Contribution for the implementation of the Total Productive Maintenance - Riberalves Case Study

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Abstract - In an increasingly competitive market, organizations have an increasing need to upgrade their production systems, using ever more sophisticated equipment and components. However, it will be necessary to ensure that production systems remain at high efficiency, quality and availability levels, thus increasing their competitive advantage. Hence, industrial maintenance plays a fundamental role in production systems, since the activities carried out in this area have a direct impact on products or services costs, quality, and deadlines. For this aim, a bibliographical revision was initially carried out, which included topics relevant to maintenance. The TPM methodology (Total Productive Maintenance) was highlighted, already widely applied over more than two decades. Thus, taking into account this methodology, the current state of the maintenance area was analyzed and subsequently improvements were introduced in the information, collection and recording processes. These enhancements were essential for the subsequent data treatment. Next, upgrades were defined and implemented in the most critical equipments, and autonomous and planned maintenance processes were initiated.

With the implementation of the TPM methodology it was possible to increase the equipments efficiency and availability and, consequently, to increment the productivity. There was an increase in line availability by about 6%, efficiency increased by approximately 4% and production by 20%.

Keywords: Maintenance, TPM Methodology, Food Industry, Riberalves

INTRODUCTION

Faced with a constantly evolving market, organizations will have to join forces to face the challenges of the business environment. To meet those challenges, created by its competitive nature an organization must seek a practice of continuous improvement in all areas, making it possible to create advantages against its competition.

Maintenance is within the various areas that provide an increase in industrial efficiency. This sector was ignored by most companies until very recently, since for many of them it was inferior to other business areas (Pinto, 2013). However, due to the enormous evolution of the production process, several paradigm changes occurred in the maintenance area, such as the TPM methodology (Total Productive Maintenance). TPM also enjoyed a rapid and great expansion in the industries, as a result of its excellent results.

This article will, therefore implement the TPM methodology in the company Riberalves, which currently presents several maintenance challenges, and a need to increase the availability and efficiency of the equipment i in order to maintain its competitive advantage and secure its position in the market top.

The developed methodology is synthesized in several stages. Initially, information relevant to the development of the case study was collected, either through observation and follow-up of the processes, or through direct contact with the individuals responsible for the maintenance area, logistics and production, and through document inquiry. In a second stage, the development, implementation and application of information records, necessary for the subsequent processing of the data, were carried out. Then the treatment and analysis of the collected data were done, identifying the most critical equipment in the production line. In the last stage, improvements were defined and implemented, and autonomous and planned maintenance processes were started.

The results obtained are of interest to industry and academia, since the implemented improvements can be applied in other companies of similar size and sector.

This article will, therefore, initially discuss the maintenance area with special focus for the TPM methodology and then implement this methodology in the

Riberalves case study, with subsequent results presentation and discussion.

Literature Review

This section fits the theoretical basis on maintenance management and TPM methodology.

I. Definition of Maintenance

In the various definitions of maintenance defended by several authors a common denominator can be observed: that is, maintenance aims to create the conditions for the equipment to work for the longest possible time.

In order to standardize and update this concept, the standard EN 13306: 2010, Portuguese version, was published, where maintenance is defined as follows: "A combination of all technical, administrative and management actions during the life cycle of a good, designed to maintain it, or restore it in a state in which it can perform the required function" (Portuguese Quality Institute, 2010).

The concept of maintenance was, therefore, subject to an evolution, taking into account the new conceptualization of equipment life. Maintenance is not restricted only to technical intervention, in equipment or installations, but it also refers to all tasks combined to maintain the equipment with the desired performance over its life cycle.

II. Function of Maintenance

The maintenance function consists of a management component and a technical component that, depending on the company size, determines the proportions with which these two components will be used (Pinto, 2002). If the person in charge of maintenance is a small company, then the activities will mainly consist of a technical component. If the company has a large productive capacity, the person in charge of the maintenance will have a greater management role.

