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Application of Quality Management Tools to Reduce Costs with Scrap in the Automated Teller Machine Industry

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Abstract:
Background*: Globalization has increased competitiveness among markets and consequently, companies have sought to optimize their production processes to reduce scrap and production costs through the implementation of advanced technologies and quality tools. The quality tools facilitate the resolution of problems that interfere with the good performance of the process, product, or service and enable the continuous improvement of the processes, contributing to the scrap reduction and increasing customer satisfaction and reducing the costs of non-conforming materials. The objective of this study is to reduce financial losses associated with scrap generation through the introduction of quality tools applied to the production process in the automated teller machine industry.*
Materials and Methods*: The research methodology used was the case study applied in company of Manaus Trade Zone. A literature review was conducted regarding the most relevant quality tools to solve problems used currently in the industry. Process mapping (flow chart) and brainstorming were used to identify the bottlenecks that prevent the scrap reduction. Furthermore, pareto Diagram, trend Graph, scatter diagram, 5 Whys Analysis and 5W2H were employed in this study.*
Results*: Through the Pareto diagram it was possible to identify the card reader was the main cause of rejection, and along with 7 other items accounted for 78% of the 2018 and 2019 rejection costs. By using the 5W2H tool, it was possible to implement action plans to solve the problems identified, which generated a significant reduction of the rejection costs raised in 2020.*
Conclusion: *The results pointed out that the quality tools are effective for identifying causes and solving problems related to scrap. From 2018 to 2020 the reduction was 95% and continued consistently in 2021, showing that the problem had been consistently solved.*
Key Word: *Quality tools; Scrap; Cost reduction.*

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I. Introduction

The globalization has led to an increase in competitiveness among markets, companies have been incessantly seeking to improve their production processes in order to reduce scrap and production costs. To optimize processes, the industry has invested in the implementation of advanced technologies and has also sought to apply different quality tools, ranging from traditional tools to more modern methods, including the Six Sigma DMAIC methodology and Lean Six Sigma.

DMAIC is used to improve an existing process and refers to the steps of Define, Measure, Analyze, Improve, and Control. On the other hand, Lean Six Sigma is a well-structured methodology that aims to eliminate waste and non-value-added activities, focuses on reducing variation in processes, eliminates defect causes, and improves performance. As a result, cost reduction, higher quality and customer satisfaction is observed. (CANÇADO, TORRES, 2019).

Another objective of using quality tools is to improve customers satisfaction and make the company more competitive in the market. Undoubtedly, quality techniques and technological advances interfere in the competitiveness of companies.

Paladini (2004) states that considering the aspect of meeting customers' needs, Quality Management is directed to the creation of a quality culture in organizations. In the current context it is also important to highlight the great challenge that companies have been facing with the Covid-19 pandemic, where the scarcity of raw materials has worsened, and procurement costs have practically tripled. Thus, it is necessary to have a process where the maximum use of available raw materials can be guaranteed, because an unscheduled loss may lead to delayed delivery to the customer and subsequent fines and even the breach of a pre-established contract.

These process losses or materials waste are known in the industry as scrap and are not easily noticed, because they are hidden throughout the production, being seen as natural consequences of the production process, making them accepted in manufacturing until the costs take a dimension that harms the company.

Thus, the scrap reduction contributes directly to reducing the cost of production and influences the planning, cost control and management expenses. As a matter of fact, industrial processes constantly demand scrap reduction and, at the same time, ensure product quality in order to meet and exceed customer requirements and expectations (STARK apud SALES, 2020).

By considering the scrap problem, the opportunity is to apply the quality tools so that the production processes in the automated teller machine (ATM) manufacturing are controlled and optimized in terms of costs. Unfortunately, companies that lack efficiency in their production processes rarely can remain stable in the market (SANTOS et al., 2020).

This research is justified by the demand of companies to control the manufacturing process of ATMs and contributes to the identification of mechanisms to reduce scrap in the industrial environment which directly impacts the costs in this branch of manufacturing. Thus, the potential for scrap reduction provides the development of competitive advantage for the organization.

In Brazil, there are two large multinational companies in the ATM industry. However, it is not common to find in the literature research on scrap reduction during the production process. This project contributes to the expansion of studies related to the optimization of ATM manufacturing processes using quality tools.

Furthermore, applying quality tools to reduce process waste can bring medium- and long-term benefits to companies, which will reflect in customer satisfaction and cost reduction due to the rejection of non-conforming materials. Therefore, the main objective of this work was to reduce financial losses through the introduction of robust quality tools applied to the production process in the ATM industry.

