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CONTRIBUTION OF LEAN MANUFACTURING CONCEPTS TO REDUCING WASTE IN DESTRUCTIVE TESTING

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ABSTRACT

This article aims to analyze the levels of waste of components used in destructive testing for releasing the assembly line of an automotive parts factory. In this way, it aims to apply an improvement that involves the reduction of the amount of parts destroyed daily, consequently reducing their monthly costs. For this, based on the case study methodology, the percentages of discard in relation to sales of all parts currently produced were surveyed, in order to identify the line that has more discarded components and, from this, to analyze the waste factors, based on the Lean Manufacturing concepts. After the waste analysis and the application of process improvement, there was a reduction in the cost of parts for destruction. The cost, which was 0.71% of the total monthly sales, became 0.19%.

1. INTRODUCTION

The manufacturing industry deals with different challenges to manage complexity in a production process due to the demand for the diversity of products offered to customers (Henao et al., 2019; Sánchez Juárez & Moreno Brid, 2016; Silva et al., 2021). The consumer has several options to select similar products. Most consumers choose based on their overall perception of quality or value. Consumers generally want the best possible return on their money. To remain competitive, companies need to identify what is important to increase consumers' perception of the value or quality of a product or service (Amat-Lefort et al., 2020; Barbosa et al., 2020; Sales et al., 2022). The past three decades have witnessed waves of different quality management approaches including Total Quality Management (TQM), Six Sigma, and Lean Manufacturing. Each approach has generated its own share of followers and opponents, sharing common values such as: customer focus, process orientation, data-driven decision making, employee involvement, continuous improvement, and committed leadership

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(Chiarini, 2020; Kebede Adem & Virdi, 2020; Shan et al., 2016; Silva et al., 2021).

The quality area of a company is becoming the focal point and one of the biggest investments that companies have made (Cardoso et al., 2022; Hadi Hashim & Oudah Sabeeh, 2021; Machado et al., 2020; Othman et al., 2020). The guiding principle is that quality must begin before manufacturing begins and capital allocations are made (Costa, et al., 2019; Sá et al., 2019; Vieira et al., 2019, Santos and Barbosa, 2006). In practice, this means that companies should start by establishing their quality goals and develop characteristic products that meet those goals (Doiro et al. 2017; Zgodavova et al., 2020; Carqueijó et al., 2022; Murat and Santos, 2022). In the same time companies should develop processes capable of delivering those products, and establish controls that allow operations to be conducted in a consistent manner that reduces waste, thereby reducing waste generation and contributing to sustainable industrial development (Alzoubi & Ahmed, 2019; Araujo et al., 2021; Reis et al., 2021).

According to the above and the contributions of Lean Manufacturing concepts, this research aimed to investigate the waste with destruction parts, analyze its main causes and implement process improvements to reduce waste and improve monthly productivity. In the investigation of waste, a production line that exceeded the target costs with destruction parts was identified, and was chosen as the target of this study.

2. THEORETICAL FRAMEWORK

It is commonly accepted that the concept of Lean Manufacturing (LM) originates from the Toyota Production System and was conceptualized after traveling from Japan to the United States. Then to Europe with the goal of improving the operational efficiency of Western companies. The basic principle of the LM is production based on the prevention of eight causes of waste. These causes are summarized as transportation, storage, process accessibility, unnecessary movement, waiting times, overproduction, tight tolerances, defects, and above all, the unused skills of employees (Fitriadi et al., 2020; Haffar et al., 2019; Rother et al., 2020; Shafiq et al., 2019). The definitions recognize that LM is a management system made up of two levels of abstraction: principles and practices. The principles represent the ideals and laws of the system, to encourage employee participation in improvement activities. The practices operationalize the principles, and they encompass a wide variety of integrated management methods, including just-in-time, quality systems, teamwork, and supplier management (Santos et al., 2014; Green et al., 2019; Marodin et al., 2015; Rose et al., 2014 Santos et al., 2017; Jimenez et al., 2019; Teixeira et al., 2021). In the integration of management systems, lean concepts are a precious help (Ribeiro et al., 2019; Rodrigues et al., 2019; Sá et al., 2022).

