A STUDY OF REDUCTION OF PRODUCTION STOPS IN A PACKAGING INDUSTRY IN THE CITY OF MARINGÁ – PR

UM ESTUDO DE REDUÇÃO DE PARADAS DE PRODUÇÃO EM UMA INDÚSTRIA DE EMBALAGENS NO MUNICÍPIO DE MARINGÁ – PR

ESTUDIO SOBRE LA REDUCCIÓN DE LAS PARAS DE PRODUCCIÓN EN UNA INDUSTRIA DE EMBALAJES DEL MUNICIPIO DE MARINGÁ – PR

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ABSTRACT

Businesses are currently under intense consumer pressure to offer lower-priced products. As a result, many are reducing prices through cost reduction, but they need some simple techniques to achieve this desired reduction. In this context, machine problems related to unplanned stops and downtime increase their costs. This study discusses the application of the Method of Analysis and Solving Problems (MASP) to reduce machine downtime in a paper packaging company's production sector. For this application, we use the eight steps of the MASP, considering quality and process improvement tools as a cause-and-effect diagram, a Pareto chart, and 5W1H. These tools made it possible to carry out a more effective analysis process so that it was possible to find the causes of machine downtime in the thermoforming sector. After identifying these causes, supervisors and employees proposed an action

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plan, executed it, and they standardise those activities. The MASP results in an easy way to find solutions to the described problem.

Keywords: Machine Stops; MASP; Processes improvement.

RESUMO

Atualmente as empresas enfrentam grande pressão dos consumidores por produtos com preços mais baixos. Sendo assim, uma das formas de se garantir a redução dos preços é por meio da redução de custos. Nesse contexto, este estudo abrange a utilização da Metodologia de Análise e Solução de Problemas (MASP) para buscar a redução de paradas de máquinas no setor da produção de uma empresa de embalagens de papel. De maneira geral, a metodologia proposta abrangeu as oito etapas da MASP. Em certas etapas foram utilizadas ferramentas da qualidade e de melhoria de processo, diagrama de causa e efeito, gráfico de Pareto e 5W1H. Essas ferramentas possibilitaram a realização de um processo de análise mais eficaz, de modo que foi possível encontrar as causas das paradas de máquinas do setor de termoformação. Após a identificação dessas causas, foi possível estabelecer um plano de ação propondo soluções, este plano de ação abrangeu ações, em seguida foi executado as ações e padronizadas.

Palavras-chave: Paradas de Máquinas; MASP; Melhoria de processos.

RESUMEN

Hoy en día las empresas se enfrentan a una gran presión por parte de los consumidores para que ofrezcan productos a precios más bajos. Por lo tanto, una de las formas de garantizar la reducción de precios es mediante la reducción de costos. En este contexto, este estudio abarca el uso de la Metodología de Análisis y Solución de Problemas (MASP) para buscar reducir los tiempos de parada de máquinas en el sector productivo de una empresa de envases de papel. En general, la metodología propuesta cubrió las ocho etapas del MASP. En ciertas etapas se utilizaron herramientas de mejora de calidad y procesos, como diagramas de causa y efecto, diagramas de Pareto y 5W1H. Estas herramientas permitieron realizar un proceso de análisis más efectivo, de manera que fue posible encontrar las causas de paradas de máquinas en el sector del termoformado. Luego de identificar estas causas, se logró establecer un plan de acción proponiendo soluciones, el cual incluyó acciones que luego fueron ejecutadas y estandarizadas.

Palabras clave: Paradas de máquinas; MASP; Mejora de procesos.

1 INTRODUCTION AND THEORICAL BACKGROUND

With the globalised economy and increased competition among businesses, there is a demand for high-quality, well-planned production. As a result, in order to reduce costs and maintain market competitiveness, modern businesses must constantly identify existing sources of waste. Organisations are under pressure to constantly evolve and reduce waste in this competitive environment (FOGLIATTO; RIBEIRO, 2009). In that way, companies must reduce the number of failed products, particularly those caused by equipment breakdown on the factory floor (FOGLIATTO; RIBEIRO, 2009).