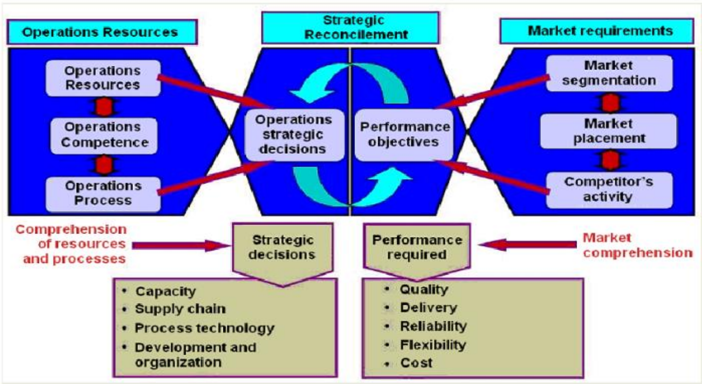
II. Review of Literature

According to Pereira et al. (2015), production management is responsible for the production of goods and services in companies and has been becoming increasingly specialized due to the several changes that have been occurring worldwide, which make the economy more integrated and competitive.

For Jacob and Chase (2009), production management is related to the execution of work quickly, efficiently, without errors, at a low cost, and at a level of service that meets customer needs. He also adds that it is focused on actions related to the supply of services and products.

Slack et al. (2002) highlights that the most useful method for modeling production is represented by the input-transformation-output system shown in figure 1. All operations can be described using this model. Input resources can be classified as transformation resources (plant and employees) that act toward the transformed resources (materials, information, and customers) that are transformed by production.

Figure 1 - General Production Management Model and Production Strategy



Source: Slack et al. (2002)

Quality Concept

Defeo and Juran (2015) define Quality as "fitness for purpose as defined by customer needs". This definition is widely used by companies that are involved in quality control or continuous improvement programs.

The concept of quality has received various attributions throughout history. In the management field, quality can be defined as "a set of properties and characteristics of a product, process or service that provide it with the ability to satisfy explicit and implicit customer needs". (ARRUDA, SANTOS & MELO, 2016).

Quality is determined by the customer, through their experiences with the product or service, and being adjusted through their perceived needs.

Scrap concept

Scrap comes from the English language whose meaning is fragment or small piece, when we say that a piece was scrapped it means that it is not good for use and must be discarded because it is no longer suitable to be used in the production process. For Sales (2020), scrap is defined as material that is unusable during the production process due to deviations from technical specifications. Because it does not meet the dimensional and quality standards, rework is impossible, classifying it as scrap.

Large companies are increasingly pressured to increase their efficiency, and search for methods that help reduce their production unit costs, which is directly related to the product's final price. Thus, scrap reduction would be one of the ways to reduce production cost. Scrap reduction is important in several aspects, especially for planning and managing cost control, because it is through this that one can measure production efficiency (STARK apud SALES, 2008).

According to Rotta and Paulo (2017), to eliminate scrap effectively, it is necessary to find the root cause of the problem, which can be accomplished through lean manufacturing tools. According to Werkema (2006) the main tools used to put into practice the principles of the Lean Mindset are Value Stream Mapping (VSM), Lean Metrics, Kaizen, Kanban, Standardization, 5S, Setup Reduction, Total Productive Maintenance (TPM), Visual Management, and Poka-Yoke.

However, the literature also shows numerous examples of the application of traditional quality tools for scrap reduction. Furstenau et al. (2019), points out that no tool is more important than another, but that all are applicable in different situations.

Quality tools

Quality tools are means that facilitate the problem solving that may interfere with the good performance of a process, product or service, and enable process improvement, thus allowing organizations to identify the cause of a problem and thus make decisions for its resolution (PACHECO et al., 2011).

According to Furstenau et al. (2019) the following quality tools are widely used to solve problems in the industry:

1. Pareto diagram which has the intention of identifying the cause that impacts most on a particular problem.
2. Ishikawa Diagram, also known as Cause-and-Effect Diagram or Fishbone Diagram, which aims to identify the root causes.
3. The GUT tool (severity, urgency, and trend), which helps determine which problems must be solved first.
4. The 5W2H tool, which aims to propose improvements and solutions for problems in general.
5. The flowchart that facilitates the visualization and understanding of the processes.
6. The check sheet, which is a way to present and visualize data.
7. Control chart that provides a faster and more comprehensive visualization of the data from a check sheet.
8. Dispersion or correlation diagram is used to prove the relationship between a cause and effect.
9. Brainstorming, known as brainstorming, assists in generating ideas for problems in general.
10. Stratification that allows to separately analyze data that assists in the identification of the problem. (FURSTENAU, 2019).

III. Material And Methods

This research is qualitative and quantitative in nature. From the quantitative point of view, it considers everything that can be quantifiable with the aim of translating into numbers, opinions, and information to subsequently classify and analyze them (SILVA; MENEZES, 2005). The research also has a qualitative character, since it uses the case study to undertake a detailed examination of the data within a given context (KOHLBACHER, 2006).

From the quantitative perspective, the data were presented in the form of tables and different types of graphs. On the other hand, the qualitative data analysis made use of the following instruments: narrative and descriptive texts, schemes, and flowcharts.

Study Location: The location of this research was in Manaus, Amazon, Brazil. The company manufactures ATM (electronic teller machines) and serves 10 clients located in the national territory.
Study Duration: The project was carried out between the years 2018 to 2021.
Statistical analysis: The data were entered into a spreadsheet in Microsoft Office Excel 2013 and later, the graphs were plotted through Excel, Minitab, and Software free R.

