the productive models, which have changed, that is, the high standardization and mass production gave rise to the production of smaller volumes and has its characteristics constantly adapted to follow the market oscillations and also the demands of consumers [1].

This was necessary because the number of companies that started to offer similar products increased, increasing the competition among them, culminating in the reduction of the prices of these materials. In this way, organizations began to modify their production flow, thus contributing to minimize waste while increasing productivity and reducing production costs [2].In this scenario, the LM emerges, which is a concept aimed at reducing waste and allowing the organization of the production management process. In addition, this philosophy aims to respond to market changes in a more flexible, fast and quality way. This increases organizational competitiveness and reduces existing waste in production activities [3].

It is worth mentioning that the increase in competitiveness among companies has made it necessary to employ systems in order to optimize production chains and an efficient way to do this is with the LM, which has been a methodology widely used in large companies due to the benefits it can bring. Therefore, this work is justified because, if applied correctly, this tool can reduce unproductive times in the inspection cell and valve packaging. This occurs, since this system relies on the principle of continuous improvement, that is, constantly improving the activities performed so that organizations remain competitive in the market

Thus, the lean manufacturing (LM)philosophy seeks to create a productive model that reduces the existing times between the order (client) and delivery (company) stages in order to meet customer expectations. However, for this methodology to be effective it is necessary that all stakeholders are committed to the process, thus allowing to achieve the projected results. Faced with this, this work sought to study a problem, which is presented in the form of a question, which is, how the LM can be applied in an inspection cell and valve spring packaging to reduce unproductive times?

To answer the question problem it was necessary to determine the objective that served as a basis to guide this work. Thus, the present study started to have as a general objective the analysis of the feasibility of implementing the LM tool in an inspection cell and valve spring packaging, in an auto parts company located in the Vale do Paraíba, in the state of São Paulo (SP).

Due to current business competitiveness, it is necessary to use a management system to improve production processes. Based on the success history of the implementation of the LM, it can be affirmed that this system brings good results when correctly applied in the inspection and packaging cell, especially in this work, which sought to reduce unproductive times.

In order to validate the relevance of the subject, research was conducted in [4] and [5] databases considering the period between 2016 and 2020, using the keywords: continuous improvement. lean manufacturing. packing. productivity increase. quality. In view of this, it is worth mentioning that the LM is considered by scholars in the literature studied a management philosophy that seeks to reduce waste while increasing productivity and quality, being this a theme of relevance at the time.

Through the [5] and [4] databases, a total of 202 publications in the [5] database and 222 documents published in the [4] portal were observed, with the combination of the words: lean manufacturing. continuous improvement. productivity increase. And few or no results when adding the keywords: inspection and packing.

[6]reveal that, through theoretical reviews, it is possible to raise the publications that surround the theme. With this, it is possible to identify what has already been written and by whom, generating a basis for the development of new works that can enrich and contribute even more to the development of this important field.

In order to have the knowledge of the number of journals published and what was written on the LM theme, the consultation was done in the [5] database. In the research conducted with the keyword lean manufacturing obtained returns of 1,957 papers published in the period between 2016 and 2020. Also in the [5] database there were 9,390 citations for the same keyword, as shown in Fig. 2 where it was also noted that there was an increase in the interest of researchers on the subject in the period between 2016 and 2020.

One of the possible explanations for this phenomenon is the fact that there is still much emphasis on the theoretical approach of the LM and its tools. Although the LM is often used in companies, most publications present a theoretical nature fortifying the reason of studying the practical nature of the LM.

II. THEORECTICAL BACKGROUND

Japan, in 1950, after being defeated in the Second World War suffered with a great crisis, and it was necessary to rebuild the country. The economy was collapsing, and most of the companies that were there had enormous financial difficulties, besides suffering to remain in the market. And it was precisely in the midst of this crisis that the Japanese TaiichiOhno and Eiji Toyoda, from Toyota, created a widely spread model that is the Toyota production system [7].

This productive model created by Toyoda and Ohno occurred after these professionals visited the United States, where they came into direct contact with the Ford model. They observed that the Ford model was efficient, however, it had a big problem, which was the enormous waste of resources.

This productive model created by Toyoda and Ohno occurred after the visit of these professionals to the United States, where they came into direct contact with the Ford model. They observed that the Ford model was efficient, however, it had a big problem, which was the huge waste of resources. With this, the basis emerged for the creation of the toyota production system, which adopted quality manufacturing and waste reduction as its guiding principles [8].

With the reduction of waste, the aim was to minimize all activities that added or did not add value to the item produced, while manufacturing with quality was aimed at producing goods free of defects. The creators of the method also stated that there was another key point for the previous characteristics to be met, which was the involvement of the collaborators, that is, without the participation of these subjects, it would not be possible to achieve the projected results [9].

Shortly after its creation, the Toyota production model began to be used in most Japanese industries. It can be mentioned that the export of Japanese products has made several entrepreneurs around the world show interest in this production system, with this, the toyota method has become popular in Europe and the United States, allowing to obtain items with quality and competitive prices [10].

In view of this, it can be mentioned that after the creation of this model the Toyota company became a reference when the subject is excellence in automobile manufacturing. The company currently has about ten factories around the world and more than thirty thousand employees in North America alone, being one of the main automakers in the world [11].

It is also important to mention that there has been an evolution of the toyota production system, which has culminated in several designations from the improvement of this model. Among these systems one can mention justin - in - time (JIT) (lean/pull production) and the LM that is the focus of this work. It is worth mentioning that initially the LM philosophy appeared, only after some time, with several modifications and evolutions, is that the LM nomenclature appeared, which is a system related to the use of quality, production and management systems that aim to add value to products and eliminate waste [9].

2.1 Lean Manufacturing

The LM is an innovative theory as far as management practices are concerned, since actions are developed that seek to gradually eliminate all sources of waste in the productive system. To this end, several procedures and simple approaches are carried out in order to make the processes perfect, having as guiding principles continuous improvement and constant satisfaction of all those involved in the process. It is important to highlight that in this case time is used as a strategic tool in the processes [3].

Therefore, it is worth pointing out that the LM philosophy aims to create a production without waste and clean, in order to minimize the time between the moment the client places the order and its delivery to the consumer. For this to occur, it is essential to create processes that ensure the quality, flexibility and speed of production flow. Thus, you can mention that this system consists of the integration of tools, operational techniques and principles that have as main objective to ensure perfection in the process of creating value for consumers [12].

In this scenario, it is worth mentioning that the LM philosophy was based on the toyota production system, so it inherited from this model characteristics such as flexibility. Flexibility refers to the ability of organizations to produce their items in small batches in order to meet the demands and market responses from the wide variation of this environment [2].

Thus, the LM consists of a lean production system, which aims to produce on a smaller scale when compared to traditional mass production systems. The reduction in production results in the elimination of existing waste in the production chain, which also allows increasing the efficiency and productivity of the production flow [1].

2.1.1 Benefits of using lean manufacturing

The implementation of the LM generates significant benefits for organizations, including better use of physical space, improved quality management, cost minimization, increased efficiency and waste reduction [13]. There are claims that some organizations that have implemented the LM use different performance measures to evaluate gain after LM implementation. Usually these new measures are not financial, but are useful to generate future financial results [14].