Kaizen is a Japanese term meaning improvement, a continuous search to make processes and products better. Its implementation aims to create non-stop effort and incremental value in business, to improve the process (by using the worker's skills), and to eliminate waste (Ma et al., 2018; Machado et al., 2020). Kaizen is a Japanese tool widely used in a variety of companies and organizations, and its basic foundation is continuous improvement. Process kaizen can be defined as improvement focused on individual processes and directed at teams and their leaders, as opposed to flow kaizen, which are improvements directed at the management (Ahmed & Idris, 2020; Comulada & Mendola, 2015; Shojaei et al., 2019).

3. RESEARCH METHOD

In this work, action research was developed because it refers to a process of change, based on the systematic collection of data, followed by the selection of an action for change, based on what the analyzed data indicates. Figure 1 below shows a flowchart of the research steps. Its importance lies in providing a scientific methodology for the management of a planned change (Kothari & Garg, 2019; Sampaio et al., 2022).

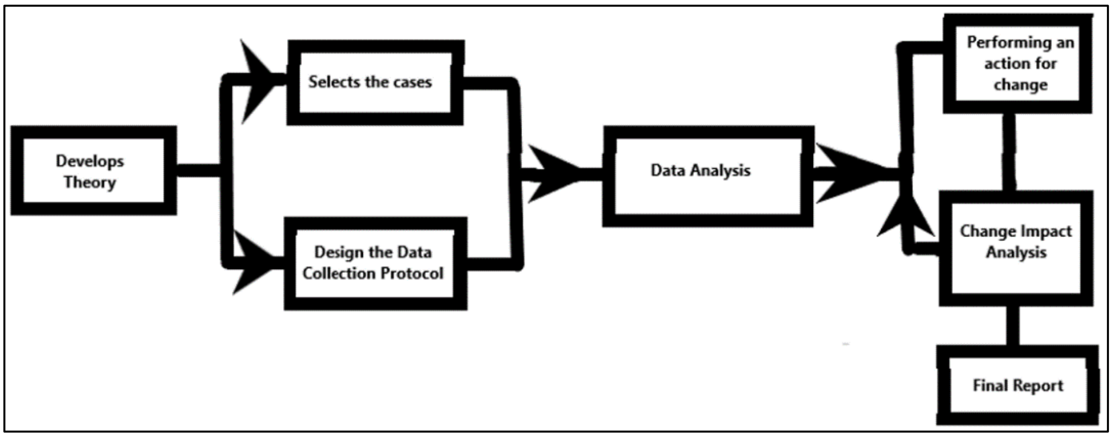

Figure 1. Methodological flow of the research

The company under study is a multinational that operates in the automotive parts industry, and supplies, in Brazil, three major automakers, and is located in the southern region of the state of Rio de Janeiro. The concepts of LM are the basis of all divisions of the company, which strives for the highest productivity and quality, using as few resources as possible, without affecting the delivery of the product to the customer. Through the data survey proposed in the following topics of the article, an in-depth study of a focus of waste in a process with no added value to the production line of the company in question was done. And, from the result of this study, a kaizen was implemented in order to achieve the company's standard goal.

The data was collected by means of a survey applied internally in the company's Production department, in order to ascertain possible waste points. The internal information system was also used to survey the costs. All the values and costs presented in the article are fictitious, in order to preserve the data and the company's image. The percentages informed throughout the work are real, and the fictitious values are proportional to their respective real values, in order not to misrepresent the result of the improvement analysis.

4. RESULTS AND DISCUSSIONS

In this section the results of the destruction test and the production process test of the part analyzed in the research will be presented.