IV. Procedure methodology

To build the theoretical foundation, a literature review was conducted to obtain information that would support the concepts and tools used in Quality Management. We used materials published in books, magazines, articles, dissertations to obtain updated information on the subject.

In terms of quality tools used in the case study, process mapping (flow chart) and brainstorming were used to identify the bottlenecks that prevent the reduction of scrap values in the production process of the company studied.

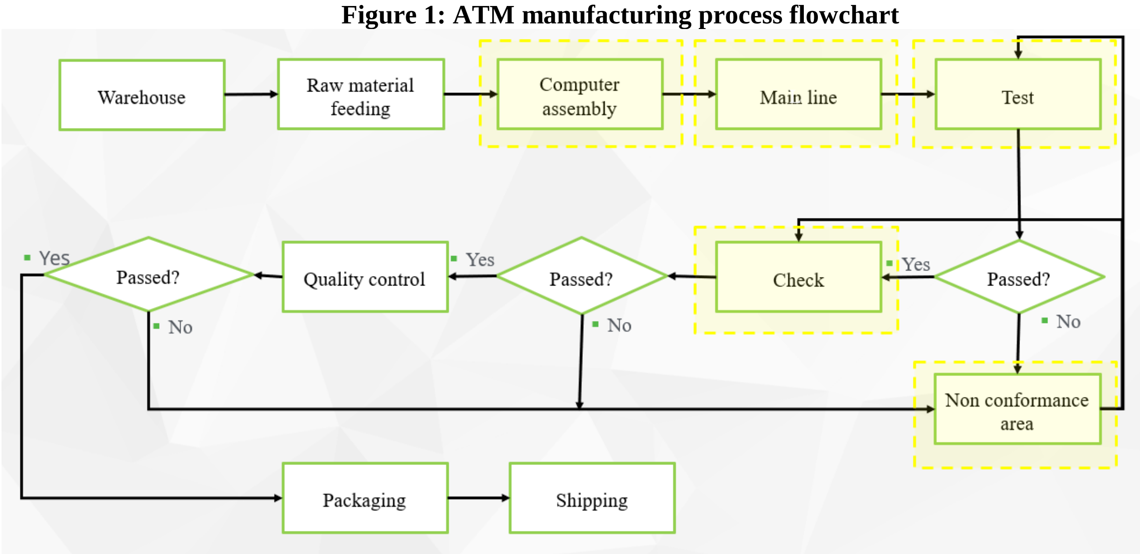
In addition, the following quality tools were used to identify the work posts that cause more scrap, as well as the main causes of raw material scrap in the production process: pareto diagram, 5-why analysis, trend chart, scatter diagram, and 5W2H.

To obtain primary data, a database was collected from the period 2018 to 2021, based on the company's records of raw material rejects available in the production area, where the type of rejects, the quantity, and the costs associated with the loss of defective parts are listed.

V. Result

The scrap project started mapping the process to identify in which steps scraps were being generated. The process flowchart is represented by the figure 1. The first step begins with the raw material incoming at the warehouse. After that, kits are separated to be fed into the computer assembly stage. Once assembled, it will be sent to the main line to be placed together with the other items in the ATM. The next step in the process is to perform functionality tests of the ATM system. If it passes the test, a compliance check is performed. Otherwise, it is sent to the area of non-conforming material.

Figure 1: ATM manufacturing process flowchart

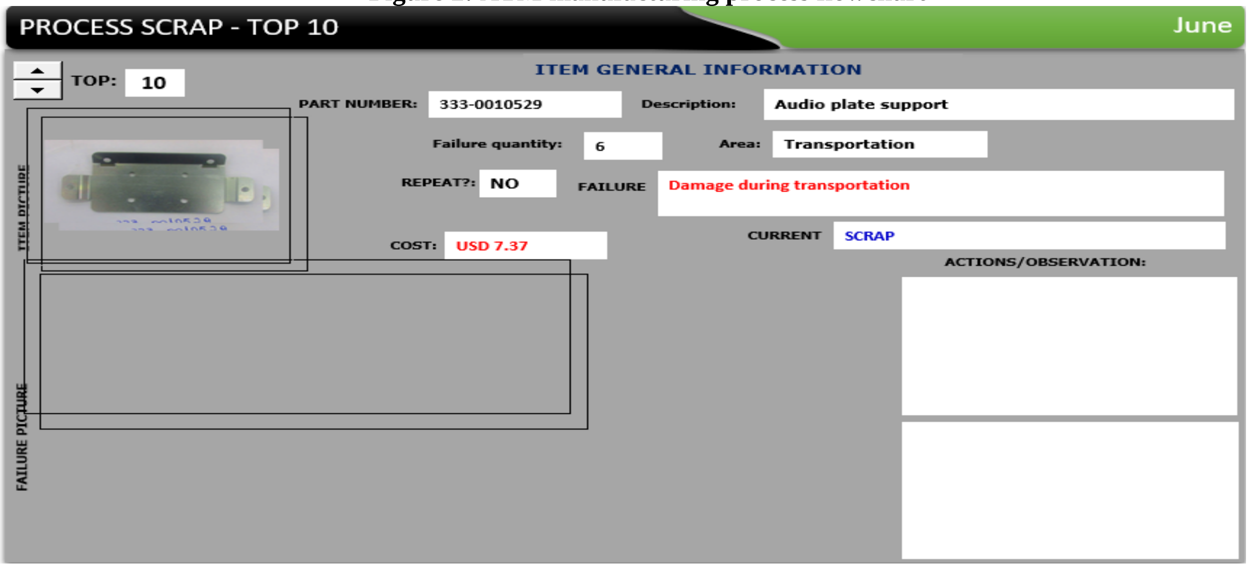


Source: Elaborated by the authors, 2022.