2.2 Seven Lean Manufacturing Wastes

According to [15], companies that adopt the LM philosophy have as their main focus to eliminate the seven existing wastes in the production flow. These wastes are divided into two distinct classes, the hidden and the visible. The hidden wastes are those that are not perceptible, so it is necessary to discover them and eliminate them to avoid their expansion in the process, which can result in several problems for organizations, among which we can highlight:

a) Equipment failures;

b) The execution of unnecessary procedures and activities;

c) Extra costs in deliveries.

For [16], as far as visible waste is concerned, it is worth mentioning that these are those that are easily observed by the team. Thus, it is necessary for the company to develop and stimulate methods to eliminate these problems, which can be:

a) The wastes;

b) The rework;

c) The defects.

For [17], it can be highlighted that waste is an element that integrates the entire production flow and can be observed in several ways, among the most common:

a) The movement of people, equipment and products;

b) The documents;

c) The infrastructures;

d) The utilities;

e) The stocks.

According to [18], waste consists of any activity performed by human beings that results in the absorption of resources without generating added value for the company. [7] and[19] classify waste in seven categories [20] that can be seen in Fig. 1.

Fig. 1: Seven wastes.
Source: [21].

The LM seeks to combat exactly these seven wastes to have a leaner production. In view of this, these elements will be discussed below, pointing out their main impacts on organizations, especially on production flows [22].

2.2.1 Lean Manufacturing

According to [23], the waste associated with the defect is directly related to the manufacture of defective items, which results in rework, because these products need to be corrected, for example. Another problem of this waste is the resources employed in the occurrence of rework or defective products. There are several causes for this, however, the main ones are:

a) The employment of the sector;

b) The lack of clarity, on the part of the client, in the specification of a product;

c) Deficiency in control processes;

d) The hiring of disqualified labor;

e) The purchase of disqualified suppliers;

f) Incapable processes.

It is worth mentioning that producing items without rework is something related to planning and prevention and not to inspections and corrections, because it is only possible to reach these levels when planning and prevention tasks are well executed. Another point that deserves attention is that products with lower quality tend to result in dissatisfied consumers, besides elevating the costs of the company, which needs to replace the products that were defective. In this scenario, it can be highlighted that only with preventive measures and continuous improvements is it possible to minimize waste from defects [24].

2.2.2 Overproduction

For [25], the waste related to overproduction occurs when companies start producing faster than they need or when more is produced than the required demand. This problem can be caused by several issues, among which we can highlight:

a) The use of practices that stimulate incentives or targets per volume of production;

b) The adoption of accounting practices that promote stock increase;

c) The elevation of machinery and equipment capacity;

d) Unbalances in production flow;

e) Deficient production planning.

Thus, overproduction tends to generate an inconvenience for many companies today, which is the high volume of finished items in stock. Moreover, this waste promotes a distorted view of reality, because it is commonly considered that the stock of finished items is an asset of value to the organization. However, this is not true, because these components tend to be outdated, which results in inventory costs until their sale [26].

2.2.3 Waiting

According to [27], waste by waiting comes from idleness by waiting time or from human idleness. There are several causes for this type of waste, the most common of which are:

a) Delays or lack of materials;

b) Large equipment setup times;

c) The absence of equipment scheduling for the production flow;

d) Non-flexible work forces;

e) Incorrect choice of the team;

f) Unbalanced lines or processes.

These problems are most observed when the physical or human resources have to wait due to delays that occur due to lack of information, lack of availability of resources or even delays resulting from the arrival of materials. A very common example of this waste is when the right tools have to be expected to start producing an item or when the signature of a professional responsible for an activity is required to proceed with an activity [28].

2.2.4 By Transport

For [29], waste by transportation is due to unnecessary movements of equipment, tools and materials, and its main causes are:

a) The bad planning of the products route;

b) Suppliers that are located far from the productive centers;

c) The complexity in the flow of materials;

d) Equipment layouts or bad production cells;

e) Disorganized work areas.

The waste due to transportation is directly related to any resources, whether documents, materials, supplies, tools, people or equipment that are transported from one space to another without a need. In view of this, it is worth mentioning that the best way to combat this form of waste is to create a productive layout that is efficient, always aiming at reducing times between operations [30].

2.2.5 By Movement

According to [31], the waste related to movement in operations occurs when it is necessary to promote unnecessary locomotion of all workers, among the main causes of these problems, stand out:

a) The existence of an inefficient flow of materials;

b) Disorganized work cells or stocks;

c) Work instructions not understood or without standard;

d) Unorganized work environments;

e) Inadequate layouts.

This problem is commonly observed when employees need to make unnecessary movements to perform a task, for example, lowering, lifting, walking or searching, which results in the interruption of the activities performed. Therefore, a study should be made of all the movements that the workers perform in order to evaluate their necessity. When it is detected that such a movement is necessary, it is important to study it in order to make it more practical, and the best way to do this is by redesigning the layout of the productive flow or reorganizing the work environment [32].

2.2.6 Due to Over-processing

For Santos and Santos [33], waste due to excessive processing is observed in activities performed by machines or by human beings. The main causes for this type of problem are:

a) The constant changes in the process;

b) Excess quality;

c) Poor preparation of work instructions;

d) The elaboration of incorrect value analyses;

e) The lack of objectivity in the specification by the clients.

In view of this, it can be highlighted that these wastes are related to tasks that do not have the capacity to add value to the item produced. A common example of this problem is the addition of steps in the process that tend to increase the quality of the products or not add value to it, resulting in additional costs that will decrease the profitability of the company. It is important to emphasize that through a thorough analysis it is possible to identify which activities are performed in the production flow and that do not bring any value to the product and that directly impact on operational costs and productivity [34].

2.2.7 By Stock

According to [35], stock-related waste occurs due to the large volume of inputs, raw materials or end products in the company. One of the main causes of this problem can be highlighted:

a) The lack of purchase patterns;

b) Lack of requisition for purchase of materials;

c) High lead time;

d) High rework rates;

e) Large lots;

f) The unbalance of production flow;

g) Excess production.

Thus, the waste in stocks is directly associated with the high volume of purchases or even storage of materials, inputs or any other resources. It is worth mentioning that to avoid the occurrence of this problem it is necessary to create a utilization rate that portrays the reality of consumption of each resource employed in the process, as well as the elaboration of a coherent planning [36].

2.3 Quality Tools

There are several tools that can be used in the LM to provide guidelines that help eliminate the waste that has been generated along the production flow, thus improving the activities related to this important organizational component [37]. The main quality tools that can be used in the LM are presented below.

2.3.1 Total Quality Control (TQC)

Total quality control or total quality is a concept developed by Duran, and this tool is considered to be an evolution of statistical process control (CEP). The difference between these components is that CEP seeks to solve problems related to the production flow, while total quality aims to solve all the objectives of the company in order to minimize cycles, eliminate waste and raise quality [38].