According to Antunes et al. (2008), seven types of waste have consequences, such as increasing process time, decreasing operational performance, and increasing costs. In the industrial context, machine downtime contributes to increased waiting time and waste process time. According to Moschin (2015), machine downtime occurs when maintenance is required due to problems affecting their performance. Furthermore, the author claims that it is impossible to eliminate machine downtimes, but it is possible to improve the process using planned periodic shutdowns for maintenance. Therefore, maintenance activities aim to ensure that machines do not stop excessively, thereby maintaining the equipment's performance, particularly in terms of reliability, safety, and cost (PINTO; XAVIER, 2009). Consequently, it is critical to developing adequate maintenance activity planning to ensure the operational efficiency of the companies' production processes.

According to the Brazilian Packaging Association (2021), the packaging sector has a significant economic impact on the Brazilian economy, growing by approximately 7% in the first quarter of 2021 compared to the same period the previous year. To show how to develop the maintenance activities, we applied the MASP in a company of paper-packaging production. The studied company experiences a high level of machine downtime. This company intends to expand its market, so it needs ways to improve operational efficiency by reducing process downtime to meet customers' requirements within the appropriate timeframe.

Aside from the practical significance already mentioned, this paper aims to show how the MASP helps structure and reduce machine downtime. This selection covers the lack of research on reducing machine downtime in packaging production industries. This application has the potential to be a guide for the investigation of equipment breakdown in the context of industries specialising in packaging production

This paper contains five sections. The first one describes the context and the research gap. The second section discusses the study's methodological steps, and the third section presents the findings and discussion of the study. Finally, we present the discussion and final conclusions in the fourth section.

2 METHOD

This paper presents a case study in a company of paper packaging production to show the application of MASP for reducing downtime machines. This section presents the methodological structure of the article. First, we present some characteristics of the studied company. Then, we outlined the eight MASP steps to follow during the study.

2.1 Company Characterisation

The research was conducted in a kraft paper packaging industry in Maringá, PR, which employs approximately 70 people. This company began operations in 1972 and has customers all over Brazil. Furthermore, the company has different sectors (purchasing, production, production planning and control, as other sectors). The research focuses on the production sector, specifically the thermoforming process.

2.2 MASP steps

The research followed a qualitative and quantitative approach, as assessments and data analysis were conducted to identify the company's causes of machine downtime and determine which sector had the most stops. A survey of data from the planning sector, production control, maintenance, and sales was required to develop the exploratory research. The data was collected from April 2021 to October 2021.

The primary objective was to describe and explain the eight MASP steps. Therefore, Table 1 describes each research's methodological stages in detail.

Table 1 – Methodological steps

MASP Step	Methodological structure
Step 1 – Problem identification	Data collection of process stops in the Zênite system and use of the Pareto Chart to present the number of hours of process stops for each of the situations.
Step 2 - Observation	Identification of the sector that most has the occurrence of process stoppages due to the breakdown of machines.
Step 3 - Analysis	Use of tools such as brainstorming and cause-effect diagrams to analyse the root causes of machine downtime in the thermoforming sector
Step 4 – Action Plan	Definition of the action plan to tackle the root causes of the problem
Step 5 - Action	Execution of the proposed action plan
Step 6 - Verification	Verification of the effectiveness of the action plan executed
Step 7 - Standardisation	Taking actions to prevent the causes of the problem from occurring again
Step 8 - Conclusion	Recap and analysis of actions taken

Source: The authors

As the first step, we collected data about production stops in the Zênite system. This system storages the machine downtimes and employees' notes. Then, we used a Pareto chart to prioritise the type of production stop. The studied data was from April 2021 to October 2021.

The main type of occurrence of production stoppage due to equipment maintenance was identified in the second step, which covered problem observation. Following that, in the third step, we used brainstorming to analyse the leading causes of machine downtime. With those opinions, we organised the causes into specific categories using the cause-and-effect diagram. To better identify the causes of machine downtime, we created a stop form in which the employee filled in the cause of the type of machine downtime.

The 5W1H tool was used in the fourth stage, which included the development of the action plan to enable the development of a plan with corrective actions for the fundamental causes of machine downtime in the thermoforming sector.

In the fifth stage, the project leader chose some workers and implemented the proposed action to address these fundamental causes. Following the sixth stage, the outcome of the previous stage's actions was verified. Finally, the actions were standardised and completed in the seventh and eighth stages, respectively.

3 RESULTS AND DISCUSSIONS

This section presents and discusses the results produced in the study to reduce production stoppages in a paper packaging company. The following subsections describe each step of MASP.