In order to improve the data gathering, a form was developed by the company's quality area to record the non-conforming material generated during the process. The form contains the following information: date, supplier name, process type, detail of the failure and the area. Using the data obtained through this nonconforming material form, it was possible to capture the failure, the quantity of defective parts, the origin of the failure, and the area where the failure was detected.

Furthermore, an electronic system was created to monitor every defective part detected in the company during the inspection process. The objective of this tool, shown in figure 2 was to register the part number, failure quantity, if the failure is repeated or not, the material cost, material description, as well as to capture the failure modes and areas that generate each type of scrap. This system sends data to an excel sheet which can be used later to analyze the data.

Figure 2: ATM manufacturing process flowchart

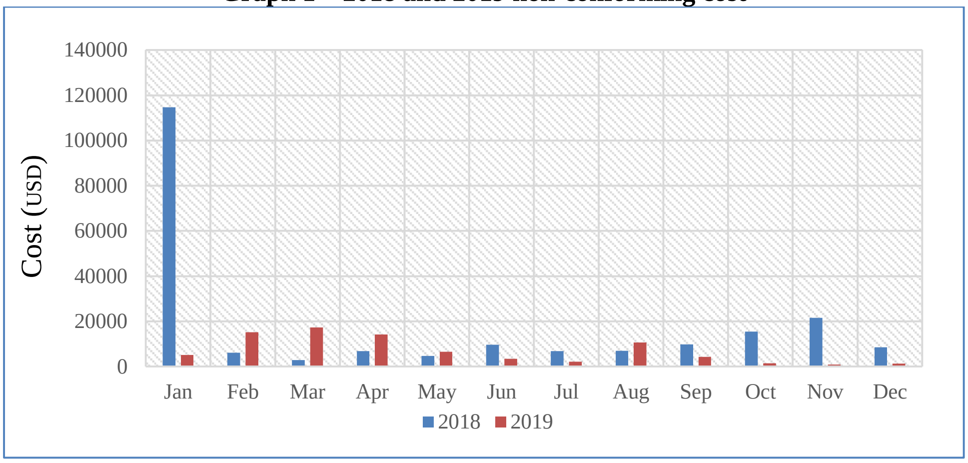


Source: ATM Company, 2019.

Based on the scrap data, the possible failures identified in the components and associated costs were raised. A Brainstorming session was held with the participation of employees from production, quality and engineering. The main failures found in the ATM manufacturing process were: broken glass, damaged board, scratched monitor, damaged front panel, damaged module, scratched plastic parts, and damaged labels. The work team began the data analysis by evaluating data from scrap 2018 to December 2019 to understand what the main opportunities and causes of the defects.

In addition, the scrap costs from 2018 to 2019 were evaluated. Graph 1 shows costs that occurred over the these two years. In January, a high loss was recorded due to a special cause, operational failures after staff returned from vacation and other causes related to newly launched models, especially need for fast deliveries without the time needed for staff training.

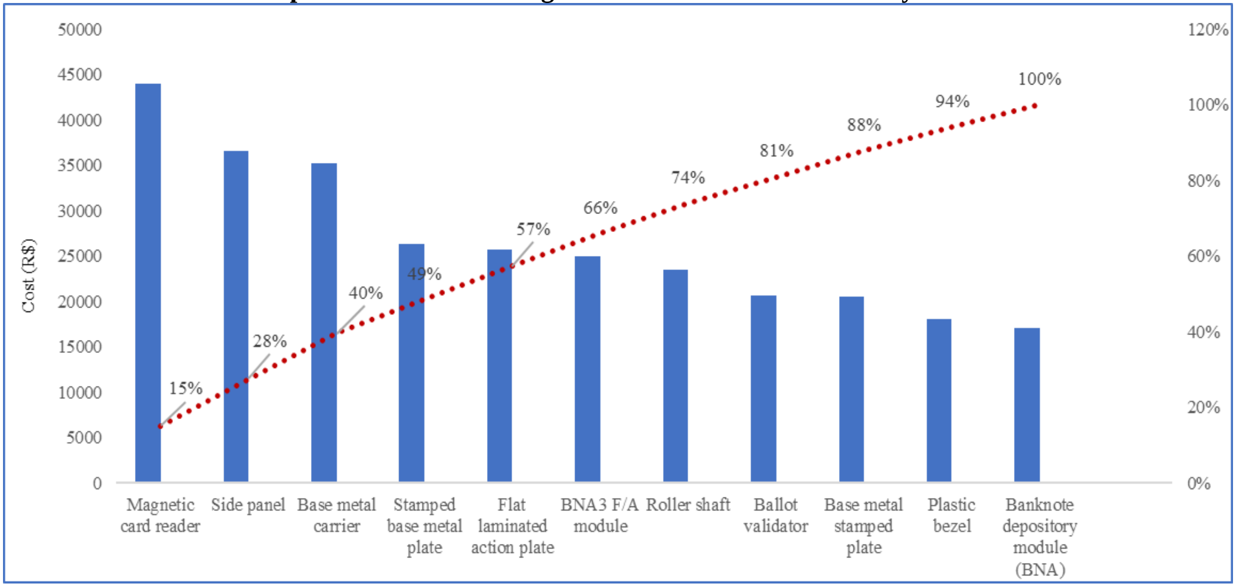
Graph 1 – 2018 and 2019 non-conforming cost