4.1 Destruction Tests

In the company, daily, before production starts, quality tests are performed on components of the produced part to ensure that there are no defects. The tests that discard parts are called destruction tests. Although they do not add value to the product, they are indispensable for ensuring its quality. To perform the destruction test, the complete part must first be assembled on the assembly line and, after it is finished, it is taken to the quality laboratory. At the lab, the part is first placed in the equipment device that applies the necessary force to test its strength. The settings of the applied force are based on the company's internal standards and on the customer's standards. After the test is completed, the part is discarded, that is, there is no reuse of parts used in destruction tests.

However, sometimes the components discarded after the destruction tests are more expensive than the scrap generated in normal production. Therefore, the costs generated with destruction parts from all the company's production lines, in relation to the total monthly sales, were surveyed. The percentage established by the company for expenses with monthly destruction tests is up to 0.2% of the total monthly sales of a certain part. As can be seen in Figure 2 below, parts A, B and C exceeded this limit at the time of the study.

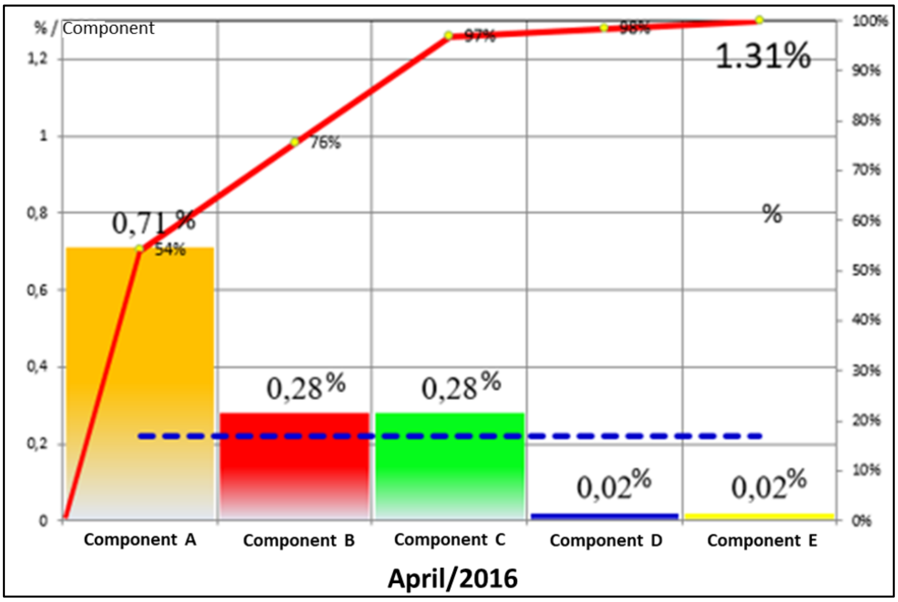

Figure 2. Percentage of destruction testing spend per part

Part A was selected for analysis and application of improvements, in order to reduce the expenses with destruction testing, due to the fact that this is the part with the highest cost among all the parts produced in the factory. Part A is composed of several components that are welded in different processes of the production line. Among them, there are three components that are checked daily in the destruction tests. These are: component F - Collar; component G - M8 nut; and component H - M12 nut. These components are welded in the production process to component A, which for this reason also needs to be destroyed on a daily basis.

4.2 Production process test of the part

Components F (collar) and G (M8 nut) are welded to component A and component C in process #03, following the layout in Figure 3. After this step, the production of the part continues its normal flow, going through the following processes, where other components are welded.