Nowadays there are differences regarding the components of the maintenance function. According to some authors the maintenance function must have an independent feature from the production function, with a well defined budget and means (Pinto, 2002). Although the production function is the company's primary objective, maintenance is the "help" for production. In this way, it is important to give due recognition to the maintenance function, giving it a parity position with the production function.

In Figure 1, the main interrelationships of the maintenance and production function are represented. The success and good functioning of the company depends, considerably, on a good articulation and management by these two functions, enabling the fulfillment of business objectives.

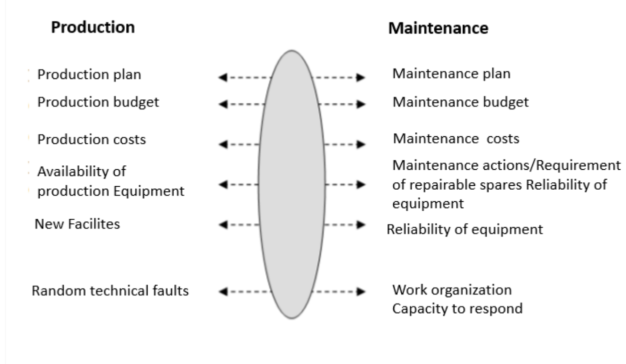


Figure 1: The Production / Maintenance interface, Pinto (2002).

In a production unit, maintenance consists of maintaining and improving the equipment availability at the lowest possible cost. In the equipment's design phase there must be a parallel work with maintenance to be able to intervene in the characteristics of the same equipment. Hence, the importance of the concepts of maintainability and reliability are related to the optimization of the equipments life cycle. The reliability represents the confidence that the equipment transmits in the accomplishment of its functions, and the maintainability referes to the speed and ease with which the maintenance is executed on the equipment. In this way, it is also up to the maintenance function, when purchasing new equipment, to base its choices on maintainability and reliability features, in order to reduce problems that condition intrinsic availability.

III. Types of Maintenance

The way the intervention in the equipment is made depends on behaviors and technical specificities, and there are denominations to classify the maintenance performance on them. According to the literature review, the classification of maintenance types differs among some authors. According to Pinto (2002) and Cabral (2006), there are three main types of maintenance:

- Corrective maintenance,
- Preventive maintenance, which is divided into systematic preventive maintenance and conditional preventive maintenance, and
- ImprovementMaintenance.

For Amaral (2016), the classification of the types of maintenance is based on the EN 13306: 2010 norms, with two major types:

- Preventive planned maintenance, which is divided into systematic, conditioned and detective;
- Unplanned corrective maintenance, which is divided into curative and palliative.

Corrective maintenance consists of repairing faults when they have already occured, and can be divided into two cases, "curative", if the intervention is definitive, or "palliative" if it is provisional, and therefore implies scheduling a new intervention in the equipment.

Preventive maintenance is geared to reduce and avoid the likelihood of equipment failures. This method of maintenance can be divided into conditioned and systematic. The conditional preventive maintenance is performed according to the state of the equipment, predicting future occurrences of failures. Systematic preventive maintenance is carried out with a fixed periodicity, requiring a general and programmed installations halt, in order to check the general condition of the equipment.

According to Amaral, there is a third type of preventive maintenance, the detective maintenance. This type of maintenance is aimed to verify the state of the components that cause hidden faults (faults imperceptible by operators and maintenance workers.

Finally, there is a fourth type of maintenance, the improvement maintenance, which aims to improve the equipment in its context, including the modifications and changes made to improve its performance.

IV. TPM Methodology

The maintenance management methodologies predominant in the literature are TPM, RCM and CBM, and the TPM methodology is the most used in the industrial sector and, therefore, discussed in this article.

The TPM or Total Productive Maintenance methodology was developed in the 1970s in Japan. This concept was introduced by the company Nippon Denso Co. Ltd. that due to the increase in the number of equipment and the need to intervene them, saw its costs increase and low efficiency of the maintenance industry. In order to solve this problem, the company decided to train operators and introduce some routine tasks such as lubrication, cleaning, inspections and small maintenance, allowing the maintenance department to have more time for more demanding tasks (Boris, 2006).