Source: Elaborated by the authors, 2022.

The Graph 2 shows the scrap data for the 11 materials that contributed the most in terms of rejection cost in 2018 and 2019. From those, the following eight types of defects represent 81% of the reject cost: magnetic card reader, side panel, base metal carrier, stamped base metal plate, flat laminated action plate, BNA module, roller shaft and ballot validator. All this items together represented approximately 236 K USD of rejection cost.

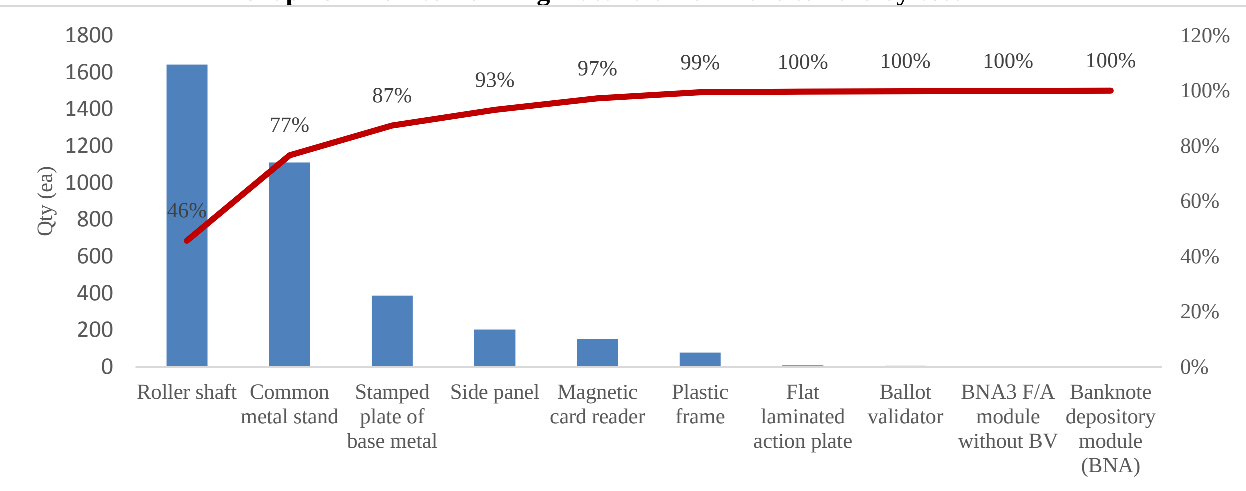
Graph 2 – Non-conforming materials from 2018 to 2019 by cost



Source: Elaborated by the authors, 2022.

Regarding the number of defective items, the scrap quantity refers to rolling axes, common metal stand and stamped plate that represent 87% of the total defective items, as shown in graph 3. As we can see, there is an important difference in terms of items that contribute to rejection cost and quantity. Three failure modes rolling axes, stamped base metal plate and magnetic card reader appear as drivers for rejection for both cost and rejected quantity.

Graph 3 – Non-conforming materials from 2018 to 2019 by cost



Source: Elaborated by the authors, 2022.

Based on the major failures found in the years 2018 and 2019, a 5-Why cause analysis was performed to investigate the root causes. Table 1 is an example that shows how the root cause analysis was performed for three main causes: magnetic card reader, top of the safe warped and rusty metal bracket. The same approach was applied to all failure modes identified during the analysis.

Table 1 – 5WHYs Analysis

Probable cause	**1º Why** (why this problem is occurring?)	**2º Why** (why the the answer to the 1st why is it occurring)	**3º Why** (Why is the answer of the 2nd why occurring)	**4º Why** (Why is the answer of the 3rd why occurring?)	**5º Why** (Why is the answer of the 4th why occurring	**Solution (**What is the problem solution?)
Magnetic card reader with reading failure	Reader does not read the magnetic card	Card reader has a faulty reading head	The supplier did not perform the correct calibration	Failure occurred in the supplier verification process		Supplier to fix the verification process of the card reader
Roller shaft	Items with oxidation	Due to excessive time in unused stock	There was no demand for use, and at the time of use they were oxidized			Rework the material Review the stock parameters to avoid losses
Common metal stand was Rusty	Support with rust due to the time of transport of the piece	The specification calls for oil protection of the part and it was not applied correctly	The supplier did not follow the oil protection process on all parts	Operational failure has occurred	There was no instruction in the supplier's packaging process	Cleaning and removal of oxidation by the supplier performed by a third party

Source: Elaborated by the authors, 2022.