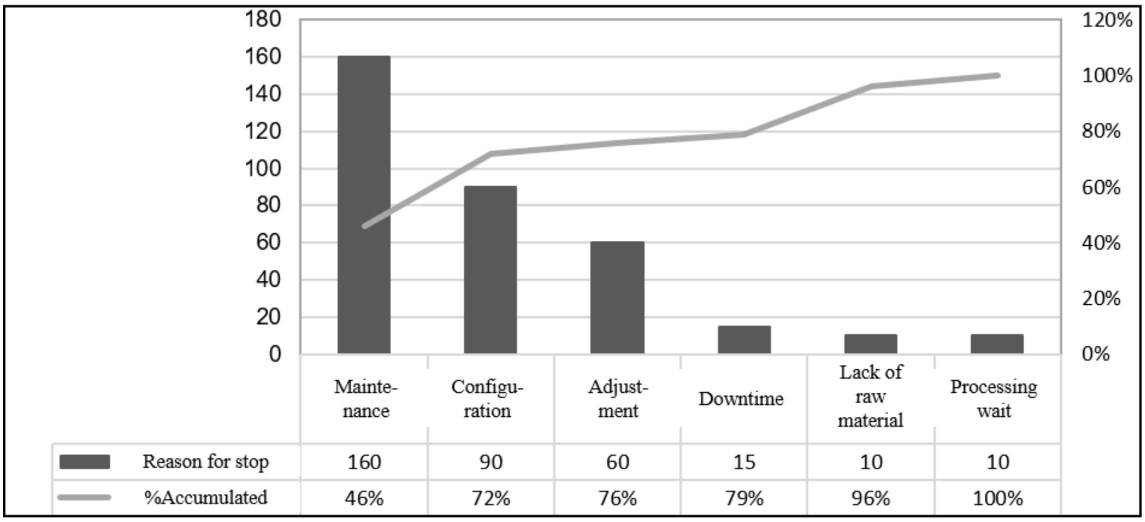
3.1 Problem identification

The company under consideration specialises in the manufacture of Kraft paper packaging. Given the context of the Covid-19 pandemic, the company's sales increased significantly. This increase was primarily due to demand increment via delivery apps during this period. Production had to be expanded in this scenario of increased sales. As a result, there was an investment in new machines and consulting to improve the efficiency of the manufacturing process.

However, the increased demand for production collided with the inefficiency of the manufacturing process. As a result, the initial goal was to identify the root cause of the operational inefficiency. A production downtime report was created in the Zênite software for this purpose. With this software, workers identified the beginning and end of the manufacturing process, and the machine stops. Thus, using this system's data, it was possible to identify the production downtime from April to October 2021.

The times collected in the Zênite software were tabulated based on the type of process stop. Furthermore, data normalisation was performed using the arithmetic mean, resulting in monthly downtime hours for each type of occurrence. Figure 1 shows the Pareto chart to summarise these data, with the left (y) axis representing the number of hours of monthly downtime. This figure shows that the downtime for machine maintenance is responsible for about 160 hours of downtime in the production process per month. After this prioritisation, the research team focused on reducing machine downtime through maintenance actions.

Figure 1 - Pareto chart of stoppage occurrences in the production process



Source: The authors

3.2 Observation

Once the maintenance activities were the most important stops, employees created an explanation meeting. At this meeting, the employees mentioned that the sector with the greatest breakages is the thermoforming sector. In addition to that meeting, we collected machine-stops data due to maintenance for each sector of the organisation. That query revealed that the thermoforming sector is responsible for more than half of maintenance shutdowns from April to October 2021. Table 2 illustrates the total monthly maintenance downtime in the thermoforming sector. The machine downtimes are in hours, presuming that this sector in question has 18 machines, and this total of hours is the maintenance downtime of all this equipment.

Table 2 - Downtime for maintenance in the thermoforming sector

Month	Time (Hour)
April	87:00
May	90:00
June	100:00
July	96:00
August	89:30
September	87:00
October	92:00
Total	**641:30:00**

Source: The authors

Therefore, based on the data analysed at this stage, it appears that thermoforming is the sector where the most downtime for maintenance occurs. In addition, it appears that the average monthly machine downtime in the thermoforming sector is approximately 92 hours. Thus, in the other stages, the study prioritises solving the root causes of maintenance activities in the thermoforming sector.

3.3 Analysis

With the data collected from the observation stage, it was possible to analyse the time spent on maintenance in the thermoforming sector is very high compared to other company sectors. Thus, in the third stage of the MASP, actions were carried out to identify the root causes of machine downtime in the thermoforming sector.