The main purpose of total quality is to ensure that the processes related to the manufacture of a product are continuously improved. This is done by seeking to act directly or indirectly to promote the reduction of impacts, as well as to anticipate any problems that may occur. This way, the quality of the processes and, consequently, of the final product is increased, resulting in the full satisfaction of final consumers. It is important to emphasize that the use of the term total is to reinforce that the total quality needs to be applied in all phases of the production flow and by all individuals related to it [39].

According to [40], Karou Ishikawa, who was an important management theorist and quality control engineer, in the 1960s created a list suggesting seven basic tools that can be embedded in TQC, both in the industrial and administrative spheres:

a) Dispersion diagrams, which are widely used in the evaluation of data on a horizontal or vertical axis, this being done in order to point out the impact of one variable on another. In this instrument, the data can be observed by a series of points, each of which presents one of the variables. With this, the position on the horizontal axis is responsible for pointing out the value of a variable while the vertical axis points out another one when there are two variables;

b) The control charts consist of a graphical model that is adopted in process monitoring. By means of this tool, it is possible to determine, in a statistical way, the control limits with the help of a middle line, a lower line and an upper line, and all the data, which are outside these limits, are treated as a special cause. It is recommended to use the control charts in order to analyze if the process is controlled, that is, without special causes;

c) Histograms, which are called frequency charts, consist of a bar chart, which is used to point out the frequency at which an item occurs. In this case, each bar acts as a class interval, while the height represents its frequency. It is worth mentioning that this tool aims to understand the behavior of a given activity, thus it acts as an important data distribution indicator;

d) The Pareto diagram consists of a graph in which it is possible to prioritize occurrences according to frequency, which helps to understand which process should be prioritized. The basis of this instrument is the rule that 80% of the consequences come from 20% of all causes, thus it is possible to observe the problems or causes of something easily and quickly. After the survey of the main observed occurrences it is possible to construct a table and its respective absolute frequency;

e) The check sheets consist of forms designed to collect and fill out the data in a concise and easy way. In this instrument, all data of items that need to be verified is recorded, thus helping to perceive the reality of the problem in an immediate way, besides allowing an instantaneous interpretation of adversities, thus contributing to reduce confusion and errors;

f) Ishikawa's diagram, also called herringbone diagram or cause and effect diagram, is a graphic structure that aims to predict and raise the causes of a problem, as well as solve its effects;

g) Flowcharts are graphical, matrix or linear representations of a given work process, and they are used to improve or illustrate the visualization of the production flow and an operational sequence.

2.3.2 Total Productive Maintenance (TPM)

It is important to mention that the total productive maintenance consists of a tool that aims to increase the useful life and performance of equipment and machines in organizations. In this way, this tool can be directly integrated to the LM, since it aims to reduce the waste that exists along the production flow. Therefore, for TPM to be applied correctly, all employees must be involved in the process, thus allowing them to acquire new assignments and responsibility in the organization [40].

For [28] this tool aims to eliminate corrective maintenance in companies, since this task brings with it a series of wastes and losses, among which we can mention:

a) Delays in fulfilling production programs;

b) Refuse;

c) Stopped equipment (which culminates in production delays and increases the company's costs).

This philosophy is based on eight work pillars, as illustrated in Fig. 2. Thus, it is worth pointing out that this division contributes to the creation of improvements in all points of the company in a matrix way, that is, even when acting on distinct issues, all are widely interconnected [34].

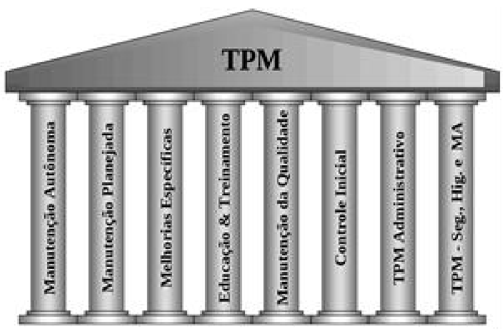

Fig.2: TPM Pillars.
Source: [41].

In this context, TPM seeks to adopt the philosophy of preventive maintenance in the organization. This type of maintenance occurs in a programmed way in machines and equipment, bringing a series of benefits to the company, among which we can mention the increase in productivity, the reduction in downtime of the production flow, the minimization of operating costs and the increase in the useful life of the equipment [10].

2.3.3 Plan, Do, Check, Action (PDCA) Tool

According to [32], the PDCA cycle is a tool created to develop and make the processes related to management execution more agile and clear. With this, this system is divided into four distinct parts, which are:

a) P = plan, which is the planning stage;

b) D = do, which is the execution stage;

c) C = check, which is the control and verification stage;

d) A = action, which refers to the development of preventive actions.

Fig. 3 illustrates the PDCA cycle.

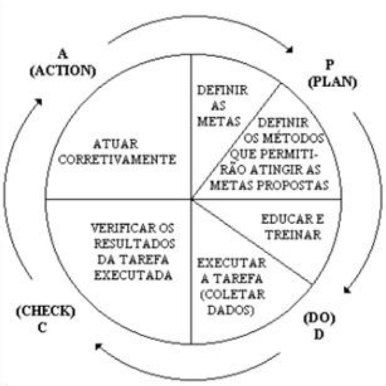

Fig. 3: PDCA cycle.
Source: [42]

PDCA starts through planning and then several actions are generated, which allows them to be executed later. After this process, the tasks performed are checked and compared if they are in accordance with what was planned and repeated several times, and tasks are performed to minimize or eliminate existing defects in processes or products [28].

2.4 LM TOOLS

There are several tools that can be used in the LM to provide guidelines that help eliminate the waste that has been generated along the production flow, thus improving the activities related to this important organizational component [37].

2.4.1 Process Maps or Value Stream

It is essential that before seeking solutions to a company's problems or measuring its performance, it is essential to understand the items it manufactures and delivers to its customers, in this way it is possible to assess whether in fact what the organization adds value to its customers. This means that it is necessary to understand if the organization has accomplished what its customers want [43].

For [44], the concept of value can be defined as the level of benefit that has been obtained due to the use of the product, that is, the perception that consumers and other stakeholders have about the fulfillment and overcoming of their expectations and needs due to the attributes and characteristics of an item. In view of this, companies need to deliver and create their values by balancing values according to the perception of their customers. It is also worth mentioning that the activities that add value to the organization are divided into two groups, the support and the main ones:

a) The support activities refer to those activities that serve as a basis or aid for the execution of the main activities;

b) The main ones consist of tasks that allow for the creation of the product, as well as its subsequent transfer to consumers.

[45]and[46], portray the Value Flow Map (VSM) as an important focus for processes providing efficient identification of where and how to improve. Fig. 4 illustrates an example of VSM.

