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RESEARCH ARTICLE **OPEN ACCESS**

APPLICATION OF THE SIX SIGMA METHODOLOGY AND USE OF THE DMAIC METHOD TO REDUCE THE LOSS RATE OF ALUMINIUM CANS IN A BEVERAGE INDUSTRY TO REDUCE OPERATIONAL COSTS: CASE STUDY: LATAX REFRIGERANTES LTDA

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ABSTRACT

Introduction: Six Sigma is an internationally recognized tool widely used in the identification and implementation of improvements in internal processes of an organization, aiming to obtain lower operating costs and, consequently, increase profit margins. During the application of this tool it is necessary to follow a defined sequence of steps and to establish quantified objectives. ***Objective:*** This study demonstrates how the application of the tool can assist in reducing operational costs by reducing losses of cans in the production process through cause analysis and implementation of action plans in a production line of soft drinks in aluminum cans in a beverage industry. ***Methodology:*** In the application of this study, steps of the DMAIC methodology were followed, where statistics tools were used to DEFINE the problems and identify the improvements, MEASURE during the phases of getting results, ANALYZE the collected data into useful information for decision making, IMPLEMENT the actions proposed in an action plan based on the previous steps and finally CONTROL the processes so that continuous improvement is a living cycle within the institution. ***Result/Discussion*:** The six sigma team of this project, applying VOC - Voice of Customer, Snake Diagram and SIPOC methodologies, could interact with internal customers about the soft drink bottling processes in aluminium cans, as well as the other processes that interact among themselves and how this industrialization process is inserted in the context of the organization as a whole. ***Conclusion*:** After the full implementation of the actions proposed by the six sigma team of this project, the objective was met. In comparison with the previous measured period, the analyzed process reduced the average percentage of can losses from 0.53% to 0.26% after the implemented actions. Thus, the financial contribution of the project to the company was an average annual operating cost reduction on aluminum can waste from $13,596 to $6,670, resulting in a loss reduction of $6,926 for the company.

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INTRODUCTION

Some types of industries, the beverage industry, the quality and safety factors are critical, regarding the supply chain from raw materials logistics, production process and delivery on the shelves to the final consumer. Such rigor is understandable since these are products that will be consumed by human beings (GRUNERT, 2005). The beverage industry in Brazil experienced expressive growth in what comprises the period from 2003 to 2016, including this can be seen with the sector's proportional growth greater than the country's Gross Domestic Product (GDP) in this same period (BNDES, 2017). Furthermore, the expressiveness of this industry has passed not only in the national sphere, but also internationally with Brazil being the third largest producer of beer and soft drinks in the world (BNDES, 2014). Nevertheless, a characteristic of this type of industry - both national and international - is the few large companies that dominate the sector and seek greater market share. One factor that all these companies have in common is the constant variation in manufacturing costs, since both the production inputs and the materials used in packaging are linked to commodity prices. For these and other reasons, the low profit margins of the sector require high efficiency and low resource use processes, either for lower production costs or for sustainability (OSTERROTH, 2017).

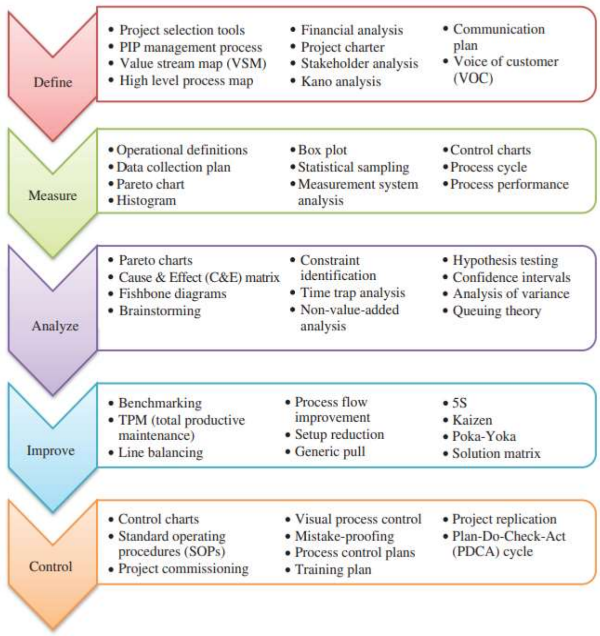
To achieve and maintain high efficiency processes, it is essential that there are constant initiatives for improvements in the production process. For a certain process to be improved, it is necessary that a sequence of structured steps be executed, using appropriate tools that compose an improvement roadmap to obtain the expected result (HARRY, SCHOROEDER, 2000). That is, it can be stated that by following this sequence of steps, the individual or the team, who establishes improvement objectives and directs the work, will obtain the expected gains or improvements in a certain target process.With this in mind, it can be stated that the Six Sigma methodology and the DMAIC method can be valuable allies in a work where the main objective is to raise the level of quality and bring expressive gains to a given process. Therefore, with the use of these two tools, this work, which is a case study, aims to analyze the causes of losses of cans in a beverage industry, as well as to propose actions and verify their effectiveness by measuring the monthly indexes of these quality indicators.The case study was conducted in a large beverage industry, which operates in the city of Manaus for over 50 years. In order to preserve the real identification of the company, the company will be referred to in the paper as Latax Refrigerantes.

BIBLIOGRAPHIC REVIEW

Six Sigma Methodology: Six Sigma was developed by the American company Motorola, as a process improvement tool, during the mid-1980s (FORMÁNEK, 2020). From this initial introduction by Motorola, Six Sigma appears to have merged with the concept of total quality management (Total Quality Management or simply "TQM") according to Green (2006). The "Sigma" is a Greek letter that brought a concept of statistics, where its application is to represent the standard deviation in relation to the average value. Therefore, when the term Six Sigma was formed, it means that there is a distance of six times in relation to the standard deviation. In practice, a process that reaches the level of Six Sigma should not produce more than 3.4 defects per million (MOOSA, & SAJID, 2010; Lei, 2015). Despite the adoption of this methodology by large companies since its original formatting, there are different definitions for Six Sigma, which can result in uncertainty and confusion (SCHOROEDER, 2008). Among the different ways of conceptualizing Six Sigma, four approaches can be listed for a better understanding of the tool.

