

The Main Benefits of Application of Six Sigma for Productive Excellence

DOI: 10.12776/QIP.V26I3.1712

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Received: 2022-07-05 Accepted: 2022-11-22 Published: 2022-11-30

ABSTRACT

Purpose: The present paper addressed the application of the Six Sigma method for process management to reduce the variability and scrap of packages manufactured at a company located in the city of Rio de Janeiro.

Methodology/Approach: Exploratory research was conducted to understand the context, analyse, and create familiarity with the problems identified in the company, making them more explicit.

Findings: Through Define, Measure, Analyze, Improve, Control (DMAIC) the company was able to identify the main causes of customer complaints and the factors that led to these complaints. Using management tools, it was possible to solve the problems with packaging outside the specifications, which was the reason for complaints from customers. The benefits of this research were the identification and analysis of the quality management tools.

Research Limitation/Implication: The present research had as a limitation the application of the method is only one company, so it is proposed as a future study of the application in different production processes of different organizations.

Originality/Value of paper: It was evidenced that there is a positive relationship between the application of Quality management methods and company billing, as there was an increase of 1.7% in company billing. In past surveys, new possibilities for improvement to be addressed emerged, making the team aware of the need to continue the process of continuous improvement.

Category: Research paper

Keywords: six sigma; quality tools; quality management; total quality management

1 INTRODUCTION

The purpose of quality is to analyse and correct non-conformity situations existing in the production processes. The achievement of customer satisfaction creates work routines which include tools and standards that make it possible to evaluate if the defined parameters are being met, so that the finished products are within the tolerance standards, enabling full internal and external satisfaction (Bastas and Liyanage, 2018; Li et al., 2018; de Sales et al., 2022; Teixeira et al., 2021). Starting from the premise of what constitutes quality, companies must adopt a quality management policy that is efficient and effective in continuously improving processes, thus achieving better results, customer loyalty, and improved business strategy, taking into account environmental issues (Bravi, Murmura and Santos, 2019; Barbosa et al., 2020; Carvalho, Santos and Gonçalves, 2020; Silva et al., 2020; de Araujo et al., 2021). The demand for quality has given rise to a series of technical standards, such as ISO 9001, which is a tool to document the culture of organizations consisting of requirements for managing the production of products and services (Fonseca and Domingues, 2018; Chen and Li, 2019; Barbosa et al., 2021), where new skills are needed (Doiro et al., 2017; Sá et al., 2019; Santos et al., 2021). Therefore, to fulfill requirements in certain processes requires the adoption of working methods aimed at standardization and control, the Six Sigma model is one such example (Fonseca and Domingues, 2018; Bravi, Murmura and Santos, 2019; Costa et al., 2019). Six Sigma, a disciplined methodology, can be applied in an organized way through a problem-solving method called Define, Measure, Analyze, Improve, Control (DMAIC), using quality tools in the development phases of small to large projects and continuous improvement (Antony and Kumar, 2012; Sharma et al., 2018; Ishak et al., 2019; Sá et al., 2020; Rodrigues et al., 2019). However, the non-convergence between developed and developing countries remains (Yülek and Santos, 2022). According to the context of quality management, this article has the following research question: what is the relationship between the application of quality management methods and corporate revenues? To answer this question a case study was conducted in a packaging company located in the city of Duque de Caxias – RJ. The objective was to apply the Six Sigma method, using the DMAIC tool, to reduce the variability and scrap of packaging manufactured by the company.

This work is divided into six sections. Section 1 introduces the study, as well as presents the research question and the objective. Section 2 contains the theoretical framework. Section 3 describes the research method. Section 4 presents and discusses the results. Section 5 concludes the study. Finally, in Section 6, the references used in the research are mentioned.