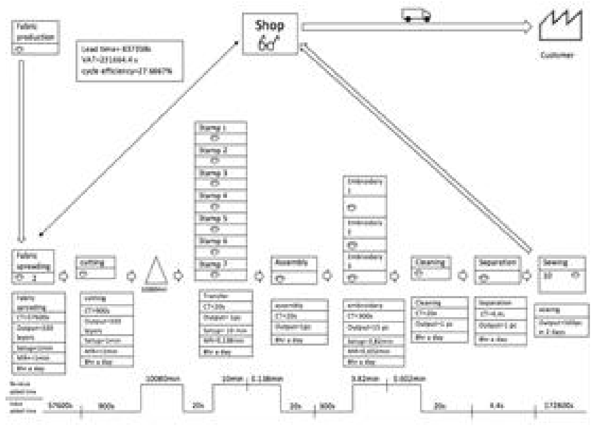

Fig.4: Value Flow Map.
Source: [46].

Observing Fig. 4 it is possible to see a value map, being that the activities present in the upper part refer to those of support and that do not integrate the productive flow, however, they act helping the accomplishment of the main activities. The activities present in the lower part of the figure are the main ones, being that they are arranged in line and their execution allows the manufacture of the good and its delivery to the consumers. In view of the above, it can be mentioned that through the mapping of a productive system it is possible to evaluate which are the tasks that tend to add value to the productive flow, as well as the process errors [47].

2.4.2 Autonomation or Jidoka

Through automation or jidoka, machine and equipment operators have the autonomy to interrupt the operation of these devices and even the production flow when an abnormality or defect is observed on the line. The principle of this tool is to work in an integrated way the decision of the human being with automation in order to avoid that the parts with defects are passed to the next stages of production. In this scenario, it can be mentioned that for such a tool to integrate the lean concept, it needs to stop performing the inspection of the process, since, this represents a waste, that is, it does not add value to the final product [40].

2.4.3 Poka-yoke

The expression poka-yoke means error-proofing, i.e., using processes that seek to reduce defects arising from errors or human failures, thereby automating or optimizing activities that are assigned to operators in order to reduce possible failures in the process. The main purpose of this tool is to serve as a base for lean production, helping in the decision making processes as well as solving problems [38].

2.4.4 Self-control

For [30] self-control in the production flow is related to activities such as prioritizing, quantifying and identifying what are the solutions to the problems observed at the time when they occur. According to the LM system, in the productive processes that count with self-control it is necessary:

a) Perform the activities without waste;

b) Perform the tasks with cleaning and organization;

c) Perform the activities correctly since the first attempt;

d) Execute the tasks safely;

e) Know how to do the activities.

In face of this, it can be mentioned that the self-control technique brings innumerable benefits to meet the expectations of the final consumer. Among these benefits are the increase in market share, the increase in profit margins, the reduction of waste, the reduction of scrap, the optimization of the work environment, the increase in productivity and the increase in satisfaction of final consumers [31].

2.4.5 Continuous Flow

The continuous flow is a tool used in the LM system, thus, it stands out that through this tool the maintenance of high stocks and the production of large lots is avoided. In this case, the flow takes place through the production of only one part at a time in order to reduce the volume of components available at a workstation [47].

With this, the lean system has as main objective to obtain products with high quality, being that for this, only the quantity of necessary components should be used. Thus, the continuous flow acts as a relevant tool for the production flow, which contributes to raise the productivity of the organization without the need to make investments [43].

2.4.6 5S

The 5S is a tool that aims to promote a cleaner work environment, that is, more pleasant, tidy, organized, clean and hygienic, and the basis of this is to change the organizational culture or the habits of employees. In view of this, it is worth pointing out that 5S serves as a support for several management systems, being this a starting point to develop several improvement and quality activities in organizations [29].

In this sense, it can be mentioned that the acronym 5S can be associated with five techniques that are used in the achievement of the stipulated objectives [31]. These techniques are illustrated in Fig. 5.

Fig. 5: 5S.
Source: [48].

Seiri or sense of use is directly related to the perception about the usefulness of available resources, as well as the separation of the useful from the non useful. Seiton or sense of ordering is the task that seeks to execute activities in the right order and put things in the right place. The Seiso or sense of cleanliness aims to remove garbage, avoid polluting and avoid dirtying the environment. Seiketsu or sense of health aims to have standard practices, values and behaviors to favor the environmental, mental and physical health of employees. Shitsuke or sense of self-discipline starts from the idea that each person has their own responsibilities, mainly their own responsibility, and this is fundamental to have adaptability with other people and the environment in a sustainable way [47].

2.4.7 Overall Equipment Efficiency (OEE)

The overall efficiency of the equipment or OEE is an indicator that can be employed at TPM. Through this tool, efforts can be directed to achieve several goals, which are to employ visual management techniques, get team employees involved in activities related to continuous improvement, make processes stable and reduce waste [49].

Thus, OEE is responsible for directly measuring the efficiencies of machines and organizational equipment in order to evaluate their performance and develop efforts to achieve the determined goals. This technique is based on three central measures: quality index, performance and availability, responsible for measuring the organization's performance in percentage [50]. Fig. 6 illustrates the OEE.

Fig. 6: OEE.
Source:[51].

Through the indicators present in the OEE it is possible to understand all the efficiency losses existing in machines and equipment. In this context, it is worth highlighting the eight losses that most impact on the efficiency of devices, which are the failures or breaks, adjustments or setups, losses related to engineering (change of tools, for example), drives, small failures, speed reduction, scrap rates and rework or shutdown. Thus, by understanding these issues it is possible to increase the performance of machines and equipment in order to eliminate waste and correct existing failures [49].

2.4.8 Process Standardization

Another tool that can be used in the LM is the process standardization, thus, this tool is used to increase the maximum performance of all the company's employees. This activity consists in documenting and registering all the manufacturing steps, as well as the work instructions in order to predict how the operations are performed, the space required to perform it, what are the parameters to be considered in the process, which machines and equipment are required and also the space required. This way, it is possible to survey which operations do not generate value to the final product, eliminating them [52].

2.4.9 Takt-time

The takt-time is obtained by dividing the daily operation time by the total quantity of parts to be manufactured daily. This parameter is closely linked to the cycle time, which is the time required for a component to be produced, that is, the time spent between the repetition of the start and end of the operation. It is worth mentioning that the cycle time is the element responsible for limiting takt-time, which is pointed out as being the bottleneck resource and not only the rhythm of the production line according to daily demand and available time [30].

It can be highlighted that takt-time is directly related to quality, since work instructions are created so that there is an instant solution for all the defects that exist in the process. If there is a repair time that is longer than the takt-time, it is necessary to remove the product from the production flow so that it can be checked or reworked in another work station so that there is no loss of time in production [35].

2.4.10 Production Leveling

As previously mentioned, the takt-time is used to determine the production rhythm, and it is responsible for determining the cycle time. However, depending on the component to be manufactured, the cycle time may exceed the takt-time, which now requires the leveling of the production flow to produce different parts, but with continuous flow [28].

This way, for the production leveling to occur in the lean system there must be intervals in the manufacturing where different items are produced in an interleaving manner and in small batches. This way, it is possible to meet the requested demand, as well as immediately meet the orders for any part that has already been produced before. In this scenario, it is worth mentioning that the production leveling is responsible for promoting the production flow flexibility and, if there are delays in the manufacturing stage, only some deliveries will be delayed, which would not be easy to achieve in large scale production systems [8].