As previously mentioned, the first approach suggests that Six Sigma is a series of statistical tools to build a sequence of steps for process improvement (GOH AND XIE, 2004; MCADAM AND EVANS, 2004). Seen from this perspective, Six Sigma is an isolated method for problem solving, not part of a management system, for example.
A second approach by Chakrabarty and Tan (2007) is that Six Sigma is an operational management philosophy, which brings benefits to suppliers, customers and company employees. A third perspective would be Six Sigma as an organizational culture of top-down management, where the main problems and business goals are analyzed by executives, so that then the teams act in identifying improvement opportunities for the achievement of these goals and problem solving (FLIFEL et al., 2017). The fourth concept discussed about Six Sigma is that it is an analysis methodology, being possible to measure the capability of a process in order to eliminate defects (VIRMANI and HUSSAIN, 2018).

DMAIC Method: The DMAIC method was also initially developed at Motorola as part of the Six Sigma methodology, which with its application over the years has proven to be an effective tool in improving quality and eliminating defects (YADAV, 2016; ANDERSSON, 2006). The DMAIC method, or also called DMAIC cycle, is an acronym for the English words: Define, Measure, Analyze, Improve, Control, which mean respectively: Define, Measure, Analyze, Improve, Control. Each term of this means a step of the method that are related to each other (SOKOVIC, et al., 2010; SIN, et al., 2015). In DMAIC a series of tools can be used according to the needs of those who are applying the method and the business metrics that want to be met, as can be seen below in Figure 1, in addition to identifying part of the tools that were used in this work, such as: the VOC (Voice of the Customer), the Pareto Diagram and the Ishikawa Diagram.



Source: adapted from Ahmed, (2019).

Figure 1. Tools of the DMAIC Method

SIPOC Diagram: The origin of the SIPOC tool can be related to Edward Deming, one of the quality gurus, and the movement propagated by him known as Total Quality Management - TQM (Gestão da Qualidade Total, in Portuguese) in the 1940s, in which one of the principles is that the processes are systemically integrated (BROWN, 2019) The term SIPOC is an acronym for the words Suppliers, Input, Process, Output and Customers - in Portuguese Suppliers, Input, Process, Output, Customer, respectively - which concerns a visual representation tool, diagrammatic type, in which critical elements of the process and their interactions are mapped (PARKASH and KAUSHIK, 2011). A simple representation of SIPOC can be seen in Table 1, and the following questions must be answered in each quadrant:

S (Suppliers): which supplier feeds the input to the process?
I (Input): which item or service must be processed in the next step?
P (Process): what are the step-by-step processing steps? If necessary, design a flow.
O (Output): what are the deliverables of what was processed in the previous step?
C (Customer): which customer will receive the output?

Table 1. SIPOC Diagram

S	I	P	O	C
Supplier	Input	Process	Output	Customer

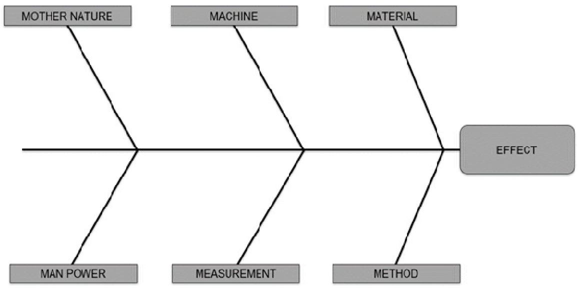
Source: Authors, (2022).

Ishikawa Diagram: According to Yang and El-Haik (2008), the Ishikawa Diagram (due to the name of the creator of the tool) also known as Cause and Effect Diagram or Fishbone Diagram (because of the visual representation) is used to classify the different factors of influence (causes) that may affect an operation that results in a problem (effect). Paladini et al. (2012) adds that the goal of the Ishikawa Diagram is to make an analysis of the steps of the production processes. By highlighting the negative effects of the process, it is possible to work on the mitigation or elimination in order to promote improvements in quality metrics and business. Another term that the Ishikawa Diagram can be referred to is the 6Ms

Diagram, due to the initials of each category that each cause may be related to. These are:

- **Method -** The way in which the task was carried out should be analysed. If there is a standardized method and if it was properly followed, the difference may influence the expected final result of a process.
- **Machine -** This category includes general failures related to machinery. Is the equipment calibrated? Was there a failure of a certain sensor, actuator or electrical component? Mechanical? Questions like these must be answered.
- **Material -** The materials used in the process should be analysed. Check if the specification is correct, if the material storage was appropriate and if its characteristics were preserved.
- **Manpower -** In this type of cause, the operational work of the people directly involved in the processing stage should be analyzed.
- **Measurement -** Assess impacts arising from specifications that are more oriented to the measurements performed, whether manual or automatic measurement. Evaluate, for instance, if the equipment is correctly calibrated.
- **Mother Nature -** This factor is related to environmental conditions and how they can interfere in the analyzed process. Factors such as temperature, humidity, pressure, wind, among others, can interfere in the process.

In Figure 2 below it is possible to see a representation of how the diagram is usually illustrated in the literature and also in this work.



Source: Authors, (2022).

Figure 2. Ishikawa Diagram

5W2H Tool: In response to the identification of the root cause of a problem or effect analysed, it is necessary to take actions to eliminate it. Thus, the 5W2H method aims to be a facilitating tool in the implementation of corrective and preventive actions, usually represented as in Table 2 (PACAIOVA, 2015).

Table 2. 5W2H tool model

	Keyword	Question
5W	What	What is the problem?
	Why	Why this action will be done?
	Where	Where is the place the action will be applied?
	When	When the action will be implemented?
	Who	Who is the responsible to do it?
2H	How	How it will be done?
	How much	How much it will cost to implement?

Source: Authors, (2022).

MATERIALS AND METHODS

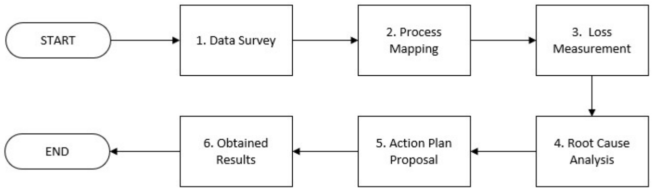
To achieve the proposed objectives of this paper, the research method used was a qualitative and quantitative case study. This research method was adopted due to the nature of this work which according to Yin (2018) is pertinent to its application when the focus of the study focuses on phenomena observed in real life and "how" and "why" questions seek to be answered.