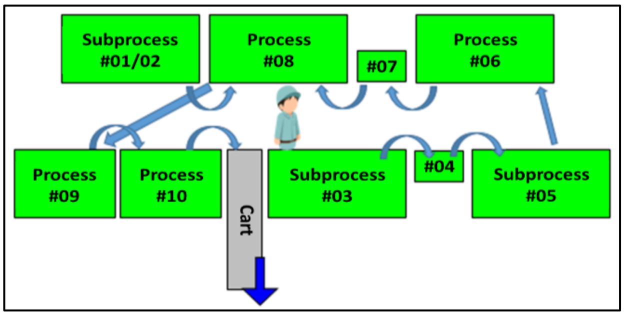

Figure 3. Layout of the production line of part A

In process #05, a component B is attached to component A, making the component collar and M8 nut housed inside, with no possibility of access by the operator at the time of the destruction test. The H component (M12 nut) is welded to the outside of the A component in process #08, which is the last welding process of this production line. Because of this, until the period before the countermeasure was applied, to perform only the destruction test of the M12 nut, a complete A-piece was required, including components that are not necessary for the destruction test.

Soon after, other components F and G were soldered to new components A and C in process #03, and this product was also taken to the destruction test. To apply the destruction test to these three components (F, G and H), a complete part A (with other components not used in the destruction test), plus new components A and C welded to other components F and G, were needed. Table 1 below summarizes the quantity of components needed to perform the destruction test before the countermeasure was applied. All the other components that were indicated in Table 1 and are left out of Table 2 now have their equivalent dummy component.

Table 1. Required number of components for destruction testing.

Component	Required quantity of components for destruction test de colar (F) e porca M8 (G)	Number of components required for nut M12 (H) destruction test
A	1	1
B	0	1
C	2	2
D	0	2
E	0	4
F	2	2
G	4	4
H	0	1

As the cost for destruction tests was too high because it included components that were destroyed unnecessarily, it was necessary to study a way to improve the process in order to use the least amount of components possible. The welding performed in each process of this production line is done via robot, which runs automatic programs. All the devices have sensors that detect the presence/absence of each component, working as poka-yoke. Once a component is missing, or out of position, the sensors do not activate and the equipment does not release the robot's movement and program. This was the reason why components were required to be welded in the manufacturing of the parts for destruction test, even though they were not actually used in the tests.

As an improvement idea, specific welding programs were created for manufacturing the parts for the destruction test. Instead of the robot program performing the welding of all components, as would be done in the standard program, this new program would weld only those components on which the destruction test is to be applied. As mentioned earlier, the robot is only released to weld after all sensors indicate the presence of all components.

Since in the new program the robots will only weld the components that are to be used in the destruction tests, it was necessary to manufacture and prepare dummy components, which are sample components manufactured in order to simulate the original components and be recognized by the sensors. In this way the dummy components, placed in the device, would trigger the sensors for the robot program to run, but would not actually be soldered and wasted. Every day these same dummy components, identified in red and with labels, would be used to release the machine to make parts for destruction. Table 2 below summarizes the total amount of components needed after creating the specific welding program for destruction test and using the dummy components.

Table 2. Required number of components for destruction testing after countermeasure.

Component	Required quantity of components for destruction test after countermeasure applied
A	1
B	0
C	0
D	0
E	0
F	2
G	4
H	1

The cost for destruction parts before the improvement was 0.71% in relation to the total parts sales in a month, i.e., if the total parts sales were $100,000 per month, there would be a cost of $710 for destruction testing. As mentioned earlier, the goal was to achieve 0.2% spending on parts for destruction testing in relation to total monthly sales, as shown in Table 3.

Table 3. Cost Reference.

Monthly Sales Value	R$ 100.000,00
Monthly Cost with Destruction Test (Before Countermeasure)	R$ 710,00
Target Monthly Cost with Destruction Test	R$ 200,00 (0.2% of Total Sales).

Data was collected before and after the application of the improvement and, from them, graphics were generated to confirm the effectiveness of the proposed actions. Taking into consideration the fictitious cost with parts used in destruction tests before the countermeasure, there was a monthly expense of R$710.00. Figure 4 below shows the percentage of use of each component after the countermeasure.