The implementation team of the scrap reduction project sought to apply the Ishikawa diagram, but as all defects were in the category of materials, the application of this tool would not add value to the project, and the 5 Whys tool was already sufficient to identify the root causes. From the causes identified in the 5 Whys analysis, the action plan was established, through the 5W2H tool, shown in table 2:

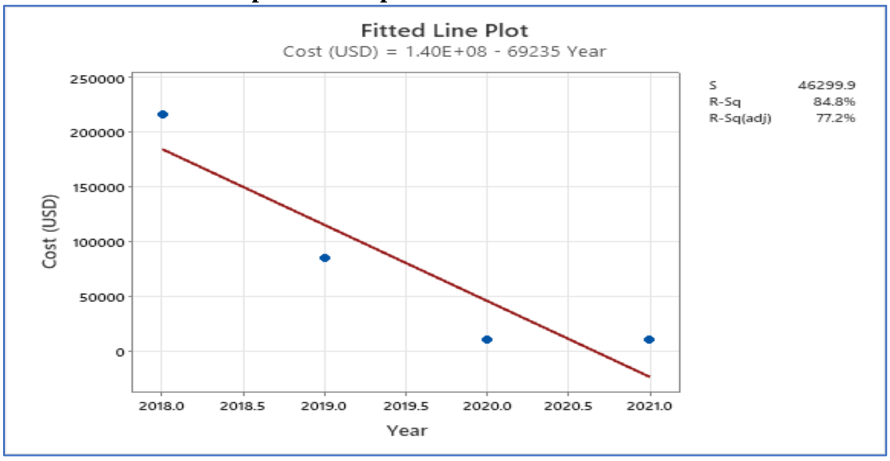
Table 2 – 5W2H

5W						**2H**	
#	**What?**	**Why?**	**Where?**	**Who?**	**When?**	**How?**	**How much?**
1	Material rework in DMC - Scrap	Reduce the amount of material in DMC stock	DMC area	Operator	30-mar-19	Hire outsourced labor - GC	R$ 2,185
2	Send material for zinc plating	Reworking the oxidized material	Samauma third party	Operator	30-abr-19	Send material to Samaúma	R$ 3,185
3	Testing card readers in production	Revalidate the fault and perform the repair of the modules	MFG	Operator	30-abr-19	Technicians of the revalidate process	-
4	Send rejected readers to the supplier	We have no repair parts for repair	DMC area	Operator	30-mai-19	Send material to Supplier	R$ 2,300
5	Fix the depository modules (BNA)	Reduce the number of modules in the DMC as much as possible	MFG	Operator	30-jun-19	Unification of Modules	-
6	Send back the ballot validator to the supplier	We have no repair parts to fix	India	Operator	30-ago-19	Send air modal	R$ 4,500
7	Send the top to straightening	There is no way to straighten at the factory	Third party	Operator	30-out-19	Send the material to Usifam	R$ 1,200

Source: Elaborated by the authors, 2022.

In 2019, after the actions were taken, the work team gathered additional scrap data, mainly related to cost reduction. The scrap project was extended until the year of 2021, when a significant reduction of scrap was observed, as shown in graph 4. From 2018 to 2020 the reduction was 95% and remained flat in 2021, showing that the established action plan was quite effective.

Graph 4 – Scrap Trend from 2018 to 2021

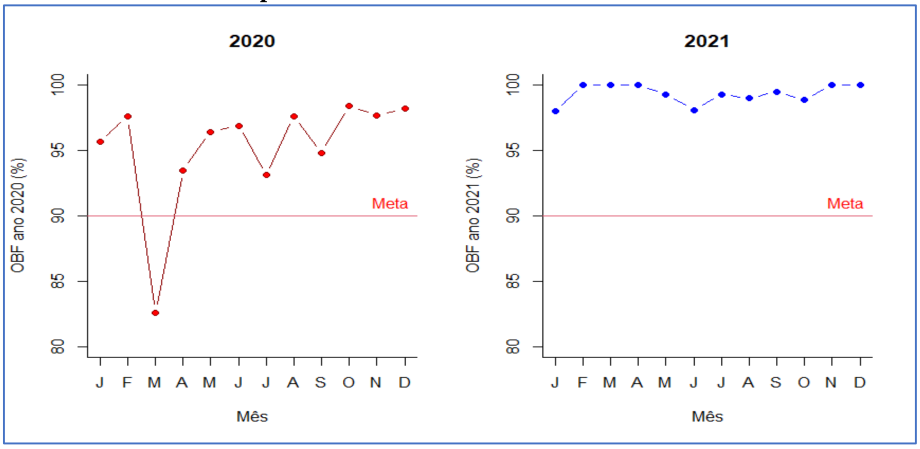


Source: Elaborated by the authors, 2022.