This scenario occurred because workers recorded the maintenance stop but did not record the changed element or what was happening on the machine undergoing maintenance. Therefore, the brainstorming tool was initially used to discuss the root causes of the machine downtime problem in the thermoforming sector. In this way, this tool identified that many actions were corrective maintenance, and there was no discussion to optimise the process.

Thus, there is a lack of control over the causes of machine breakage in the thermoforming sector. For this reason, supervisors from the thermoforming sector and employees from the maintenance sector created a team to solve this problem of lack of control of maintenance events and discover the root causes of the high amount of machine breakdowns.

One of the points raised at this meeting was the need to create a control sheet for maintenance occurrences in the thermoforming sector. Figure 2 exhibits the control maintenance sheet. They put it in a transparent folder on the side of all machines in the sector. In addition, to highlight its importance, the folder has a red sticker with capital letters “MAINTENANCE”.

Figure 2 - Corrective Maintenance Sheet

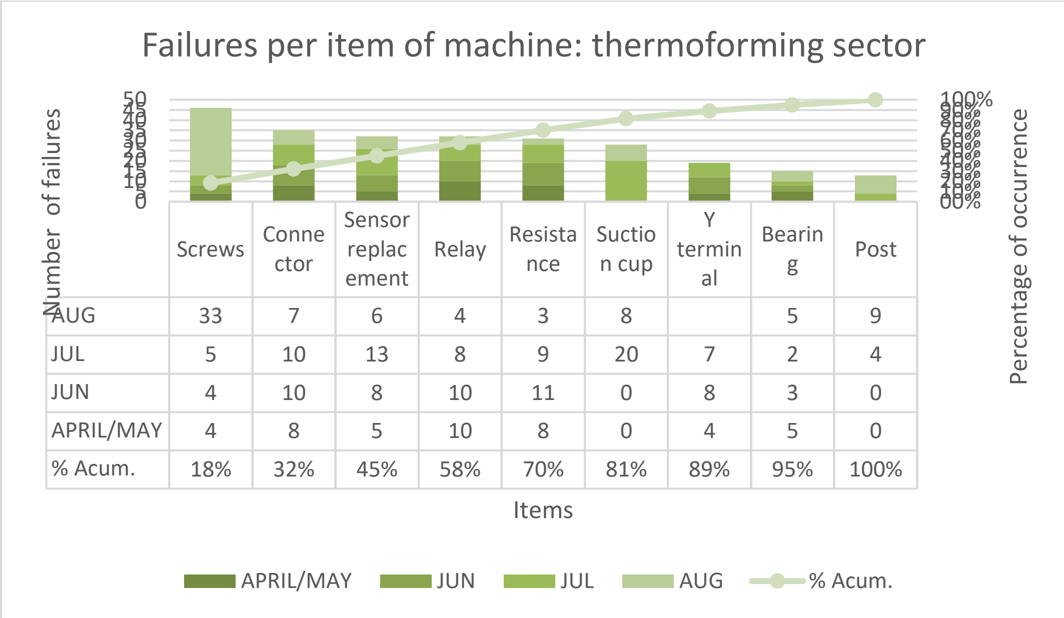
			MANUTENÇÃO CORRETIVA TERMOFORMAÇÃO	
			FOR-MAN-0	Revisão 0
Nome Máquina				
DATA	OP	INÍCIO	FIM	DESCRIÇÃO

Source: The authors

As a result, a meeting was held with all thermoforming employees, explaining the form and how this process of controlling corrective maintenance occurrences would work. Therefore, from that moment on, every maintenance stop indicated in the system should be accurately described in the corrective maintenance sheet. As seen in Figure 4, it was necessary to describe the name or process that causes the action in this control sheet. In addition, this token is exchanged for a new one every month.

This corrective maintenance control sheet made it possible to understand the causes of machine breakdowns. Therefore, with this sheet, we collected the total number of failures that occurred for the different items of the machines in the thermoforming sector. The period considered was from April to August 2021. Figure 3 shows the Pareto chart of data collection used to analyse the most occurred failure. The five items with the most occurrences of failures are: screws (46 occurrences), connector (35 occurrences), sensor (32 occurrences), relay (32 occurrences) and resistance (31 occurrences).