2 THEORETICAL FRAMEWORK

Six Sigma is a strategic management tool, aimed at elevating the performance and productivity of companies. It is focused on client satisfaction. This satisfaction is obtained by working for continuous improvement of quality and processes. Six Sigma is disciplined to statistics. What marks in the method, is the structuring formed by the use of tools that allow statistical study and analysis of the variabilities inherent in the processes (Hakimi, Zahraee and Mohd Rohani, 2018; Pereira et al., 2019; Ponsiglione et al., 2021). DMAIC as a tool that, when used, enables the identification, quantification, and minimization of recurring problems in processes and improves their performance after implementation. When Implementing Six Sigma using the DMAIC model, one should present it logically, in a coherent sequence and defined by the phases DMAIC (Arafeh et al., 2018; Costa et al., 2019; Rifqi et al., 2021).

Considered a methodology that enables the application of Six Sigma, the DMAIC, seeks in five stages presented in an organized way, the development and implementation of projects (Alshamlan et al., 2022; Daniyan et al., 2022; de Sales et al., 2022). The stages are organized into phases according to Figure 1.

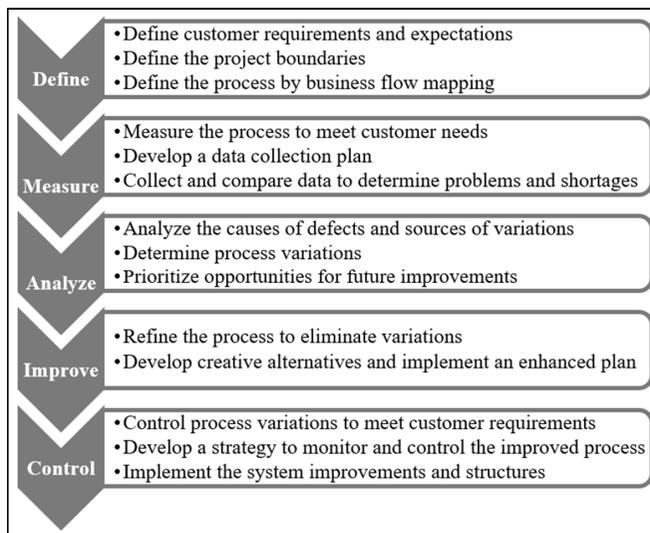


Figure 1 – DMAIC Flow (Improta et al., 2017; Shamsuzzaman et al., 2018)

The implementation of Six Sigma starts initially by focusing on the customer’s needs. To obtain success with the adoption of the method, it is necessary to listen to the client and have consistent criteria for performance analysis. The organization must have financial resources, trained personnel for the development of the adopted methodology, and the involvement of other areas of the company in the process (Laureani and Antony, 2018; Muraliraj et al., 2018; Cardoso et al., 2022). The DMAIC uses in its steps some technical tools and methods used in quality management that can be used in an integrated way in

cycles of continuous improvement of process and products. These, aim at optimization in the planned stages (Muraliraj et al., 2018; Suharno and Zagloel, 2019; Dutta and Jaipuria, 2020). Quality tools consist of a methodological process to assist organizations in problem solving. They organize the understanding of techniques that lead to obtaining diagnosis, generating and analyzing decision alternatives (Hakimi, Zahraee and Mohd Rohani, 2018; Park, Dahlgaard-Park and Kim, 2020; da Silva et al., 2021). Examples of tools for quality management are (Table 1).

Table 1 – Quality Management (Improta et al.,2017; Shamsuzzaman et al., 2018)

Quality Tool	Objective
Check Sheet	A structured and prepared form of data collection and analysis that can be used for various purposes
Pareto Diagram	Applied to prioritize the problems as it shows in a bar chart which factors are most significant
Brainstorm	Maximum exposure of ideas focused on the solution of a problem
Ishikawa Diagram	Search for the causes of the problems
Attribute Control Chart	Control product characteristics that do not need a measuring instrument to be known
Software for Statistical Study	Optimization of data analysis that assists in the management of tasks inherent to Quality management
Production Autocontrol	Prevent a defect from passing to the next process phase

3 METHODOLOGY

In the present study the approach used was exploratory research with the purpose of understanding the context, analysing and creating familiarity with the identified problems in the company, making them more explicit (Yin, 2017; Kothari and Garg, 2019). The context of the case study is described in sections 3.1 and 3.2 where it is possible to identify initial benchmarks using quality tools and statistical data of the problems to be solved among the outlined framework. Known the real scenario of the process in the production line, it is established the goals of performance and quality to be achieved. The problems encountered in the initial situation were treated with solutions methods resulting in a new situation that was deployed and analysed with quality tools.