2.4.11 Quick Changeover and Quick Setup

The setup time needs to be low in order to produce in small batches and without failures, which can also contribute to make the system more flexible and able to satisfy the needs and demands of consumers. With this, quick tool change and quick setup are tools used in the LM to optimize the production system [43].

Fast tool changes allow a considerable reduction in equipment set-up costs, as well as avoiding large stocks due to higher set-up times. In addition, with this tool it is possible to reduce the adjustment errors that may occur during setup [10].

To understand the setup method employed in companies, it is necessary to perform movement and time evaluations to understand whether the elements are external or internal, and the main objective of this is to turn the internal setup external. The internal ones are those performed only when the machine is stopped, while the external ones are executed with the equipment in operation. To achieve this, it is recommended to train the operators and standardize the parts, thus allowing a multifunctionality in operations [40].

2.4.12 Just-in-time

The just-in-time is a system employed in production management, being responsible for evaluating what needs to be transported, purchased or produced before the exact moment, that is, pointing out what needs to be in the right place and at the right time. This way, the raw material or the product arrives at its place of use only when it is required, for this, it starts from the pulled production system, which is a component responsible for developing through a demand, that is, producing only what the customer wants. Thus, with this tool it is possible to reduce the stock of materials, establish continuous improvement in processes, increase continuous efforts to solve problems and establish a continuous production flow [29].

2.4.13 Kanban

The kanban system uses plates, signs or cards, which are used in material handling processes and production, serving as a basis for controlling orders and activities in order to point out the supply or production need. The kanban tool is visual and its most used component are the cards, which act informing the production flow the need to feed a work station or produce. This methodology works based on three distinct colors, green (operating conditions), red (attention) and red (urgency) [47].

2.4.14 Kaizen

For [53], kaizen or improvement is a tool that values continuous improvement, thus increasing profitability and productivity without requiring high investments, as well as contributing to lower production costs and waste. For this tool to be successfully implemented, it is important that everyone involved in the production flow gets involved with it. This is necessary, because only these subjects are able to point out the points where there is waste, as well as ways to eliminate them. According to [54], the great theorist of kaizen philosophy, Masaaki Imai lists ten principles that should be followed in companies, while [55] mention the ten principles as the ten commandments of kaizen:

1. Waste is enemy number 1. To eliminate it you must get your hands dirty;

2. Gradual improvements made continuously; it is not a punctual break;

3. Everyone in the company has to be involved, from the top and middle managers, to the base staff; the methodology is not elitist;

4. The strategy must be cheap. The productivity increase must be done without significant investments. Astronomical sums should not be applied on technology and consulting;

5. Apply anywhere; not only for the Japanese;

6. It is based on a visual management, on a total transparency of procedures, processes and values; it makes problems and waste visible to the eyes of all;

7. Focuses attention on the place where value is really created ("genba", in Japanese);

8. It focuses on processes;

9. Gives priority to people, to humanware; believes that the main effort for improvement should come from a new mentality and people's work style (personal orientation to quality, team work, cultivation of wisdom, moral elevation, self-discipline, quality circles and practice of individual or group suggestions);

10. The essential motto of organizational learning is learning by doing.

Thus, it can be said that kaizen is a tool of continuous improvement that is guided by actions. This way, teams start to create and implement solutions and also innovate or create processes that already exist in the organization, which contributes to dispense with high investments [11]. Fig. 7 illustrates the phases involved in applying the kaizen tool.

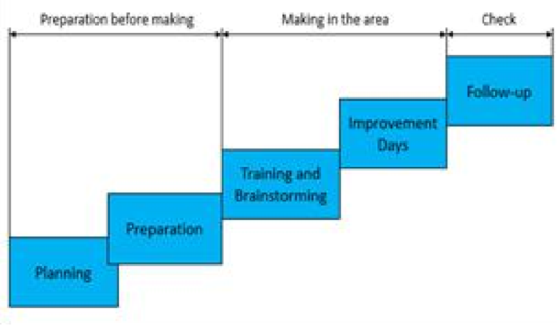

Fig. 7: Kaizen phases.
Source: [54]

2.4.15 GenbaWalk

The genba walk is a tool that has as its principle to make the employees spend more time on the factory floor instead of just in the offices. Going to the factory floor is something necessary, because it is there that the actions actually take place and, being there, the professionals start to understand in a complete and deep way the productive flow. Moreover, going into this environment allows talking to the operators who work directly with the processes, which helps to understand the problems in order to find more creative ways to solve them [47].

III. MATERIAL AND METHODS

When developing a research, one must consider in its methodological trajectory the classification of appropriate techniques for solving the investigated problem. It is necessary, then, to highlight the methods that guided the development of the study in focus, taking into consideration the nature, the objective, the approach and the procedures used in the construction of the research. Based on this thought, this chapter presents the methods selected for the execution of the project that was outlined.

3.1 Research Classification

Attending to the methodological criteria directed to the researches in the Production Engineering area, this study adopts the following types of researches: applied, as for its nature; descriptive, as for its objective; and, by the approach, qualitative, following the method of action research as illustrated in Fig. 8.

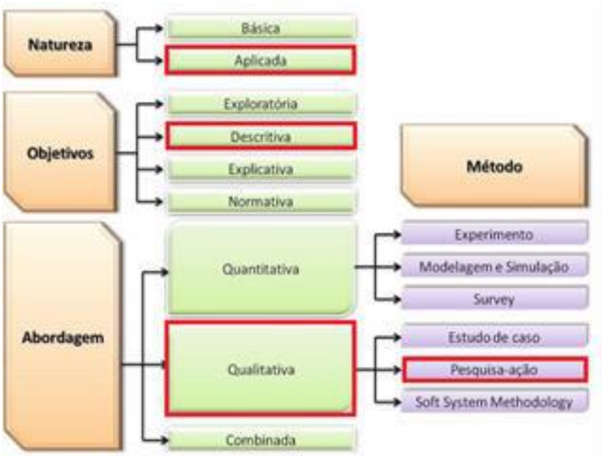

Fig. 8: Classification of scientific research in production engineering.
Source: Adapted from [56].

The software Catia V5 R19 (DassaultSystemes), AutoCad 2013 (Autodesk, Inc.) and Excel 2020 (Microsoft) will be used to perform the simulations and data analysis. To achieve the objectives defined in chapter 1, the approach to the problem followed the principles of action-research, since the procedures recommended by it contemplate the nature of the study in vogue, since it sought to generate knowledge for practical use, related to the solution of a problem identified in an auto parts factory.

It must be taken into account that practical research, as [57], "is characterized by its practical interest, that is, that the results are applied or used immediately to solve problems that occur in reality". In this context, as for the objectives, the research has a descriptive character, since from the knowledge and understanding of the premises of the LM, its tools and techniques, it was possible to use them in the proposed study.

According to [58] studies, there are several definitions about action-research, as well as several procedures for different applications. The best concept for action-research, elected by [58], is "a form of action-research that uses consecrated research techniques to inform the action that is decided to take to improve the practice".