Description of the object of study

The place of study of this work was in the industrialization sector of the company Latax Refrigerantes Ltda, which is a company in the beverage industry. The object of study was in the sector of bottling of soft drinks, more specifically in the production line of cans K-01.

Key stages of the work

The study was divided into 6 main stages, as can be seen in Figure 3.



Source: Authors, (2022).

Figure 3. Research development stages

Stage 1 - Data Survey: At this stage the reports of production volume of cans for the period September 2020 to May 2021 were accessed, detailing the production volumes of each model in order to identify the models with greater representativeness of the total volume.Also, from the same period of September 2020 to May 2021 the reports of losses in the manufacturing process were consulted, thus it is possible to identify in which models there is the presence of these losses and their relevance in relation to the total manufacturing volume.

Stage 2 - Process Mapping: In addition to these reports to assist in the quantitative analysis of the project and to provide a comparison of "before and after", the processes were also mapped using tools such as the snake diagram and the flowchart, so it is possible to visualize how the industrialization stage is inserted in the context of the company, as well as the industrialization processes and their interactions, as can be seen in Figure 3.

Stage 3 - Measuring Losses: At this point all the points of losses of the object of study were mapped, more specifically in the production line and its peripherals, assigning an identification to each of them. Thus, it is possible to measure the quantity of losses in each phase of industrialization.

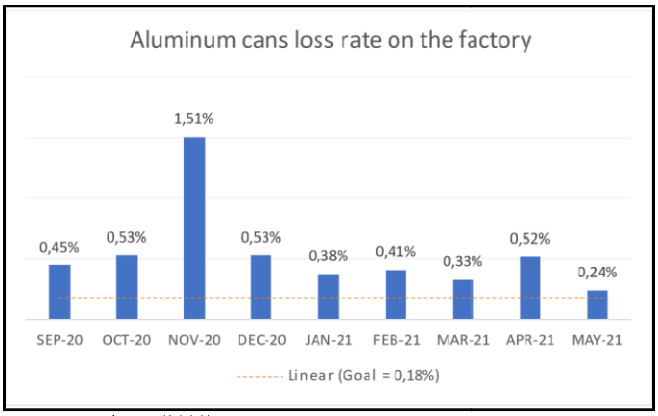
Step 4: Cause Analysis: For the cause analysis activity, two well known and effective tools were used: the Ishikawa Diagram and the 5 Whys.

Step 5: Action Proposals: After the identification of the causes through the use of the tools previously, the action plan was implemented with the use of the 5W2H tool, being assigned to the activities according to the associated causes, as well as the execution deadline, the person responsible for the action, the why and the how it will be developed, as well as the costs involved for the implementation.

Step 6: Results Obtained: After all the previous steps, from data survey to the implementation of the action plan, it was possible to measure again a period after the interventions, thus explaining the quantitative results compared to the data survey done initially.
These results are expressed in the reduction of both the percentage of losses and the reduction of financial losses for the company.

RESULTS AND DISCUSSION

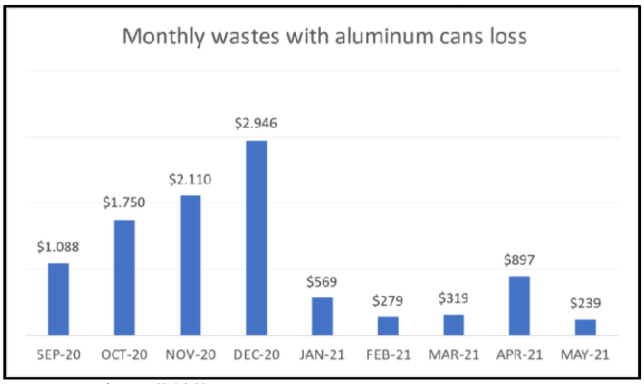
Following the DMAIC methodology for a better deepening of the potential improvement project, tools were applied in the Definition stage, in order to identify if the Lean Six Sigma methodology could be applied. To this end, a survey of data and indicators was conducted to map the losses and their representativeness for the operation, as shown in Figure 4. Through the data survey and shown in the graph of Figure 4, it was observed that in the period from September 2020 to May 2021 the average loss of cans was 0.54%, being 0.36% above the defined target.



Source: Authors, (2022).

Figure 4. Average monthly losses of aluminum cans.

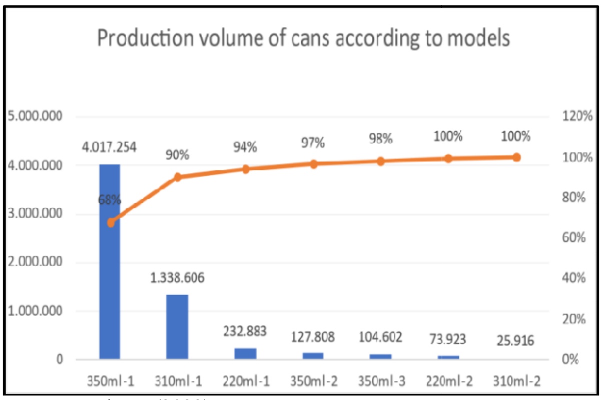
As there is no possibility of recovering the cans lost in the process for reuse, these losses also represent a financial impact for the company that can be seen in the graph of Figure 5, and considering the accumulated losses of the same period, represented for the manufacturing plant an expense of approximately US$ 10.000.



Source: Authors, (2022).

Figure 5. Monthly expenditure on can losses

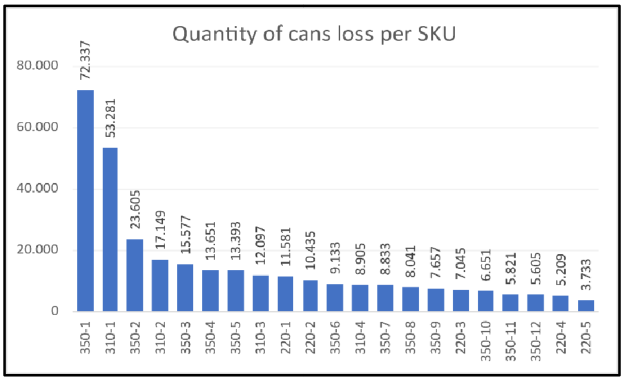
Compiling the total production volume in the same period one observes the production of 5.929.991 units.