3.1 Problem Analysis

The problem addressed stems from complaints about the quality of a 1,000ml bottle designed for the packaging of motor oil. The company produces it using the blow molding process, where a heated plastic tube is inflated by air from a compressor. The transformation of the product takes place when a tube of the heated raw material is attached to a split mold and is then filled (blown) with the

desired shape. The raw material used in this process is a thermoplastic, presented in the shape of small grains. To produce its packaging, the company specifically uses High Density Polyethylene.

The parameters specified in the package design can vary due to the control conditions of temperature, pressure, speed, and time. For the new product, variations in specifications occurred in the manufacturing process (Zgodavova, Lengyel and Golemanov, 2008). These variations caused dimensional deviations, specifically in the neck diameter, a defect internally known as neck ‘ovalization’, and problems in neck height. These deviations were identified by the company’s quality control and registered in an electronic spreadsheet. Though, the bottles with the above-mentioned deviations presented good functionality in the customer’s filling line because the non-conformities did not interfere in the product performance and were conditionally released to the customer.

The acceptance of the product under these conditions was possible due to the possession of the Assegura Quality Certificate. The client granted this certification after the supplier went through an evaluation process, which attested that its products went through a qualification process and became suitable to be received, through test certification, waiving the receiving inspection. Quality is Assured is a partnership between supplier and customer that confers a level of confidence about products or services, which reach the expected quality, meeting the needs.

The company researched, having the Assured Warranty Certificate, and performed the control of nonconforming outputs. However, there were variations in its specifications and products were delivered with defects considered tolerable in the knowledge that the malfunctions did not interfere with the functional performance of the product. However, the dimensional deviations of the bottleneck were controlled defects known to the company and its customer. For a period, the customer accepted the deviations, aware of the history that proved that such conformities did not impact their process.

The client is a large company in the automotive lubricant industry, located in the city of Rio de Janeiro. It went through considerable internal changes, which consisted of changes in the workforce, certification in standards, changes in the policy for evaluating its suppliers, and winning over more discerning customers, who would submit it to periodic audits at their facilities. The changes impacted the results of the packaging manufacturing company, specifically, the receiving process by its customer, who opted to perform visual and dimensional inspections by sampling on the received packages and agreed to no longer accept products in a conditional state of quality. After this new procedure the complaints regarding bottle neck sizing increased significantly. They impacted the approval time for releasing the bottles to the customer’s filling line, increased scrap due to internal Quality Control rejections, and reduced throughout 2018 the amount of packaging delivered to the customer. These facts resulted in a loss of 1.9% of annual revenue.

Given the performance in 2018, the company's board of directors requested improvement actions from those responsible for the unit. Soon, those responsible for the unit, knowing that the bottles presented good functionality in the filling line, proposed an improvement project that aimed to adjust the specifications of the technical design to the measures achieved by the manufacturing process. Their main arguments were the low cost of the project, the sustainability of the action, and the historical records of the daily dimensional analysis of Quality Control, which registered over a period, the divergences of the specifications established in the packaging project with the result of the manufacturing process.

3.2 Data Collection and Numerical Survey

The information to build this case study was acquired through a structured interview, which collected information about the actions taken by the packaging production company, located in the city of Duque de Caxias – RJ. The company used the DMAIC methodology and developed actions to improve its process in sequenced phases. Starting with the Define phase, followed by the Measure, Analyze, Improve, and Control phases, which presented the actions taken to solve the existing problems in the company's packaging production process. For the project, the team used the following quality tools: Check Sheets, the Pareto Chart, the Ishikawa Diagram, the 5W2H, Control Charts, and the statistical study by Minitab software. As a complement, the control phase presents the control methods adopted to guarantee the improvement stage actions, with actions aimed at identifying the existence of variations that may occur and affect the final product quality of the company's products.