[57]conceptualize action-research as an action or the resolution of a collective problem, and the researcher and participants in the situation or problems are involved in a cooperative or participatory manner. Therefore, this is a qualitative method that generates critical knowledge about the change presented in the system. Still according to [58], it is a variety of action-research, in which research techniques are employed, of sufficient quality to face peer criticism at the university to inform the planning and evaluation of the improvements obtained.

[58]and [57] explain that most improvement processes need this sequence: problem identification, planning, data collection, data analysis and action planning, action implementation, monitoring and evaluation of results. Fig. 9 illustrates the steps of the research-action study.

Fig. 9: Stages of research-action.
Source: Adapted from [56].

The use of the LM in this study was through the use of the seven waste concept of the LM and its techniques. It also addresses the uses of root cause analysis tools (cause and effect diagram and 5 why) and genba walk. These tools were used to analyze the process flow and to find wastes that affect its flow, create improvements and solutions to be applied to the process, implement the actions created and, finally, evaluate if improvements occurred and in what degree of satisfaction.

3.2 Data Collection

In order to achieve the proposed goals, data was collected for this survey over a period of one month, which means a production of 2,500,000 valve springs. For this, the production line was observed, which is composed by:

- Winding;
- Heat Treatment;
- Rectification;
- Muzzle;
- Blasting;
- Blocking/compression and force adjustment;
- Inspection;
- Packaging.

It is worth mentioning that the research used the procedures and instruments described below to accomplish the data collection:

3.2.1 Observation in Loco - Genba

For [59], the objective of observation is to accurately capture the inherent aspects of a phenomenon in practice. Complementing the concept, [60] inform that it consists in examining facts or phenomena that one wishes to study and not only see and hear.

To identify the problem in the inspection cell and packaging of product X, the concept of the seven wastes of the LM was applied with the objective of evaluating the actions that add value and those that do not add value during the development of the flow. The points observed in the genbaare presented in Fig. 10.

Fig. 10: The Seven Waste of the LM.
Source: Authors.

3.2.2 Interview

In order to complement the study with the seven wastes of the LM, semi-structured interviews were conducted with managers and production collaborators to discuss planning, execution, evaluation of effectiveness and monitoring/control. In this way, the researcher followed a script previously established as an instrument of information collection, having the freedom to add new questions during the dialogue.

The interviews aimed to qualify the analysis of the documentary research, since the result presented in the documents, its advances or setbacks are permeated by the human make. In this scenario, [60], affirm that the interview is a meeting of people, with the intention of obtaining information about a certain issue through a dialogue of professional nature, which in this work was to seek improvements to the waste already identified.

3.2.3 Analysis of Documentation

[59]states that "documentary research corresponds to all the information collected, whether oral, written or visualized. According to [61], the documental research carries out the examination of materials of diverse nature that have not yet received an analytical treatment, or that can be reexamined through complementary interpretations. Thus, this type of research allows the study of facts with which it would not be possible to have another form of contact, for temporal reasons or distance. With regard to documental research, the following documents have been read analytically:

a) Production notes, where productivity, scrap and eventual problems during the work shift are mentioned;

b) Production schedule, where it is informed what, when, how much and where it should be produced;

c) Fertigungsvorschrift which is the manufacturing specification defined in the product development.

3.3 Identification of the Field of Study

The study was carried out for the auto parts factory X with headquarters in Germany and branch in Brazil. It is also worth mentioning that the researcher is part of the staff, so this work was the result of a major problem observed by him in the production flow. The company was founded in 1999 and currently manufactures auto parts for the chassis line and engines with direct sales to automakers and systemists. The organization is located in the city of Taubaté, state of São Paulo, being this a privileged location, because it has access to the main highways (Dutra, Carvalho Pinto and AyrtonSenna).

The company occupies ten thousand square meters of built area and a land of forty thousand square meters of total area. The X auto parts factory has a diversified number of equipment, such as: ovens, computer numerical control (CNC) machine tools, presses, powder painting lines and special processes such as salt bath, mechanical assembly and ring and clamp setting. The factory also has a team of specialized engineers for the development of the products, for this the professionals are using development software according to the needs of the process, such as Catia, Inventor, Siemens NX, AutoCad and Solidworks.

The company's quality assurance sector is based on the certification of standards that manage the entire quality management system and coordinates with extensive experience of its technical staff the releases of products to the customer, counting on a complete set of instruments and measuring machines. Aiming at excellence in its production processes, the auto parts factory X is increasingly implementing LM projects focused on manufacturing, seeking continuous improvement and flexibility in its processes to reduce manufacturing time and product delivery to the customer while meeting the established quality requirements.

3.4 Method Choice

According to [58], action-research constitutes "a one-off approach in which the researcher takes an existing practice from somewhere else and implements it in his or her own sphere of practice to make an improvement. The use of the LM methodology with the 5Why tool is based on the fact that it is a universally accepted technique used in company transformation projects.

The 5 Why is a tool or technique that aims to reach the real root cause of a problem by asking five times the reason for an event. It is simple and can bring interesting answers that before were not perceived by the team, but the results can be even better if combined with other tools, such as the cause and effect diagram, one of the seven quality tools used for quality control management and its composition takes into account that the causes of problems can be classified into six different types of main causes that affect the processes [62,63]:

a) Method - It is a method used to perform the work or a procedure;

b) Raw material - The raw material used in the work that can be the cause of problems;

c) Labor - Hurry, imprudence or even lack of qualification of the labor can be the cause of many problems;

d) Machines - Many problems are due to machine failures. This can be caused by lack of regular maintenance or even if it is inadequately operated;

e) Measurement - Any decision made previously can alter the process and be the cause of the problem;

f) Environment - The environment can favor the occurrence of problems, it is related in this context to pollution, dust, heat, lack of space, etc.

IV. RESULTS AND DISCUSSION

Once the procedures used were defined and based on the method determined for the proposed study, research was conducted in the valve spring process. It is important to emphasize that there was a division into two stages to better meet the objectives defined, the first part being the application of the questionnaire and the second part, more practical was to visit the genba, specifically in the process of inspection and packaging of valve springs where it was identified the problem, flow and working procedures, taking time, repetitive activities that did not add value to the product and cause root, followed by a proposal to reduce activities that did not add value to the product, resulting in increased production capacity.

4.1 The Problem

Fig. 11 illustrates how the process of packing and inspection of valve springs occurred, the process was carried out without a specific standardization, in which one can observe an inadequate use of time and unnecessary movements to perform the activities.

Fig. 11: Packing and inspection.
Source: Authors.

The company counts yet with two packaging areas, which develops the packaging activity for five clients. Fig. 12 illustrates that for each client it was adopted a different packaging procedure, which made this process more complex, especially in the A2 client's work process in which it was necessary three steps before packaging the mechanical component.

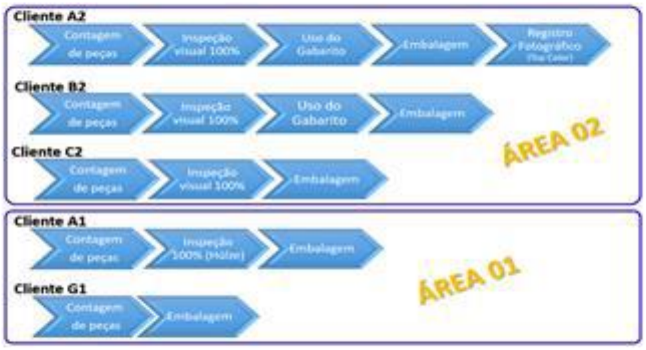

Fig. 12: Procedure performed for the various clients.
Source: Authors.