Figure 3 - Pareto chart of the number of failures per item of machines in the thermoforming sector



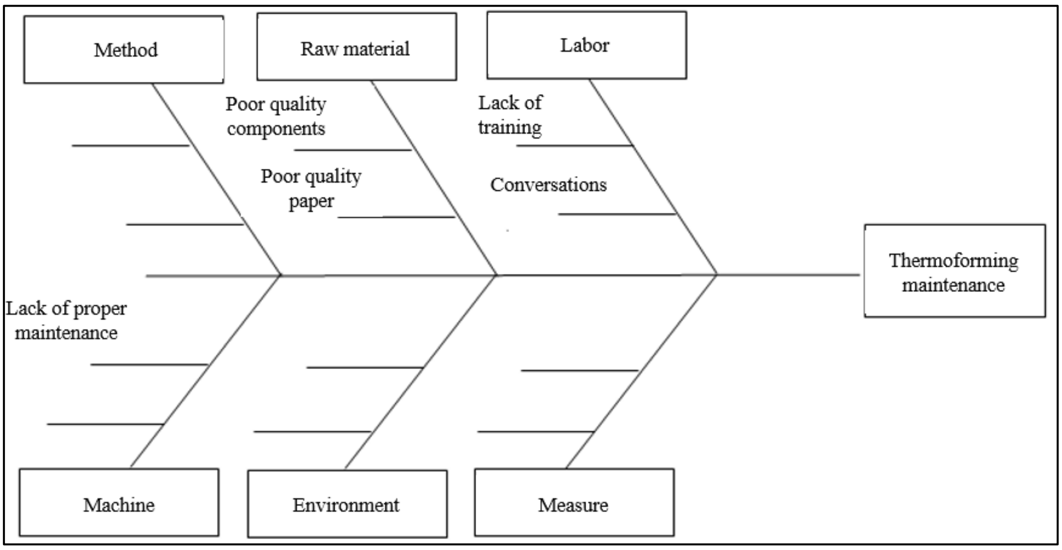
	Screws	Connector	Sensor replacement	Relay	Resistance	Suction cup	Y terminal	Bearing	Post
AUG	33	7	6	4	3	8		5	9
JUL	5	10	13	8	9	20	7	2	4
JUN	4	10	8	10	11	0	8	3	0
APRIL/MAY	4	8	5	10	8	0	4	5	0
% Acum.	18%	32%	45%	58%	70%	81%	89%	95%	100%

Source: The authors

From the data presented in Figure 3, it appears that.

With the understanding of the items that had the most failures, the research team, the thermoforming sector supervisors, and the maintenance sector employees used a new brainstorming to raise the main cause of these failures. For example, we found that many of the items that failed, particularly sensors, relays, and resistors, were of low quality, as the company's policy was to prioritise low-cost items. In addition, from the information gathered in this brainstorming, the cause-and-effect diagram was prepared, as shown in Figure 4.

Figure 4 - Cause and effect diagram



Source: The authors

From the data presented in the cause-and-effect diagram of Figure 4, it is possible to identify the main root causes of machine downtime problems in the thermoforming sector. In the labor category, there is a lack of training for employees in the thermoforming sector. They expressed many difficulties concerning the care they should have with the machines, including how to turn them on or off correctly. In addition, in this category, it was also identified that conversations between employees end up causing errors in handling machines, thus generating stops for maintenance.

In the machine category, only one cause was identified: the lack of proper maintenance of the machines. This problem is directly linked to the fact that often, in a rush to get the machine back into operation, maintenance is not carried out correctly. Finally, two root causes were identified in the raw material category: poor quality parts and bad paper. As mentioned before, the company presented a criterion for purchasing items by price, leaving aside whether the items were of quality or not. Thus, the company sought cheaper papers, and often the papers purchased came with varying thicknesses, causing damage to the machines.

3.4 Action plan

As presented in the previous step, the cause-and-effect diagram identified and analysed the root causes of the machine downtime problem in the thermoforming sector. As a result, a new meeting was held with the supervisors of the thermoforming sector and the maintenance sector employees to create an action plan. In this way, Table 4 presents the action plan prepared to deal with the root causes.

Table 4 - Action Plan

What?	How?	Who?	When?	Where?	Why?
Training for employees	Develop training sheets and train all employees	Quality sector	2021	Thermoforming	To reduce maintenance
Quality parts	Look for suppliers that guarantee quality parts	Purchasing sector	2021	Thermoforming	To reduce maintenance
Apply preventive maintenance	Develop a preventive maintenance checklist and set a date for the application	Maintenance manager	2021	Thermoforming	To improve machine performance
Paper weight variation	Buy only quality papers rolls of the correct weight	Purchasing sector	2021	Thermoforming	In order not to harm the machine

Source: The authors

Once the action plan (Table 4) was completed, the team defined the needed actions to implement it. In these actions, they considered various company sectors, such as quality, purchases and maintenance. Despite being focused on the problem of machine downtime in the thermoforming sector, the action plan covers different sectors of the company under study.