In this way the TPM emerged, as methodology that intends to involve all the employees in the process, improving the productivity and the operations quality.

The TPM methodology is then defined as "a new attitude of responsibility of all, as the goal of maximizing overall efficiency through elimination of all losses", based on the objective of zero failures, zero defects and zero accidents.

V. The Pillars of TPM Methodology

The development of the TPM methodology is supported by eight pillars, namely: autonomous maintenance, focused maintenance, planned maintenance, maintenance for quality, learning and training, environment and safety, office TPM and initial equipment management (Figure 2). The following will be developed in more detail:

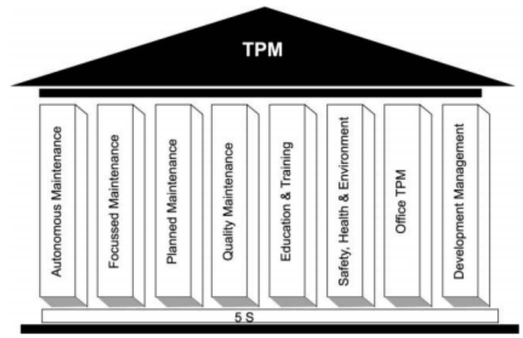


Figure 2: TPM Pillars suggested by JIPM, Ahuja et al. (2008).

a) P1 - Autonomous maintenance

Autonomous Maintenance is the pillar that allows basic maintenance care to be applied through the operators responsible for the equipment. The goal is to free up the maintenance department for activities that add more value. According to Pinto (2013), an autonomous maintenance program consists of eight levels of group activities:

1. Initial cleaning;
2. Locate sources of dirt;
3. Make cleaning equipment easier;
4. Standardize maintenance activities;
5. Learn general inspection practices;
6. Guide for autonomous inspection;
7. Organize the work areas;
8. Start self-management.

b) P2 - Focused maintenance

Focused maintenance, also known as continuous improvement events, identifies areas with potential for improvement where the impact is significant, and the cost effort associated with its implementation is reduced (Pinto, 2013). These improvement events are performed to maximize equipment efficiency by eliminating waste and improving performance in the work areas, such as creating protections to minimize contamination of processes and products and relocating components to improve their access to the collection of debris.

c) P3 - Planned maintenance

The planned maintenance consists of planning and controlling maintenance, ensuring the absence of defects in equipment and defective products, ensuring customer satisfaction. With the implementation of this pillar, people gradually move to proactive approaches, allowing stocks of parts and materials to be reduced, availability maintained at the desired level, and an improvement in the equipments reliability and maintainability (Pinto, 2013).

d) P4 - Maintenance for quality

Maintenance for quality intends to create conditions to prevent defects, generated by the equipment, aiming to achieve zero defects (Pinto, 2012). To prevent these defects, it is important to be aware of the components in the equipment that influence its quality and thus understand the cause of the defects, allowing for the reduction of waste.

e) P5 - Learning and training

This pillar is dedicated to promoting learning and training, thus helping to make all other pillars successful. The learning and training of human resources should be an evolutionary process, just like the TPM methodology (Pinto, 2012).

f) P6 - Environment and Safety

This pillar ensures that the improvements made by the remaining pillars will not reduce safety, health or even harm the environment (Pinto, 2013). This pillar aims to guarantee a safe and appropriate working environment, in order to eliminate accidents and to provide standard operating procedures (Ahuja and Khamba, 2008).

g) P7 - Office TPM

Administrative departments play an important role in supporting the various activities of a production system. Thus, the TPM office should take advantage of the TPM methodology and use the knowledge and tools practiced in the maintrnance operational environment in administrative processes (Pinto, 2013).

The TPM office can reduce or eliminate eight large losses (Pinto, 2013):

1. Losses associated with processing.
2. Losses in areas such as: purchasing, marketing and accounting.
3. Losses due to communication failures.
4. Losses due to stoppages or inactivity.
5. Losses due to lack of precision.
6. Losses due to failure of office equipment.
7. Losses due to customer complaints owing to delivery failures
8. Losses with costs related to urgent deliveries.

h) P8 - Initial equipment management

With a market in constant innovation, it is increasingly important to carry out an initial management of the equipment, especially in companies in which consumer goods have a reduced life cycle.