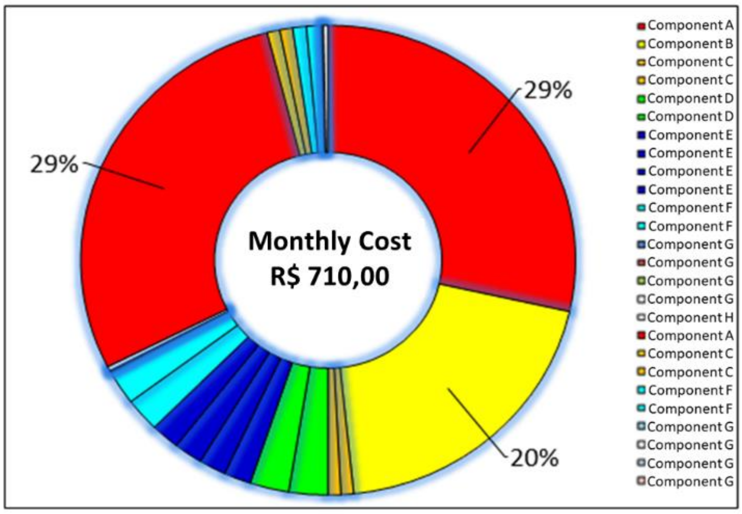

Figure 4. Percentage of each component in the monthly cost after countermeasure.

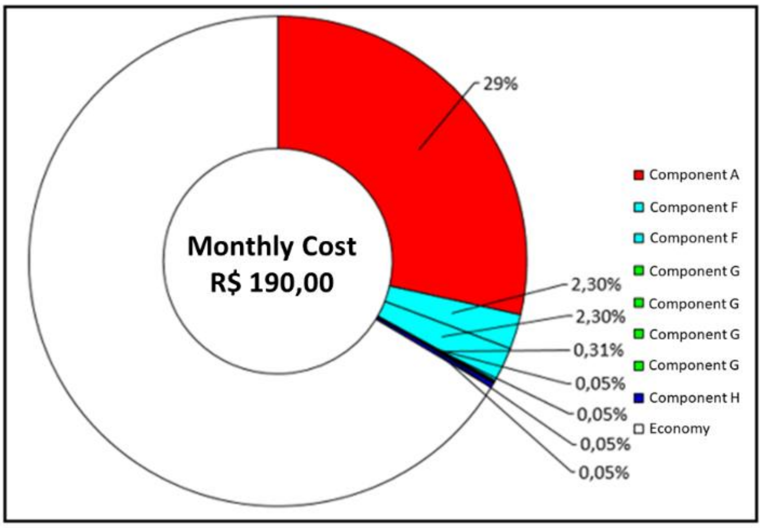

Figure 5. Reduction in destruction parts usage after improvement.

After the application of the actions, it was possible to reduce the monthly cost of destruction tests from R$710.00 to R$190.00, reaching an even greater reduction than the goal. It can be observed in Figure 6, below, that after the applied improvement, the percentage of expenses with parts for destruction tests was reduced to 0.19%, i.e., a reduction of 73.24%.

In the months compared in Figure 7 the savings generated were R$1,040 after the countermeasure. Therefore, projecting these results over a one-year period, the savings generated can reach R$6,240.00.