Source: Authors, (2022).

Figure 6. Volume of can production according to the models

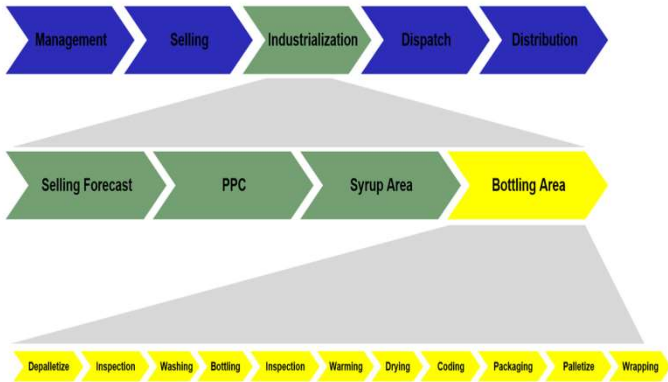
Through the Pareto diagram it is noted that two of seven items represent 90% of total losses, as represented in the graph of Figure 6. To complement the data stratification, the graph in Figure 7 demonstrates the losses per unit and per SKU - Stock Keeping Unit.



Source: Authors, (2022).

Figure 7. Volume of lost cans per SKU

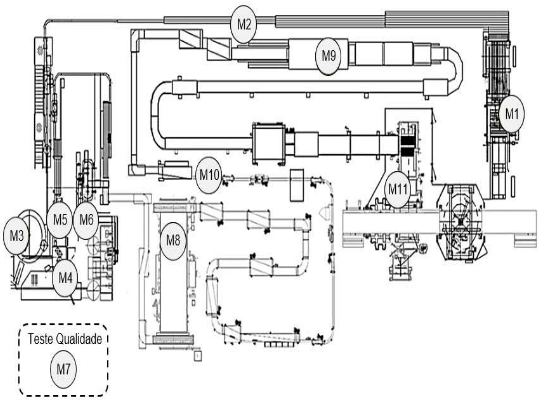
After the data survey, other tools were used in the Definition stage to identify stakeholders and their needs through the VOC(Voice of the Customer) technique and the Snake Diagram in order to map and isolate the main production processes for implementation of this project. From direct interviews with customers, it was possible to identify that the main need is to meet the indicator of losses of cans, as well as it was possible to define valid requirements, which serve as the target of the project as well as which indicators will be used to monitor the achievement of the goal, as shown in Table 3. The use of the Snake Diagram allowed for the demonstration of the context of the industrialization process in the company's organization and inwhich stage of the process it is related. As can be seen in Figure 8, the last process is the beverage bottling stage.



Source: Authors, (2022).

Figure 8. Snake diagram of the process

In order to isolate and further detail the process related to the theme of this work, a SIPOC diagram was prepared to visualize the inputs, processes and outputs, as well as the supplier and customer relationships. As can be seen in Table 4, the related process lies between the can washing process (rinser) and the beverage filling (filler).



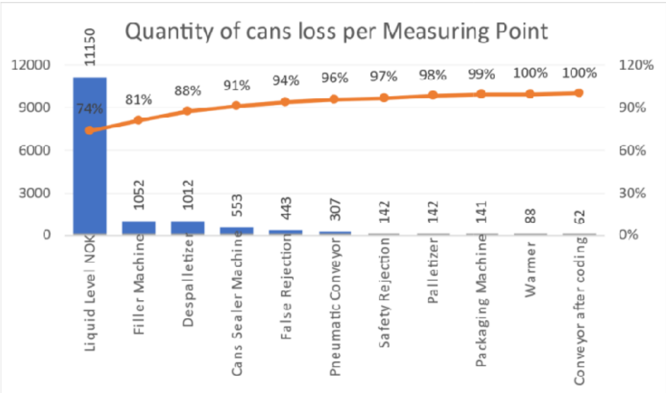
Source: Authors, (2022).

Figure 9. Production line of cans K-01

Once the process in question was identified and the processes were mapped in detail, it was possible to define which points of the production line would be used to measure can losses in the process and subsequently analyze the causes. Figure 9 illustrates the layout of the production line with the points identified for data collection (can losses) and Table 5 describes each area. To perform a survey of losses in a given period of time, once the process has already been mapped and the measurement points defined, the exact measurement locations were defined, as well as the method and frequency. It is what can be seen in Table 6. After thirty days of measurements and compilation of the collected data, a pareto diagram was assembled. In this way, it was possible to identify the main causes of can losses, as well as their representativities within the set of samples. As can be seen in the graph in Figure 10, eleven different causes for losses of cans were identified in the process of the can production line K-01. Of all these, three causes were identified that added together accounted for 88% of the causes of can losses in the process.

The causes were:

- Can losses due to irregular level, accounting for 74% of the measured losses;
- Can losses at the filling machine, representing 7% of the measured losses, and
- Losses of cans at the depalletizing machine, representing 7% of the measured losses.

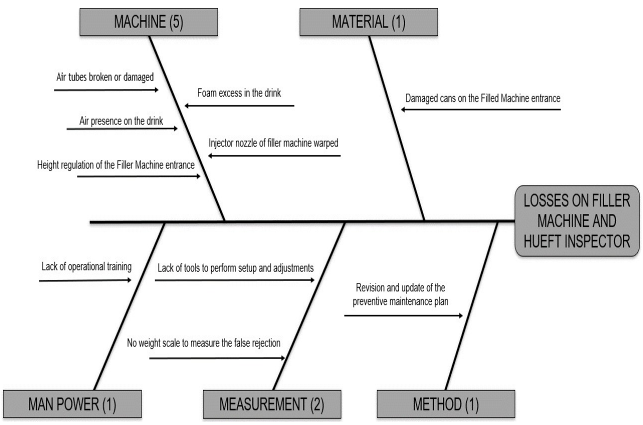


Source: Authors, (2022).