The initial equipment management allows to use the experience developed with the improvement processes to avoid previous errors. In the development and acquisition of new equipment it is important to consider decision factors such as manutibility, reliability, safety, durability, setup times, and ease of cleaning.

CASE STUDY: RIBERALVES

Riberalves, owned by the Jerónimo Martins Group since the 1990s, is exclusively engaged in the industry and processing of cod (Jornal Público, 2011). Its industrial unit in Moita is one of the largest in the world, operating in the cod sector, which allowed the company to increase production by 60%.

It is currently the world's largest cod processing company, processing more than 100,000 tonnes of fish per year, equivalent to 10% of all the cod caught worldwide.

Its Moita industrial unit is divided into three industrial buildings:

- the first unit is where the product is received, washing and drying the cod;
- in the second unit the cod goes to the cutting line, where it is cut in the most varied patterns of flitches, which are subjected to soaking, deep freezing and glazing processes;
- in the third unit the cod is packed and shipped.

This study examines only the packaging unit, which consists of two warehouses and 12 packaging lines. The first warehouse is responsible for the cod conservation, waiting to be packed, andd the second warehouse is responsible for the conservation of the already packed cod.

The 12 lines are divided into 5 groups, depending on how the cod is packaged: lines 1 and 9 pack cod in box, lines 2 and 6 pack cleaned cod, lines 5 and 12 pack cod to bulk, lines 3, 7 and 10 pack cod in cuvets and lines 8, 11 and 11A pack cod in bags. It is in these 12 packaging lines that there is a greater level of automation and mechanization of the equipment and consequently greater challenges in the maintenance level.

Taking into account the objectives of this study and to understand the state of the production lines, an analysis was made on the times and reasons for stopping the production line. It was concluded that the lines face frequent and time-consuming stops, affecting an average of 18% of productive time. Of the various reasons found for these stops, unplanned maintenance accounts for 31% (Figure 3).

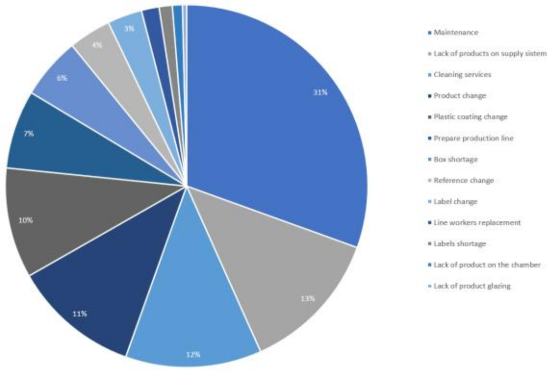


Figure 3: Time of line stops on the unit Packing.

In order to develop this study, a pilot line was selected that will be tested by the TPM methodology, aimed at increasing the availability and efficiency of the equipment. Line 1 was selected because it has the highest value in the economic impact indicator, when it is unavailable to produce.

The line 1 packaging process is shown in a simple and succinct way in Figure 4.

Figure 4: Packaging process of line 1.

After the production processes of soaking, deep-freezing and glazing, the cod loins are transported and then packaged. They are initially discharged into the three existing bins on line 1, following their respective supply standards.

Then the quality control is done, and these loins are placed individually, in each compartment of the horse's neck carpet. The loins are transported by the circular carpet to the weighing unit, where each loin is weighed and later collected on the arm conveyor. The collected loins are calibrated in order to obtain the programmed weight, which can vary between 0.6kg, 1kg and 2kg.

The already calibrated and combined calves in the weighing unit form a "dose". This follows on the carpet of the doses up to the box distribution mat.

Subsequently, the doses are boxed by following on the supply mat to the packer, where their are labeled and protective film is applied.

At the end of filming, the box goes into the oven where the air between it and the film will be reduced.