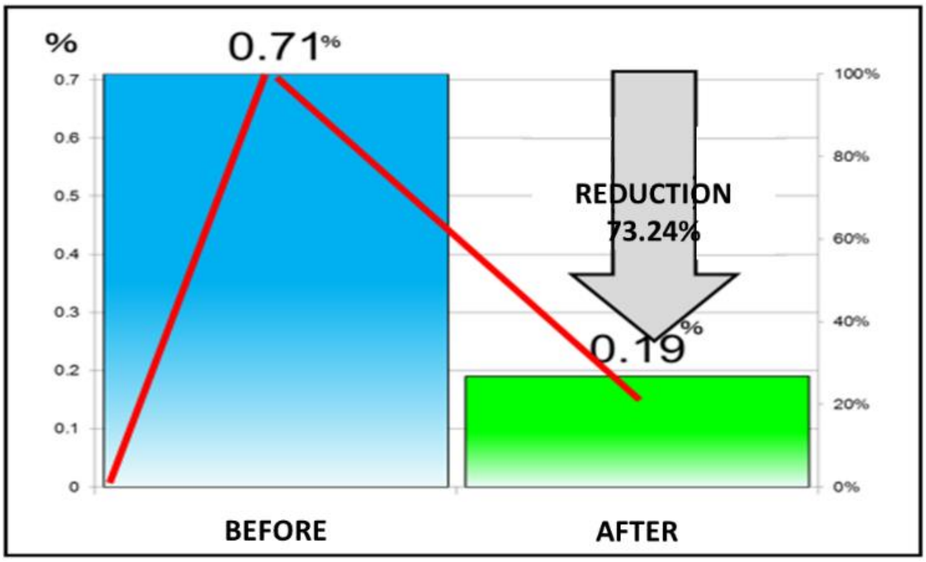

Figure 6. Porcentagem de gasto com peças para testes de destruição.

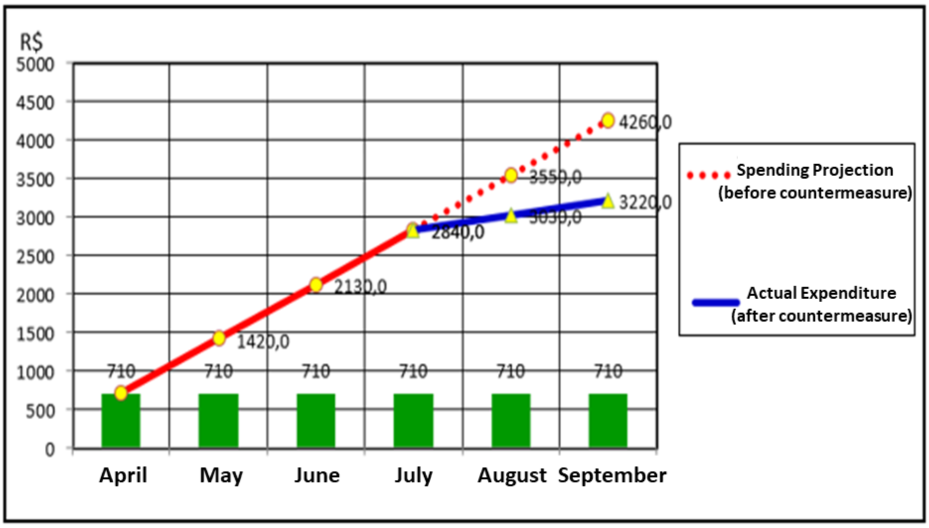

Figure 7. Economia gerada por mês, após aplicação da melhoria de processo.

5. CONCLUSION

Because competition among companies is always growing and the search for cost reduction is increasingly necessary, it is essential to understand in detail where the largest costs with non-value-added activities are. Once these activities have been found and their respective costs have been identified, it is necessary to implement actions to reduce or, if possible, eradicate them. Through an analysis of the production process flow, the cause of the waste was identified: it was necessary for the components to go through all the processes of the line in question, although the destruction tests needed to use components from only two processes. Components from other processes that do not need to be verified in this destruction test were used on a daily basis - generating unnecessary waste.

With the creation of the dummy parts, to be used in the activation of the assembly equipment and release of the poka-yokes, it was possible to decrease the amount of components used daily in the destruction tests. This way, after the kaizen implementation, it was possible to reduce costs more than the initial goal: by the company's rule, the monthly cost goal with destruction tests is up to 0.2% of the total monthly sales of each product. With the improvement applied, a total cost of 0.19% per month was reached for the components of the product in question. Due to the positive result achieved in this process improvement, a study will be done in the other production lines of the company where there is destruction testing, in order to apply these concepts and actions both in the lines that are already in mass production, and in the lines that are in the installation and startup phase.

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