Figure 10. Quantity of can losses per measurement point

Analysis: Once the main can loss variables in the process were identified, problem analysis methods, Ishikawa Diagram and 5 Whys, were applied to each of these processes:

N1. Filler and Heuft Analysis.
N1.1 Application of the 5 Whys Tooldemonstrated in Table 7.

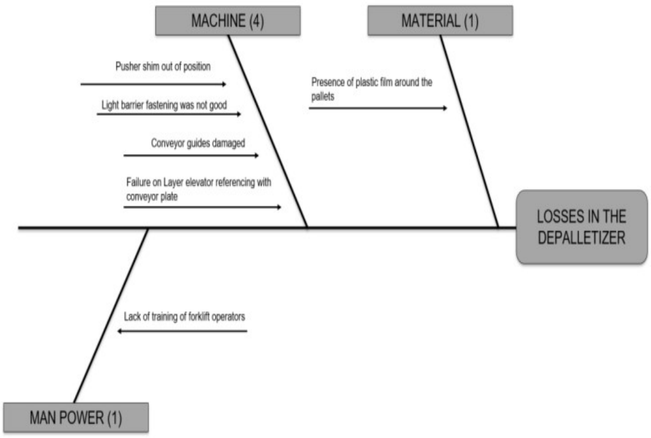


Source: Authors, (2022).

Figure 11. Tool 5 Ishikawa Diagram applied to the Filler and the Heuft

As can be seen in the Ishikawa Diagram, ten causes were identified in the Filler Machine and the Heuft Inspector, and most of them - five causes - were related to the machine. Broken components such as the air tubes and the inlet star of the filling machine warped are among the machine causes.

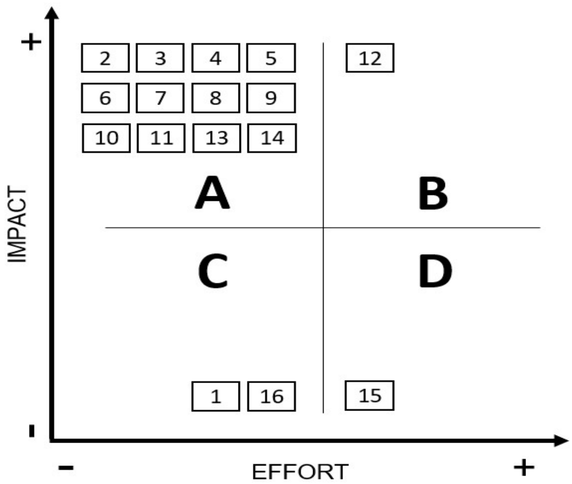
N.2 Depalletizer Analysis
N2.1 Application of the 5 Whys Tool demonstrated in Table 8.



Source: Authors, (2022).

Figure 12. Tool 5 Ishikawa Diagram applied to the Depalletizer

Ishikawa Diagram: Analyzing the Ishikawa Diagram applied to the Depalletizing Machine again it is observed that of the causes mapped, most also focus on the machine category. Of the six causes, four fits into this category, problems such as damaged conveyor and components out of position or misaligned appear in the analysis as shown in Figure 12. After identifying the root causes, they were listed in Table 9 and then the tool Effort X Impact Matrix was applied in order to prioritize the actions directed to the causes identified, focusing on the points that will bring more results for the project.The result of the application of the matrix can be seen in Figure 13, where based on the expertise of the team it was possible to observe two causes that have a low level of effort and low impact and twelve have a low level of effort, but represent a high impact in relation to the process problem analyzed. Based on this evaluation, for the two causes in quadrant C (low effort X low impact) immediate actions must be taken and for the causes in quadrant A (low effort X high impact) an action plan must be established.



Source: Authors, (2022).

Figure 13. Effort X Impact matrix of root causes according to root cause

Actions: In Table 10 can be seen the action plan for the causes mapped in thequadrant C, which actions should be prioritized the execution in the shortest possible time.

Table 3. Application of VOC Methodology - Voice of the Customer

Project	Reduction of aluminum cans waste			
Client	CTQ (Critical to Quality)	Need	Valid Requirement	Indicator
Industrial Operation Manager	Cans waste	Meet the cans loss indicator	<=0,18%	% of cans loss
Production Coordinator	Cans waste	Meet the cans loss indicator	<=0,18%	% of cans loss
Quality Coordinator	Cans waste	Meet the cans loss indicator	<=0,18%	% of cans loss
Quality Coordinator	Process Capacity	Meet the CPK of liquid content	CPK >=1,33	CPK

Source: Authors, (2022).

Table 4. SIPOC of the can manufacturing process

S (Supplier)	I (Input)	P (Process)	O (Output)	C (Customer)
Ball and crown	Pallets of empty cans	Cans storage	Delivery of cans	Warehouse
Warehouse	Delivery of empty can pallets	Transfer of cans to the production line	Delivery cans for production	Depalletizer
Depalletizer	Empty cans	Depalletize the pallet layers	Cans for the electronic prescco inspector	Electronic inspector prescco
Electronic inspector	Empty cans	Inspect cans	Cans with quality ok	Rinser
Rinser	Cans empty and inspected	Wash cans internally	Washed cans	Filler machine
Filling machine	Clean cans for filling	Filling of cans	Cans with soda	Cans sealer machine
Cans sealer machine	Cans with soda without cap	Sealing of cans	Sealed cans	Electronic level and sealed can inspector
Electronic level and sealed can inspector	Cans sealed and with soda	Inspect filling level	Filled cans	Warmer
Warmer	Filled cans	Heating of the can and soda	Cans with room temperature	Coder
Coder	Filled cans	Code the cans with batch and expire date	Coded cans	Packaging machine
Packaging machine	Filled cans	Box wrapping of cans	Cans in wrapped box	Palletizer
Palletizer	Box of cans	Arrange boxes in layers on pallet	Filled pallets	Wrapping machine
Wrapping machine	Filled pallet with boxes	Wrap the filled pallets	Pallets wrapped	Warehouse

Source: Authors, (2022).