In view of this, it was chosen to apply the LM in area 2, it is worth mentioning that this process started based on the interview/questionnaire mentioned in item 3.2.2 of this study and through the use of the genba walk tool in which the researcher, who worked in the office of the company under study, walked to the factory floor and identified the problems mentioned above. As pointed out by [47], this tool allows the subjects to experience the reality of the factory floor, in addition to getting in direct contact with the employees who perform the activities. Getting in touch with these individuals is essential to solve possible problems in production.

The researcher also used the three gen's, which is the genba, which is when you visit the site to understand where the problem came from, which in this case, was the area of packaging. After that, the genbutsu was performed, that is, the product with problem was evaluated, which is the place where the activities were carried out, in which several problems were observed, among which, one can mention the excessive movements, irregular layout, among other things. Gingitsuwas also performed, which is a moment in which one seeks to understand the causes of the problems encountered. After that, it was decided to time the times of the executed activities, with that, one hundred experiments were made for each type of spring or client generating the averages presented in Fig. 13.

			Atividades e Tempos									
			Levar a caixa KLT vazia e limpa até o posto de trabalho	Encher as caixas com peças a serem inspecionadas	Levar a caixa até a bancada de inspeção	Efetuar inspeção das peças	Alinhamento das peças (SEM gabarito)	Alinhamento das peças (COM gabarito)	Depositar peças alinhadas com gabarito na embalagem final	Foto do posicionamento da Top Color	Levar caixa KLT até o palete	TOTAL
PROJETO / CLIENTE	ÁREA 2	- CLIENTE A2	30s	15s	25s	23 min	N/A	4min 47s	53s	15s	12s	30 min
		- CLIENTE B2	30s	15s	25s	23 min	N/A	4min 47s	53s	N/A	12s	30 min
		- CLIENTE C2	30s	15s	25s	28min 48s	4min	N/A	N/A	N/A	12s	34 min
	ÁREA 1	- CLIENTE A1	2s	15s	N/A	60s	N/A	N/A	N/A	N/A	10,9s	1 min 43s
		- CLIENTE G1	2s	15s	N/A	N/A	N/A	N/A	N/A	N/A	10,95	28s

Fig. 13: Average time spent in the execution of the activities.
Source: Authors.

In fact, area 2 has the longest times and activities, especially in the activity of inspecting the parts with times of 28 minutes and 48 seconds to perform this task for customer C2 and 23 minutes for A2 and B2 customers. These activities contributed to the execution time of all tasks being 34 minutes for client C2 in area 2 and 30 minutes for client A2 and B2 and, for this reason, this area became a priority in this study.

The fastest activity in this sector was to take the kleinladungsträger (KLT) box to the pallet. In area 1, the execution time of the activities was shorter, 1 minute and 43 seconds for client A1 and 28 seconds for client G1. After analyzing all the processes it was observed that some activities did not add value to the product, which increased the execution time of the processes. Among these tasks, one can mention taking the empty and clean box to the work station, filling the boxes with the parts to be inspected, taking the box to the inspection bench and taking the KLT box to the pallet, as shown in Fig. 14.

			Atividade/tempo que não agrega valor ao produto				
			Levar a caixa KLT vazia e limpa até o posto de trabalho	Encher as caixas com peças a serem inspecionadas	Levar a caixa até a bancada de inspeção	Levar caixa KLT até o palete	TOTAL
PROJETO / CLIENTE	ÁREA 2	- CLIENTE A2	30s	15s	25s	12s	1min 22 s
		- CLIENTE B2	30s	15s	25s	12s	1min 22 s
		- CLIENTE C2	30s	15s	25s	12s	1min 22 s
	ÁREA 1	- CLIENTE A1	2s	15s	N/A	10,9s	28 s
		- CLIENTE G1	2s	15s	N/A	10,95	28 s

Fig. 14: Time of activities that do not add value to the product.
Source: Authors.

The activities shown in Fig.14 consumed about 1 minute and 22 seconds in area 2 and 28 seconds in area 1. This time, at the end of the processes performed in the company were high, so it is noted that it was necessary to work to reduce and/or eliminate these tasks. Fig. 15 illustrates the spaghetti diagram of area 1, in which one can see the layout of the productive flow, as well as the activities executed by the operators.

Fig. 15: Spaghetti diagram and area layout.
Source: Authors.

Fig. 16 illustrates the spaghetti diagram of area 2, in which you can see the layout of the production flow, as well as the activities that were performed by the operators.

Fig. 16: Spaghetti diagram and Layout of area 2. Source: Authors.

Areas 1 and 2 were provisionally given the springs to be inspected in a großladungsträger (GLT) box. An equipment called "elevator" is rented in area 1, in this one the GLT box is introduced, in this way it gradually turned this box with springs into a vibratory chute, which poured them into smaller boxes, model KLT, model adopted by all customers until the present moment.

It is important to highlight that 13 minutes and 24 seconds were spent to change the content of the GLT box (about 8,000 springs) for the KLT boxes, moreover, in this interval the area 1 was stopped, because the freight elevator was stopped due to the filling of the boxes. Another point that deserves attention was that if the springs to be inspected were not in the KLT boxes, the inspection and packing time in area 2 would be longer, because the operator would have to manually fill the KLT boxes, as illustrated in Fig. 17.

Fig. 17: Manual overflow of packaging. Source: Authors.

4.2 In Searchof the Solution to the Problem

After this finding it was possible to develop the Ishikawa diagram to find out what were the main problems in the packaging area. Fig. 18 shows the constructed diagram, with this it was observed that most of the activities were related to the movement, being this the main cause (root cause) of the problem in study.

Fig. 18: Ishikawa diagram for the problem under study. Source: Authors.

After using this tool, it became clear the root cause of the problem, which was the excess of displacement/movement and activities that did not add value to the product and/or process. With this, it was determined with the company's management the goal of increasing the productivity of the sector by about 5% in order to optimize the tasks performed. After several meetings and many brainstormings it was suggested the acquisition of false bottom basket, easel, pantographic pallet, roller conveyor and readjustment of the bench and layout of area 2. Using the software Catia V5 R19 it was possible to illustrate and simulate the process as illustrated in Fig. 19.

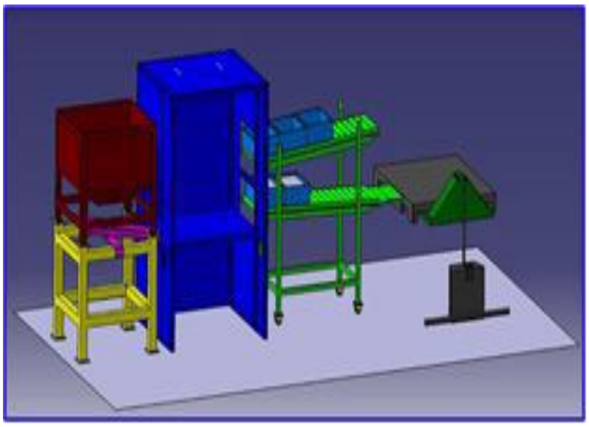

Fig. 19: Design of the new equipment and adaptation of the layout of area 2. Source: Authors.