4 RESULTS AND DISCUSSIONS

4.1 Define Phase

The Define phase used the Project Charter, a document that presents the activities of the team involved in the project, involving them in the project objectives (Costa, Silva and Pinto Ferreira, 2017). The objectives were: adjusting the specifications of the technical design of packaging to the achieved measures by the production process to reduce scrap; reducing rejections at the customer's receiving stage; Delivering a greater quantity of 1,000ml per day; Satisfying the customer, increasing the guarantee of use of the products delivered; and Increasing sales by 1.5% per year.

Table 2 – DMAIC Timeframe

Month		Jan. 2019	Feb. 2019	Mar. 2019	Apr. 2019	May 2019	June 2019
Phases	Define						
	Measure						
	Analyze						
	Implement						
	Control						

The project was carried out by employees involved in the bottle production process, people who had statistical data and information about the product design, employees from the Project, Quality, Production and Mechanical Maintenance sectors. The project was presented and executed according to the schedule shown in Table 2.

4.2 Measure Phase

The bottles were sized daily and had their data posted on a Check Sheet. The out-of-specification measurements presented in the check sheet reflected the reasons for complaints received by customers during 2018, which was the major cause of the reduction in revenue, but it was necessary to organize the data and visualize the relevance of the problem through a Quality tool. To do this, the team used the Pareto chart (Suharno and Zagloel, 2019).

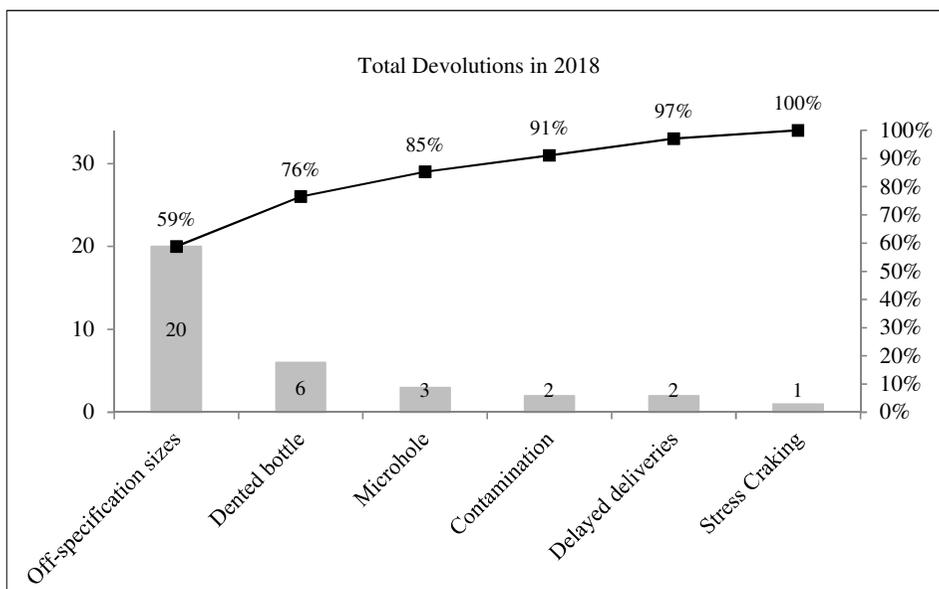


Figure 1 – Return Causes Flow

The complaints received from the customer were studied statistically, making it possible to identify that the complaint for not meeting the specifications represented 59% of the total. The percentage of each cause of return is shown in Figure 1 (Pareto Chart).

4.3 Analyse Phase

In this phase, after analysing the data and generating ideas for discussions, a Brainstorming session was done by a group of voluntary members to reach the solutions to the problems. The purpose of using the tool was the development of the team, the launching and the specification of the participants' opinions, focusing on solving the problem quickly and satisfying the customers (Krotov and Mathrani, 2017). As recommended, the chosen leader was the one who had the ability to synthesize the suggestions and take what was useful. The aim was not to waste time at this stage so that the length of the meeting could be set before its start.