Table 5. Identification of the loss measurement points

Measure Point	Description of the loss point
M1	Depalletizer Machine
M2	Pneumatic Conveyor
M3	Filler Machine
M4	Cans Sealer Machine
M5	Filling level inspection machine - Heuft
M6	False rejection inspection machine
M7	Quality destructive test
M8	Warmer machine
M9	Packaging machine
M10	Conveyor after coder
M11	Palletizer Machine

Source: Authors, (2022)

Table 6. Measurement method for losses on the can line

Measurement Point	Description of Variables	Method of Measurement - by quantity	Measurement Location	Frequency	Responsible
M1	Can losses in the Depalletizer	Lost cans on the Depalletizer	Depalletizer	Daily From 01-JUL-2021 To 31-JUL-2021	Employee 1
M2	Can losses in the Pneumatic Conveyor	Lost cans on the Cans Sealer Machine	Conveyor of empty cans		Employee 1
M3	Can losses in the Filler Machine	Lost cans due to Production	Filler Machine		Employee 1
M4	Can losses in the Sealer Machine	Lost cans due to Production	Cans Sealer Machine		Employee 1
M5	Can losses at Inspector Heuft due to false rejection	Lost cans by the false rejection	Heuft Inspector		Employee 2
M6	Heuft's Inspector Safety Rejection	Rejected cans - Safety Mode	Heuft Inspector		Employee 1
M7	Destructive Analysis of Quality Assurance	Samples destructed according to Production	Quality Laboratory		Employee 3
M8	Can losses in the Warmer	Lost cans due to Production	Warmer		Employee 4
M9	Can losses in the packaging machine	Lost cans due to Production	Packaging Machine		Employee 5
M10	Can losses in the Conveyor after coding	Lost cans due to Production	Cans Conveyor		Employee 6
M11	Can losses in the Palletizer	Lost cans due to Production	Palletizer		Employee 4

Source: Authors, (2022).

Table 7. 5 Whys Tool applied to the Filler and Heuft

#	Problem Description	1 - Why?	2 - Why?	3 - Why?	4 - Why?	5 - Why?
1	Air tubes broken or damaged	The tubes' material is fragile and must be replaced.	Stainless Steel tubes were tested but it didn't work.	Steel tubes are difficult to handle and perform the setup	N/A	N/A
2	Foam excess in the drink in the beginning of the ramp process	Due to high temperature of the drink	Due to the Filler Machine didn't reach thermal balance.	Due to the washing by the Washing Machine is not enough.	Due to the minimum amount of water consumption.	N/A
3	Air presence on the beginning of ramp process.	Due to the wrong pressurization in the Filler Machine	Unskilled operators doing the work	Due to the renewal of the operators	N/A	N/A
4	Damaged cans on the Filled Machine entrance	Production line conversion	Wrong adjustment of the Filler Machine	Failure on the elevation system of the Filler Machine	Third party service execution was not correct	N/A
5	Revision and update of the preventive maintenance plan	N/A	N/A	N/A	N/A	N/A
6	Lack of tools to perform the setup and adjustments	The needed tools were not mapped	There was not available capital to purchase the tools.	It was not forecasted on budget.	N/A	N/A
7	There was not a weight scale to measure the false rejection	The calibration and installation were pending the execution.	The calibrations services are made by third party companies	N/A	N/A	N/A
8	Height regulation of the Filler Machine entrance.	Production line conversion	Wrong adjustment of the Filler Machine	Failure on the elevation system of the Filler Machine	Third party service execution was not correct	N/A
9	Injector nozzle of filler machine was warped	High usage time of the equipment	There was no technology update on the Filled Machine	It was not forecasted on budget.	N/A	N/A
10	Operator skills on the Filler machine setup not appropriate	Due to the renewal of the operators on this line.	Lack of training to the operators.	N/A	N/A	N/A

Source: Authors, (2022).

Table 8. 5 Whys Tool applied to Depalletizer

#	Problem Description	1 - Why	2 - Why	3 - Why	4 - Why	5 - Why
1	Presence of plastic film around the pallets	The supplier involves the pallets in plastic	To minimize the loss of cans by fall over	N/A	N/A	N/A
2	Lack of training of forklift operators	Working methods are out of date	N/A	N/A	N/A	N/A
3	Pusher height out of position	No support available in layer muffler	N/A	N/A	N/A	N/A
4	Light barrier shakes resulting in failure	Vibration of the floor	Lack of a stiffer support	N/A	N/A	N/A
5	Conveyor guides damaged	Lack of periodic plan for guides replacement	It was not forecasted on budget	N/A	N/A	N/A
6	Failure on Layer elevator referencing with conveyor plate	Due to an electrical failure in the Depalletizer panel	The equipment loses the reference and doesn't reach the conveyor height	N/A	N/A	N/A

Source: Authors, (2022).

Table 10. Action plan for quadrant C (low effort X low impact)

Actions	Responsible	Deadline	Local	Argument	Procedure
What?	**Who?**	**When?**	**Where?**	**Why?**	**How?**
Order the manufacturing of new air tubes for the filler machine.	Colaborator 7	22/05/2021	Filler Machine	To correct the irregular level problem	Manufacturing the new tubes and completing the missing kits
Provide the installation of defective valvules identification module	Colaborator 8	20/06/2021	Heuft Inspector	To correct the irregular level problem	Installing valve identification module

Source: Authors, (2022).