In order to guarantee the sustainability of the results achieved with the scrap reduction project, top leadership included two scrap-related indicators in the Site's scorecard: OBF % and ATM OPSD %.

The OBF% (out of box failure) shown in graph 5 represents the % of ATMs that did not fail during installation. The target set for this indicator was 90%. The performance was very low in the month of March 2020 but has already reached great levels in all months of 2021. We can see a signification improvement, when we compare 2020 to 2021 graphs.

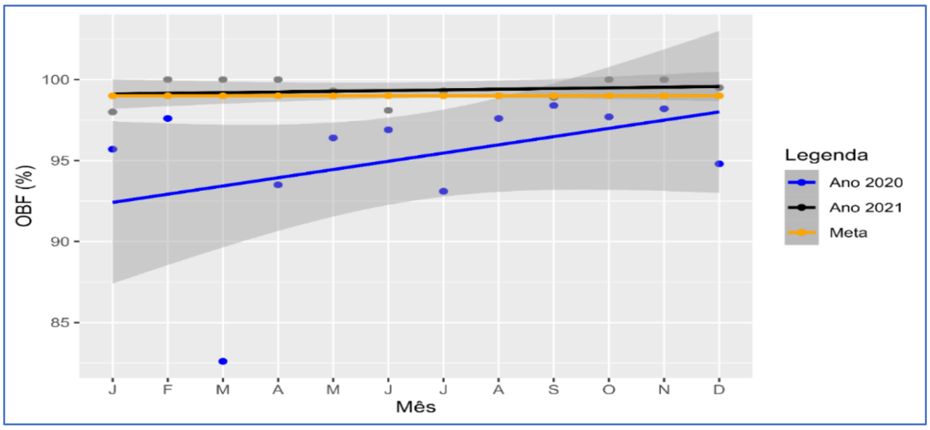
Graph 5 - Indicador OBF% de 2020 e 2021



Source: Elaborated by the authors, 2022.

Graph 6 shows the variability and the trend line over the months measured by the confidence interval related to scrap: OBF % in the years 2020 and 2021.The data shows that in 2021, the variability was significantly lower than that of 2020.

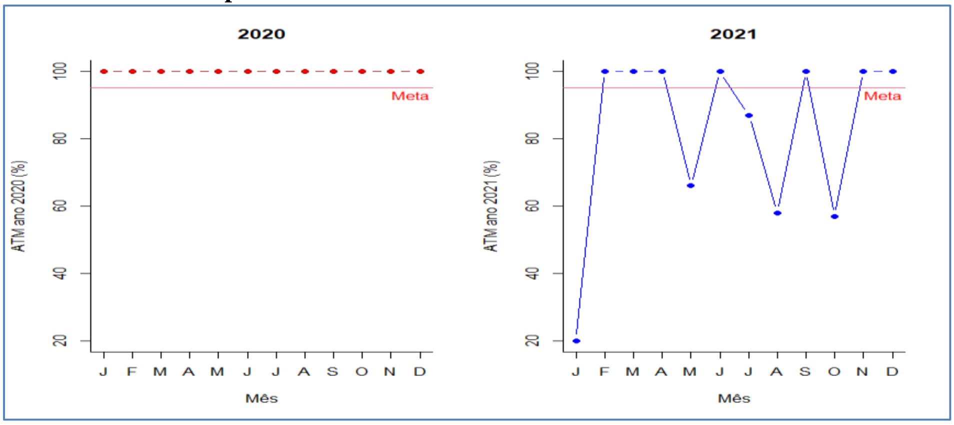
Graph 6 – Variability and trend of the OBF% Indicator for 2020 and 2021



Source: Elaborated by the authors, 2022.

On the other hand, ATM OPSD% measures the percentage of ATMs delivered to the customer on time. Graph 7 shows the behavior of this indicator in the years 2020 and 2021. In 2021, some months presented results below the target, especially in April, August, and October.

Graph 7 - ATM OPSD Indicator% of 2020 and 2021



Source: Elaborated by the authors, 2022.

VI. Discussion

This study began with a literature review on production management, followed by the definition of the concept quality, which is related to the degree of satisfaction of the product requirements set. Subsequently, the term scrap, which is commonly used in the company as material loss, was studied.

The literature review covered the following and main quality tools used in the industry for defect reduction:

- Pareto diagram, used to identify the cause that impacts most on a particular problem.
- Ishikawa diagram, used to identify root causes.
- The GUT tool (gravity, urgency and trend) that helps prioritize the resolution of problems.
- The 5W2H tool that aims to propose improvements and solutions to problems.
- The flowchart that facilitates the visualization and understanding of processes.
- The check sheet, which is a way to present and visualize data.
- Control chart, which provides a faster and more comprehensive visualization of the data from a check sheet.
- Scatter or correlation diagram which is used to prove the relationship between a cause and effect.
- Brainstorming, known as brainstorming, assists in generating ideas for problems in general.
- Stratification that allows you to separately analyze data that assists in identifying the problem;
- 5 Whys analysis which is commonly used in industry for cause analysis.