Based on the results of the Pareto chart, the team used the Ishikawa diagram to search and analyse the roots of the problem. The team concluded that the problem was the “machine factor”, because its equipment and accessories were not able to fully reproduce the defined specifications of the bottle. Figure 2 shows the result of the survey of the inherent to the customer's complaint factors.

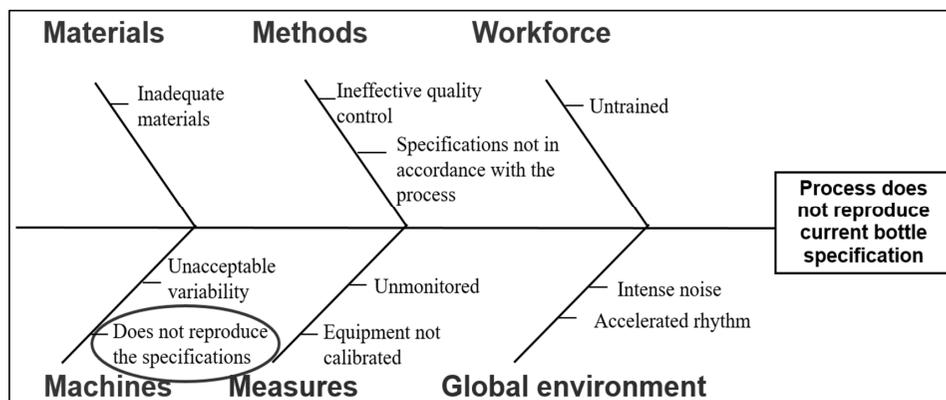


Figure 2 – The Result of the Survey of the Inherent to the Customer's Complaint Factors

After defining the factor responsible for the problem, the team came up with two alternatives to correct the specifications, which would be: adjusting the bottle specifications to the current process or making modifications in the mold and accessories to achieve the parameters and continue with the current specifications.

4.4 Implement Phase

In the implement phase, the solutions and ideas presented in the previous phase had to be planned and tested. Actions were planned for solving the problem. The first action was to correct the problem, because adjusting the specifications according to the outcome of the process, the problem would be solved (Costa, Silva and Pinto Ferreira, 2017; Dutta and Jaipuria, 2020).