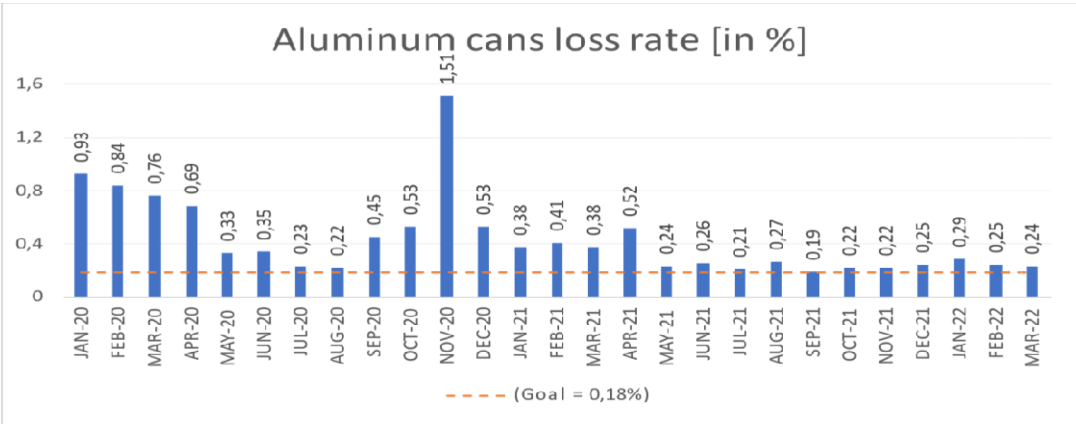
Table 11. Action plan in 5W2H format for the causes identified

Actions	Responsible	Deadline	Local	Argument	Procedure
What?	**Who?**	**When?**	**Where?**	**Why?**	**How?**
Order the manufacturing of new air tubes for the filler machine.	Colaborator 7	22/05/2021	Filler Machine	To correct the irregular level problem	Manufacturing the new tubes and completing the missing kits
Provide the installation of defective valvules identification module	Colaborator 8	20/06/2021	Heuft Inspector	To correct the irregular level problem	Installing valve identification module
Quote and buy input table for Filler Machine	Colaborator 1	30/06/2021	Filler machine	Ensuring productivity and keep loss indicator low	
Improve the size of the magazine of cardboard dividers	Colaborator 5	13/07/2021	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Quote new air tube kit for the Filler Machine	Colaborator 7	10/08/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplyingspare parts
Perform tests with stainless steel tubes and evaluate feasibility in the process	Colaborator 5	16/08/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards andsupplying spare parts
Inspect and enable the counter sensor of cans input.	Colaborator 5	26/08/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Review the trigger time of Heuft pusher.	Colaborator 6	29/08/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Review mechanical conditions of the Heuft pusher	Colaborator 5	29/08/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Notify the supplier about impact of wrapping pallets with plastic.	Colaborator 8	13/10/2021	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Quote the plates of pneumatic conveyor for the replacement	Colaborator 8	13/10/2021	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Include the air tubes in the automatic supply list.	Colaborator 4	15/10/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Perform inspections to evaluate the equipment’s conditions	Colaborator 5	13/11/2021	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Create conversion standard for the Filler Machine	Colaborator 3	20/11/2021	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Update conversion standard of the Sealer Machine	Colaborator 10	21/11/2021	Sealer machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Create a one-point lesson for Sealer Machine chucks replacement.	Colaborator 10	21/11/2021	Sealer machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Revise inspection procedure of Sealer Machine chucks	Colaborator 10	18/12/2021	Sealer machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Replace the input table of Filler Machine	Colaborator 2	15/01/2022	Filler machine	Ensuring that activities are being executed	Follow-up with the activities
Replace the conveyor rollers of the input pallets.	Colaborator 2	17/01/2022	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Create a one-point lesson about the Warmer temperature	Colaborator 12	31/01/2022	Laboratory analysis	Reduce quantity of destructive samples in analysis	Consulting normative literature and identifying opportunities to reduction
Create a one-point lesson about the Sealer Machine tests	Colaborator 12	31/01/2022	Laboratory analysis	Reduce quantity of destructive samples in analysis	Consulting normative literature and identifying opportunities to reduction
Perform survey of spare parts needed for the Filler Machine and Valves	Colaborator 3	17/02/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Include the necessary items listed as priority in the automatic supply list.	Colaborator 4	30/02/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts

Continue ….

Create a one-point lesson about the Sealer Machine tests	Colaborator 12	31/01/2022	Laboratory analysis	Reduce quantity of destructive samples in analysis	Consulting normative literature and identifying opportunities to reduction
Perform survey of spare parts needed for the Filler Machine and Valves	Colaborator 3	17/02/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Include the necessary items listed as priority in the automatic supply list.	Colaborator 4	30/02/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Perform survey of parts needed to improve the operation of the conveyor.	Colaborator 5	15/02/2022	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Replace the guides of the conveyors between the Depalletizer and the Rinser.	Colaborator 5	16/02/2022	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Revise preventive maintenance plan of the Sealer Machine	Colaborator 1	18/02/2022	Sealer machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Quote and buy a digital thermometer	Colaborator 11	18/02/2022	Laboratory analysis	Reduce amount of destructive samples in analysis	Consulting normative literature and identifying opportunities to reduction
Correct the reference program of height of the layers' elevator	Colaborator 6	18/02/2022	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Purchase and replace warped plates.	Colaborator 1	18/02/2022	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Conduct improvement survey in the pneumatic conveyor adjustments until the Rinser input.	Colaborator 5	18/02/2022	Depalletizer and Pneumatic Conveyor	Ensuring good standards for the equipment and improvements	Adjusting the equipment
Create a log book to register the losses per line segment	Colaborator 3	26/02/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Review preventive maintenance plan for the filling valves	Colaborator 8	09/03/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Quote and buy tool kits for the setups and adjustments	Colaborator 9	09/03/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Revise the procedure of valves inspection	Colaborator 7	09/03/2022	Filler machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts
Training of line operators in the new conversion standard	Colaborator 10	09/03/2022	Sealer machine	Ensure the equipment is updated and on good standards to operate	Creating and updating standards and supplying spare parts

Source: Authors, (2022).



Source: Authors, (2022).

Figure 14. Loss rate of cans before x after the implemented actions

The pattern adopted for the implementation of the actions was the 5W2H tool. Next, an action plan was established for the causes of the blue quadrant and in complements more actions of scope and review of internal procedures. Again, the 5W2H tool was used in the preparation of the action plan, as can be seen in Table 11. After the implementation of the previously listed actions, it was possible to measure the monthly can loss rates by comparing the period before the proposed actions - from January 2020 to April 2021 - and the period after the implementations - from May 2021 to March 2022, as shown in the graph in Figure 14. As can be seen, the average loss index from January 2020 to April 2021 was 0.53% and after the implemented actions, in the period from May 2021 to March 2022, the average loss was reduced to 0.26%. It was possible to observe that there was a reduction in the can loss index, considering the average of the monthly indexes, by about 0.27%. The objective of the project was to reduce the rate to 0.18%, which is the department's current target. Achieving this rate would represent a saving of $8,979 in annual operating costs. However, by reducing the rate from 0.53% to 0.26%, the annual cost reduction was around $6,926 for the company.