3.5 Action

Considering the action plan presented in Table 4, the proposed actions were carried out. In the following subsections, we describe the actions performed for each root cause of the analysed problem.

3.5.1 Action 1- Employee training

According to the action plan, the lack of employee training influenced machine downtime, including correctly turning the machine on and off. In addition, they also operated the machine even if it had defective parts, and paper accumulation was left in the machines. Because of this, a training sheet was prepared for all employees, and two people were assigned to the multiplier role, that is, employees who are obligated to deliver the training sheet to every new employee in the thermoforming sector. The selection criterion for multipliers is that they must be efficient collaborators and have a high knowledge of the thermoforming process.

The multipliers must also clarify any doubts about the training sheet for new and old employees. The points to solve are the following:

a) Explain how the process should be noted in the company's information system;
b) Explain how the work order must be read correctly, in order to identify the service to be performed;
c) Explain what the machine settings should be for the production of the different items in the company's catalog;
d) Explain how to execute the test in the laboratory and how to make the card problem in case of problems;
e) Explain the necessary care with the equipment responsible for cooling the machines;
f) Explain how the machine wires must be organised and handled for the safety of employees and machines;
g) Explain how to close and change the mould.

When the multiplier explains any of these items to the new employee, he/she must check if there was a correct understanding; if so, the worker made the note on the training sheet. However, it should be noted that certain mechanical and electrical operations for machine maintenance are not explained to employees due to the complexity and dangerousness of the actions. Therefore, if there is any problem like these, they are passed on to those responsible for the maintenance sector.

3.5.2 Action 2- Quality parts

This action was intended for the maintenance and sales sectors, as some parts came with poor quality. Therefore, it was verified through the action plan that the resistances acquired for the machines were coming with a skinny thickness, which caused many electrical problems. In addition, in the face of these electrical problems, there was a constant breakdown of relays.

Faced with this scenario, the action was taken to change suppliers and correctly pass the resistance model that is used, so the sales department received a sheet with quality standards so that before making the purchase, it could verify if the supplier entered that pattern.

3.5.3 Action 3 - Raw material (non-quality paper)

The low quality of purchased paper was the leading cause of machine breakdowns, especially in the newer machines. The varied grammage explains the low quality that the purchased paper presented, causing failures at the time of its processing. To solve this problem, it was initially necessary to assess the quality of the papers sent by the company's three suppliers to identify which one had defects.

Once it was identified that only one of the suppliers had low-quality paper, that single supplier was excluded from the shopping list. In addition, a procedure for evaluating new papers that arrive at the company was defined, in which the company's quality control sector verifies their quality.

3.5.4 Action 4 - Preventive maintenance

The fourth and last action carried out covered the implementation of a preventive maintenance program. In this way, those in charge of the company's different sectors and the maintenance sector employees created a team to prepare a checklist of the necessary steps to carry out preventive maintenance activities. From this meeting, they defined preventive maintenance activities in the thermoforming sector on the 5th and 20th of each month. Moreover, the other sectors stipulated other days of the month.

Another point to note is that on the days determined for preventive maintenance, the employees themselves, with the help of those in charge and the maintenance manager, carry out these preventive maintenance activities. To facilitate the execution of the maintenance activities, the employees of the maintenance sector beforehand provide trolleys with tools, oils and grease. In addition, they planned three hours for preventive maintenance activities. If any machine already presents worn or burned parts in this period, the maintenance department directly exchanges or communicates who should do it.

3.6 Verification

After the implementation of the action plan, it was possible to verify positive points, and one of these points was the implementation of the training sheet that contributed to the emergence of the multiplier function, which helped employees better understand the process and eliminate doubts. In the case of side conversations, employees received work safety training to understand the importance of attention when operating the machine with care.

The application of preventive maintenance generated many positive results, because through it, it was found that some of the machines had some parts and loose screws that caused even other parts to break. Therefore, preventive maintenance allowed these problems to be eliminated. Regarding poor quality parts, changing the supplier proved to be effective in stops in the process due to shorts or burning in the resistances and relays of the machines, as it reduced these problems and the durability of some parts increased.