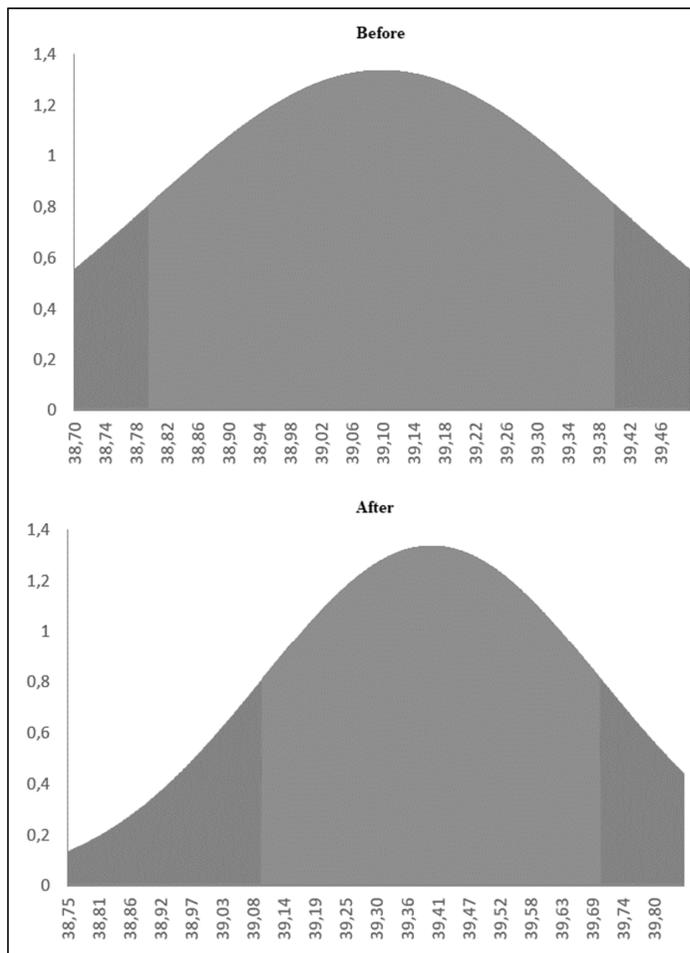


Figure 3 – Bottleneck Diameter Capability Study

The first action was performed according to the statistical study of the data recorded in the check sheet. The Minitab software commands read the stored information and generated data for the capability study of the stored information, the current specification values and the new specification suggestion. The term capability is related to a kind of control and measurement of the process capacity to repeat the parameters of a given specification. A controlled process may not have the ability to accurately replicate and meet desired limits (Costa, Silva and Pinto Ferreira, 2017; Pereira et al., 2019). The study performed of the data

showed the behaviour of the process in relation to the current specifications, from which it was possible to see the limits of the process. With this result, a new specification was developed for the diameter and height of the bottle neck. In Figure 3, the bottleneck diameter study performed by the Minitab software.

In the first graphic of Figure 3, the process specification presented samples were above the upper specified limit (LSE) and that they did not reach the target of the project specification. The second graph, already with the new limits, suggested that the specifications should be modified. An adjustment of the values in relation to the target was proposed, raising the lower specified limit (LEL) by 0.05mm and the upper specified limit (ULS) by 0.35mm.

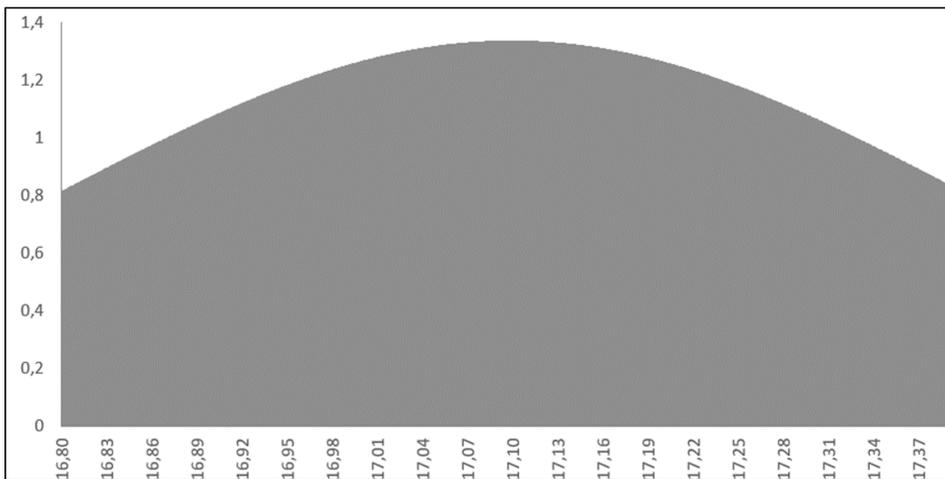


Figure 4 – Bottleneck Height Capability Study

In Figure 4, the process presented outside the specified lower and upper limit samples. Therefore, they did not reproduce the design specification. From the result, the second chart proposes the increase of the limits, so that both the process and the design specifications can be guaranteed.

4.5 Control Phase

This phase aims to ensure that the implemented improvements are kept over time. For this, quality control mechanisms must be established (Shamsuzzaman et al., 2018). To perform the production self-control, checkpoints were created within the production line, containing tables with computers to record the visual aspects of the packages, process parameters and records of the results of the "pass no pass" (poka-yoke) gauge tests, used to evaluate the neck ovalization. The SPC (Statistics Control Process) of the variables was performed using control charts by attribute.