CONCLUSION

This paper was developed with the purpose of evaluating the reduction of operational costs related to the reduction of can losses in the production process through cause analysis and implementation of action plans in a soft drink production line in aluminum cans in a beverage industry. Using qualitative research methods, the research data were obtained through documentary research for the preparation of a case study, in which the effectiveness of the tools were tested: Six Sigma, DMAIC Method, SIPOC Diagram, Ishikawa Diagram and 5W2H, as well as their contributions to the achievement of the study objective. The results obtained were satisfactory, as they showed a reduction in the rate of can losses of approximately 0.27% in relation to the average of the period from January 2020 to April 2021, the period prior to the study, due to the implementation of the 35 improvement actions identified and implemented during the study. Therefore, the project achieved the client's expectations by providing cost reduction, from 0.56% to 0.26% of the can loss rate, which represents savings of around U$ 6,926 per year. Besides the economic aspect for the company, the importance of this study is due to the dissemination of knowledge applied to the production processes of an industrial branch (the beverage industry) that expands every day, allowing the application of the methods used in this study to drive improvements in this and other industrial segments. Some difficulties were raised during the study, such as the delay in performing stages 1 and 2 (data collection and process mapping) inherent to the complexity of the processes at the aforementioned company and the limitations of this study involved the disregard of other components whose defects do not represent the total loss of the can, such as the seal.

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REFERÊNCIAS

Harry, Mikel J.; Schroeder, Richard. Six sigma: the breakthrough management strategy revolutionizing the world's top corporations. A Currency Book, published by doubleday, a division of Random House Inc, 2000.

Formánek, Ivo. Six Sigma Method and its Applications. VŠPP Entrepreneurship studies, 2020.

Grunert, Klaus G. Food quality and safety: consumer perception and demand. European review of agricultural economics, v. 32, n. 3, p. 369-391, 2005.

Teixeira Júnior, Job Rodrigues; Cervieri Júnior, Osmar; Galinari, Rangel. Panorama setorial 2015-2018: bebidas. In: Banco Nacional de Desenvolvimento Econômico e Social (Brasil). Perspectivas do investimento 2015-2018 e panoramas setoriais. Rio de Janeiro : Banco Nacional de Desenvolvimento Econômico e Social, 2014. p. [39]-45.

Cervieri Júnior, Osmar. Panoramas setoriais 2030: bebidas. In: Panoramas setoriais 2030: desafios e oportunidades para o Brasil. Rio de Janeiro : Banco Nacional de Desenvolvimento Econômico e Social, 2017. p. [69]-78.

Osterroth, Isabel et al. Operational state related modelling and simulation of the electrical power demand of beverage bottling plants. Journal of Cleaner Production, v. 162, p. 587-600, 2017.

Schroeder, Roger G. et al. Six Sigma: Definition and underlying theory. Journal of operations Management, v. 26, n. 4, p. 536-554, 2008.

Hahn, Gerald J.; Doganaksoy, Necip; Hoerl, Roger. The evolution of six sigma. Quality Engineering, v. 12, n. 3, p. 317-326, 2000.

Green, Forrest B. Six-Sigma and the revival of TQM. Total Quality Management and Business Excellence, v. 17, n. 10, p. 1281-1286, 2006.

Virmani, Naveen; HUSSAIN, M. Z. Understanding the Need of Six Sigma in Manufacturing Industries: A Review. 2018.

Chakrabarty, Ayon; TAN, Kay Chuan. The current state of six sigma application in services. Managing service quality: An international journal, v. 17, n. 2, p. 194-208, 2007.

Flifel, AbdalhkeimFa; Zakić, Nebojša; Tornjanski, Aleksandra. Identification and selection of Six Sigma projects. Journal of process management and new technologies, v. 5, n. 2, 2017.

Virmani, Naveen; Hussain, M. Z. Understanding the Need of Six Sigma in Manufacturing Industries: A Review. 2018.

Yadav, Amit; Sukhwani, V. K. Quality improvement by using six sigma DMAIC in an industry. International Journal of Current Engineering and Technology, v. 6, n. 6, p. 41-46, 2016.

Andersson, Roy; Eriksson, Henrik; Torstensson, Håkan. Similarities and differences between TQM, six sigma and lean. The TQM magazine, 2006.

Sokovic, Mirko; Pavletic, Dusko; Pipan, K. Kern. Quality improvement methodologies–PDCA cycle, RADAR matrix, DMAIC and DFSS. Journal of achievements in materials and manufacturing engineering, v. 43, n. 1, p. 476-483, 2010.

Sin, Ang Boon et al. Structural equation modelling on knowledge creation in Six Sigma DMAIC project and its impact on organizational performance. International Journal of Production Economics, v. 168, p. 105-117, 2015.

Ahmed, Selim. Integrating DMAIC approach of Lean Six Sigma and theory of constraints toward quality improvement in healthcare. Reviews on environmental health, v. 34, n. 4, p. 427-434, 2019.

Brown, Charlie. Why and how to employ the SIPOC model. Journal of business continuity & emergency planning, v. 12, n. 3, p. 198-210, 2019.

Parkash, S.; Kaushik, Veerender Kumar. Supplier Performance Monitoring And Improvement (SPMI) Through Sipoc Analysis And Pdca Model To The Iso 9001 QMS In Sports Goods Manufacturing Industry.LogForum, v. 7, n. 4, 2011.

Yang, Kai & El-Haik, Basem. (2008). Design for Six Sigma: Roadmap to product development, McGraw-Hill, 2a Edição.

Paladini, Edson Pacheco et al. Gestão da qualidade: teoria e casos. Rio de Janeiro: Campus, 2012.

Pacaiova, Hana. Analysis and identification of nonconforming products by 5W2H method. Center for Quality, 2015.

Yin, Robert Kin. *Case study research and applications: design and methods.* Sixth edition. Los Angeles: SAGE, 2018.

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