However, as the object of study, the following tools were selected: brainstorming, pareto diagram, 5-why analysis, Ishikawa diagram, trend chart, and 5W2H action plan, because they are the most widely employed tools in the industry that showed greater effectiveness in problem solving. For the analysis of the causes of scrap failures, the 5 Whys analysis has already shown to be efficient, being redundant the application of the Ishikawa diagram since all failures would be within the category of materials.

With the application of the process mapping, it was possible to identify the scrap-generating areas and lines and define a process to capture rejects, using the non-conforming product form and the scrap registration system. After the mapping, the pareto chart was used, where it was possible to break down the 2018 and 2019 data by cost and quantity of nonconforming items. For the four failures with the highest quantity, trend graphs were created to understand the behavior of the data over time.

Based on the main failures found in 2018 and 2019, a 5-Why cause analysis was applied for root cause investigation and the 5W2H tool was applied to define the actions, responsible parties, and deadlines. After the actions taken, there was a significant reduction in material rejects. From 2018 to 2020 the reduction was 95% and remained consistently in 2021, showing that the established action plan was effective.

To ensure the sustainability of the results obtained over the years with the scrap reduction project, the results were presented at a monthly meeting of top leadership, where the OBF % and ATM OPSD % indicators were evaluated. Both indicators showed results above the established goal of 90% and 95%, respectively.

VII. Conclusion

The quality tools were applied throughout the production process at the workstations that caused raw material rejections. It was identified through the pareto chart, which lines presented more rejects, the causes were identified, and corrective actions were established to tackle the root causes.

Furthermore, device and tools were developed to reduce scrap and increase quality in the ATM production process of a company in the industrial district of Manaus: two tools were created to capture and manage data: the non-conforming material sheet and the scrap register system.

The results pointed out that the quality tools are effective for identifying causes and solving problems related to scrap. From 2018 to 2020 the reduction was 95% and continued consistently in 2021, showing that the problem had been consistently solved.

References

[1]. ARRUDA A. I.; SANTOS, E. C. A.; MELO L. S. S. (2016). Análise da Gestão da Qualidade em Uma Indústria de Alimentos: enfoque nos princípios em Caruaru – PE: Estudo Sobre a Utilização das Ferramentas da Qualidade. ENEGEP.

[2]. CANÇADO, T. O.B; CANÇADO F.B; TORRES, M, L,A. Lean Seis Sigma e Anestesia. Revista brasileira de Anestesiologia. 13 de Setembro de 2019.

[3]. DEFEO J. A; JURAN J. M. Fundamentos da qualidade para líderes. Tradução: Ronald de Menezes. 1ª edição, Porto Alegre, Editora Bookman, 2015.

[4]. FURSTENAU, L. B. et al. Utilização das ferramentas da qualidade para redução de perdas de produção em máquina CNC. 2019.

[5]. JACOB, F.R; CHASE R. Administração da produção e operações – O essencial. São Paulo, Editora Bookman, 2009.

[6]. KOHLBACHER, Florian. The Use of Qualitative Content Analysis in Case Study Research. Forum Qualitative Social Research, Vol 7, Art 21, 2006.

[7]. PACHECO et al. Ferramentas da qualidade: estudo da sua aplicação e uso nas organizações certificadas. ENEGI 2011.

[8]. PALADINI, E. P. Gestão da qualidade: teoria e prática. 2.ed. São Paulo: Atlas, 2004.

[9]. PEREIRA et al. Administração de Produção e Operações: Evolução, Conceito e Interdisciplinaridade com as demais Áreas Funcionais. XII SEGET.

[10]. ROTTA, I. S.; PAULO M. A influência dos aspectos comportamentais na aplicação de ferramentas lean para a redução de scrap: um estudo de caso. Revista Produção em Foco, Intituto Superior Tupy, Santa Catarica, 2017.

[11]. SLACK et al. Administração da Produção – Edição Compacta. São Paulo: Editora Altas, 2002.

[12]. SALES, R.G. Mapeamento dos defeitos em processos de soldagem MIG/MAG robotizado com foco em popostas de melhorias na redução de scrap: estudo de caso em uma empresa do segmento automotivo. Dissertação (Mestrado em Engenharia de Produção). UNESP, Guaratinguetá, São Paulo, 2020.

[13]. SANTOS et al. Avaliação estatística da Variabilidade de medida no processo de gesso. Encontro Nacional de Engenharia de produção, 40, 2020. Foz de Iguaçu. Rio de Janeito, 2020.

[14]. SILVA, E; MENEZES, E. Metodologia da Pesquisa e Elaboração da Dissertação. 4ª Edição, Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, 2005.

[15]. SILVA et al. Aplicação da metodologia Seis Sigma para melhoria contínua da qualidade da em uma indústria alimentícia. Revista Produção Online. Florianópolis, 2020.

[16]. WERKEMA, C. Lean Seis Sigma – Introdução às Ferramentas do Lean Manufacturing. Belo Horizonte: Werkema Editora, 2006.

Suede Rodrigues. "Application of Quality Management Tools to Reduce Costs with Scrap in the Automated Teller Machine Industry." *IOSR Journal of Business and Management (IOSR-JBM)*, Vol.25, No. 04, 2023, pp. 15-24.