The use of the self-control provided greater control over the manufactured product, from the identification of defects to the records that will help in future

studies of the process and expand the control over the product that was previously performed exclusively by the Quality Control sector. A standard procedure for self-control was developed and incorporated into the Quality System. The implementation took place after training was given to the employees about the methodology procedure, which approached the awareness of the importance of package quality evaluations and the search for quality according to the customer’s voice. The methodology was applied not only to the 1,000ml bottle but to all other types of packaging produced at the plant.

In Figure 5, it is evident that the improvement actions had a satisfactory result. The out-of-specification measures, which previously represented 59% of the complaints, do not appear in the graph. There was a reduction in the other problems that were scored before. Dented bottles are now the main reason for complaints, representing 50% of the total complaints, however, defective units appear in fewer quantities in 2019.

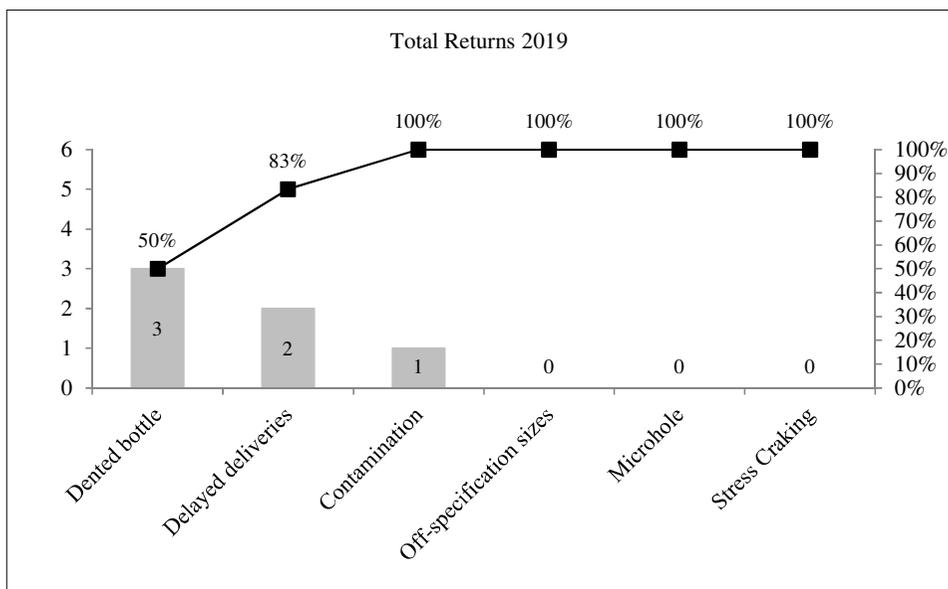


Figure 5 – Total Returns 2019

As the implementation of quality tools and quality management methods, the reduction of failures and improvement of effectiveness are evidenced in Figure 5. With the reduction of waste, increased efficiency and effectiveness of the manufacturing process, the reduction of expenses with defective products and the increase in the quantity of products produced are observed. Therefore, quality management helps increase revenue by reducing waste and defective products.

To adjust the bottle specifications to the optimized process or make modifications to the mold and fittings to the current specifications the customer needs to agree. Because the product must meet the demands of the end customer.

5 CONCLUSION

The practical benefits of this research were the identification and analysis of the quality management tools that could help to improve the bottle production process and the direct gains of the organization. The research managed to use the DMAIC to improve the production process and thus reducing waste and improving the final quality of the product and reducing customer complaints, thus reducing spending on rework. Through DMAIC, the company was able to identify the main causes of customer complaints and the factors that led to these complaints. Hence, the objectives of the study were achieved. It was evidenced that there is a positive relationship between the application of quality management methods and company billing, as there was an increase of 1.7% in company billing. Using quality management tools, it was possible to solve the problems with packaging outside the specifications, which was the main reason for complaints from customers. Among the main tools applied in the company studied, the DMAIC were highlighted.

In past surveys, new possibilities for improvement to be addressed emerged, making the team aware of the need to continue the process of continuous improvement. In this context, future studies should be conducted to identify the relationship between top management commitment to quality management and business sustainability. The present research had as a limitation the application of the method is only one company, so it is proposed also as future study of the application in different production processes of different organizations.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.



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