Regarding paper with different weights, which even interfered with production, it was found that excluding the supplier who sold low-quality papers brought improvements in production. This improvement occurred because the machines work properly with good quality paper.

In an overview, the proposed and executed action plans were positive, enabling the company to reduce machine downtime significantly. Table 5 shows the number of hours of downtime for maintenance in the thermoforming sector after the execution of the action plan.

Table 5 - Downtime for maintenance in the thermoforming sector after execution of the action plan

Month	Time (Hour)
December	55:35
January	61:00
February	59:20

Source: The authors

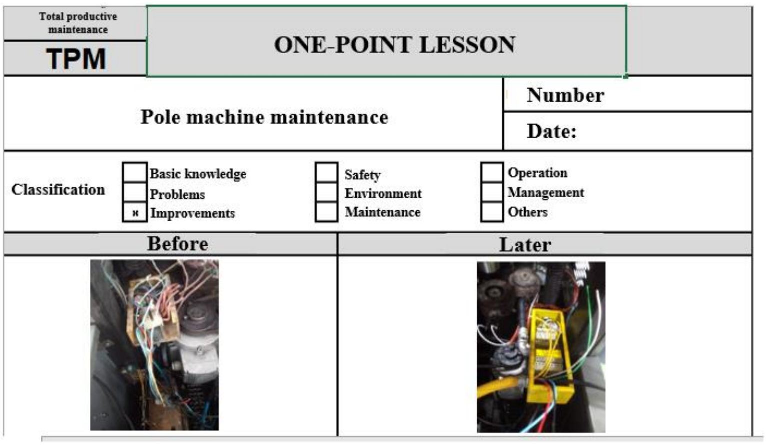
From the data presented in Table 5, it appears that considering from December 2021 to February 2022, the average monthly downtime for maintenance was approximately 59 hours. Knowing that the last monthly time was about 92 hours, the monthly average was reduced by 33 hours.

3.7 Standardisation

After verifying the effectiveness of the executed action plan, the actions carried out were standardised. Therefore, some changes were made to the corrective and preventive maintenance form. In addition, certain points of the training sheet were adjusted.

Another improvement made after verifying the effectiveness of the action plan was the creation of a form called “one-point lesson”. This form allowed for more in-depth documentation of the failures that occurred in the machines, making it possible to identify the right and wrong way of carrying out maintenance activities (Figure 5).

Figure 5 - One-point lesson



Source: The authors

Another aspect regarding the one-point lesson sheet is that this document allows the company to record existing failures and how maintenance actions must be carried out correctly. Therefore, it is expected to keep machine downtime for maintenance as low as possible.

3.8 Conclusion of actions

From completing the seven previous steps of the MASP, it was possible to identify the main type of production stop and develop and execute an action plan to solve the problem. In addition, it is verified that these improvement actions must be carried out in the long term, otherwise, there is a high chance that the problem will return.

Therefore, there is a need to check daily if the action plan is still effective since future problems not covered by the current action plan occur. Another point is that MASP can be applied in other sectors of the company to expand the reduction of machine downtime in all the company's production sectors.

4 FINAL CONSIDERATIONS

This paper presented a detailed application of MASP to reduce machine breakdowns in a paper-packing production company. Using the MASP helped to identify the sources of the machine downtime problem, analyse the root causes and propose an action plan to solve them. Therefore, considering the eight steps of MASP, this study focused on the machine breakdown problems and the thermoforming sector. Subsequently, the action plan significantly reduced the downtime due to machine breakdowns in the thermoforming sector. After that, the effectiveness of the actions was verified, and finally the standardisation and conclusion of the actions were achieved.

In this way, with the accomplishment of this study, it was possible to increase the machines' productivity and motivate the collaborators, allowing the company to reach the proposed production goals. It should also be noted that the average downtime for maintenance in the thermoforming sector was reduced by 33 hours, showing the effectiveness of the actions.

A limitation of this study is that it was carried out only for the thermoforming sector, leaving the need to reduce machine breakdown in other sectors and solve other sources of production downtime. In addition, the research considered a short period of evaluation of the effectiveness of the actions carried out, requiring the long-term verification of the effectiveness of the actions.

For future works, we suggest expanding the implementation of the MASP for the other problems found and the other sectors. A longitudinal case study can also be carried out to verify the effectiveness of long-term improvement actions.

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