With this change, it was expected:

a) Reduce the travel costs of the operators;

b) To keep the pallets always at the height of the collaborators' hands;

c) Reduce the physical effort, allowing the springs to be inspected to be near the operator;

d) Create a buffer of inspected parts, reduce the time spent with overflow and decrease the occupation of the elevator 1.

It is worth mentioning that the cost of these modifications was R$ 11,066.67 (in reais), because it was possible to reuse baskets and some materials already existing in the company studied, however, the productivity gains can be much higher with this improvement. Through the payback calculation it was possible to verify that this investment will be paid in 12 months, excluding the productivity gains thus obtaining the approval of the costs before the board of company X. It can be seen in Fig. 20 the new inspection and packing bench already delivered to company X.

Fig. 20: New inspection and packaging bench for line 2.
Source: Authors.

4.3 After Improvement

After receiving the new inspection bench for line 02, the need to review the layout and organization of the area was found, and 5S was used for this. As mentioned in item 2.3.7 of this study, the 5S is a tool that aims to promote a cleaner, tidier and more organized working environment. Fig. 21 shows several pallets allocated in the corridor and little space available for work on the new inspection and packaging bench, because it was using space assigned to the finished products exit area.

Fig. 21: Inspection and packaging area before the 5S.
Source: Authors.

With the application of 5S, the layout was revised, which consisted of reallocating the area of finished products to the area near the bottom wall of the shed. Changes were also made to the position of the old inspection and packaging bench in area 2, which continued in use (dedicated to special operations), reallocation of the inspection and packaging bench to the area next to the central aisle and repainting of the floor and space delimitation strips as shown in Fig. 22.

Fig. 22: Inspection and packing area after 5S improvement and revision.
Source: Authors.

After the installation of the cabin next to the central aisle several changes were observed in the execution of the activities, among which we can mention the reduction in the movement of the operator to collect parts to be inspected, the reduction in the movement to collect empty boxes, the reduction in the movement of boxes with parts inspected to the pallet. With this, the displacement of the employee started to occur every five boxes.

In area 1, after the change of the common pallet box for the pantographic pallet box it was observed that there was a gain of about 3 minutes and 29 seconds. In view of this, it can be mentioned that for the study period, which was the year 2019, 2,218 pallets were made, resulting in a gain of 116 hours after the implementation of the improvement in area 1, which is equivalent to 14.4 days of work with a journey of 8 hours. With this extra time it was possible to inspect and package about 3.12 million pieces, resulting in a productivity gain. Fig. 23 shows the pantographic pallet box in use.

It is worth mentioning that there was a (average) reduction in operator movement resulting in a gain of 170h/year, representing the possibility of increasing production by 294,099 pieces. Thus, the productivity gain in area 1 was 15%, while in area 2 was 9%, exceeding the initial estimates which were 5%.

Fig. 23: Pantographic pallet box in use in area 01. Source: Authors.

Another point that deserves attention is that the overflow time reduced from 13 minutes and 44 seconds to 2 minutes and 40 seconds after the use of the false bottom boxes. Thus, there was a reduction of time per overflow from 10 minutes and 44 seconds, in addition to the reduction of down-time from areas 1 and 2 to 106 hours per year, which allowed to produce about 153 thousand pieces more.

The LM methodology contributes in fact to the reduction of unproductive times in the companies, which in this work was the valve spring packaging sector. There are several tools that can be used to implement the LM philosophy, among which we can mention the 5S, the TPM, the just in time, the Ishikawa diagram, among others. In this work, the Ishikawa diagram was used to find out what was the root cause of the problem observed in the valve spring packaging sector in company X.

After that, it was found that the main cause of this was the unnecessary displacements of the employees, which made the subjects move without needing to. With these displacements, the times for the execution of the activities were increased, mainly the overflow, which was 13 minutes and 44 seconds. After the installation of the improvement this time was reduced to 2 minutes and 40 seconds, that is, by changing a conventional pallet for a removable bottom, a productivity gain of 10 minutes and 44 seconds was achieved.

Another improvement installed was the layout adjustment, with this, the employees started to move less, which resulted in an increase in productivity. Initially, it was estimated an expense of 22 thousand to implement the improvement, however, its final value was 11 thousand, or half of what was projected. In addition, the return or payback time for this investment was 12 months, being relatively fast due to production gains.

It can also be mentioned that initially it was projected an efficiency increase of 5% in the lines, however, at the end of the improvements this value was 15% for line 1 and 9% for line 2. Thus, with the project executed, the company started to produce about 153 thousand more pieces per year, besides and to reduce the risks for the health of the collaborators.

V. CONCLUSION

The automotive industry and other private enterprise industries are continuously seeking to increase production capacity and revenue/profit. For this, employees need to be involved and susceptible to changes and paradigm breaks with the new concepts provided by the LM. Thus, the proposed study had as main objective to make an analysis and prove the feasibility of using the LM tool in a cell of inspection and packaging of valve springs of a German company of auto parts, here called X and located in Taubaté - SP. Thus, scientific articles, specialized books and dissertations on the principles of the LM in private manufacturing processes were researched, which allowed to offer subsidies and suggest improvements that can be adapted in the packaging and inspection sectors.

The interview with the managers and other collaborators of the process together with the analysis of the documents directly in the genba allowed the identification of the waste in the process, using the principles of the LM. The following wastes were found: lack of standardization of the work routine, inadequate or underused equipment/actives, employees with excessive movements or displacements that did not add value to the product. Thus, this waste allowed the preparation of Ishikawa's diagram that showed that the excessive movement of employees was the root cause of the problem, which was broken down in detail in this work.

In the new scenario no lack of standardization of the work routine was found, the equipment/assets were readjusted and reallocated and activities that did not add value were eliminated. Thus, it is possible to conclude that the implementation of the LM tool in an inspection cell and valve spring packaging is totally feasible, showing gains in the process, since the seven wastes of the LM together with the Ishikawa diagram allowed to raise and eliminate the wastes, as evidenced by the results presented in Chapter 4, thus achieving the general objective of this work and dissemination of the LM concepts to the entire university community, scientific and other stakeholders.

The study in question had as practical implications the empirical nature of the researcher who used the experience and experience of eighteen years in company X. It is worth mentioning that another limitation of this work was the time of the research, which was relatively short, being opportune to carry it out in the company considering a longer and empirical period of time of the researcher.

It is recommended as a suggestion for future work the use of simulation/modelling software and the application of a value flow map in the valve spring sector in order to clearly identify the takt-time of each cell/sector and the actual or new 'bottleneck' of the process. It is also suggested to evaluate the impacts provided by the LM in a company that adopts this philosophy, comparing it with a company that does not.

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