It is also checked whether the weight of the carton is as desired. Boxes that comply with the standards advance to the conveyor belt. Once the entire packaging process is complete, the master cartons are stored in cold storage chambers at -18 ° C and shipped to the customer.

The maintenance control over the equipment in the packing section is done through autonomous, planned and corrective interventions. Regarding the autonomous maintenance, carried out by the operators, this focuses on cleaning activities at the end of the shift, only when it is necessary.

Planned maintenance interventions refer to disaster prevention activities, although they are not routinely performed on equipment. In these inspection activities, when the components wear is noticeable, the substitution request is not always carried out. However, it is the corrective actions that take up most maintenance activities.

This packing section has, almost permanently, two maintenance technicians who carry out preventive and corrective interventions. When corrective interventions are required, these are quickly reported, so that the maintenance department can immediately trigger the equipment repair. If it is not repaired by its complexity, a specialized external company or the components manufacturer is adjudicated.

The whole process of maintenance of the Riberalves company is recorded manually, including line stop records, planned maintenance plans and information regarding the resolution of equipment failures. The computerized record, after manual recording, is only used in line stop records.

Development and Implementation of the Methodology

I. Registration and Collection of Information

Data collection is critical to ensuring that the best decisions are made and the best maintenance strategies defined. For this, in the first phase it was necessary to understand how the registration and collection of information was carried out. In order to achieve this objective, interviews with the operators, documentation consultations and an observation in the field were carried out in order to understand the entire process of recording and collecting information.

At the beginning of each shift, a stop card is delivered to the operator, who is responsible for manually filling the stops that occur on the production line. At the end of the shift, the operator delivers the stop card to a person responsible for manually entering this data into the Excel file.

After several shifts were observed, the following deficiencies were verified:

- The information is not recorded correctly in the stop card;
- The operator does not always record the stops;
- The information is incomplete, the stoppage is recorded, but without specific cause;
- Delay between the recording of information and its treatment.

As a consequence of these shortcomings, one of the problems is the lack of data regarding the equipment downtime, and thus, it is not possible to accurately record the time lost in each equipment.

In order to fill in the incorrect and incomplete information record, improvements were made to the data sheet, which now includes information about the equipment in which the fault occurred and the origin of the fault.

After the implementation of the new stoppage for about eight weeks, it was concluded that the treatment process continues with a large delay, requiring human availability to enter the data into the system. To avoid this delay was adopted a new method of registration, developed in Excel, through Visual Basic of Applications (VBA), having been integrated into the company's computer system.

With the new electronic records, it is possible to check stops that occur on the production line any time. In addition, it is also possible to systematize the process, since through the systematic recording of information, we can analyze a failure pattern for a given equipment.

II. Treatment and Analysis of Information

With regards to the information processing, this has also become easier since the records are completer and more reliable, allowing a more in-depth treatment of the reasons for stopping the line.

A Pareto analysis was performed to identify the equipment with the highest total stopping time. The graph in Figure 5 indicates that Baepack, Dose Transport and Circular Transport equipment account for more than 80% of the total stop time for line 1.

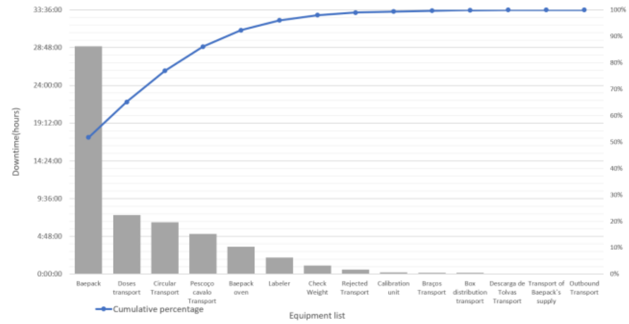


Figure 5: Pareto of the equipment downtime.

Through the improvements introduced in the registers, it was also possible to count the number of failures by equipment (Figure 6). This variable allows to distinguish the equipment with greater impact in line 1, not only by the total time of halt, but also by the frequency of equipment failures

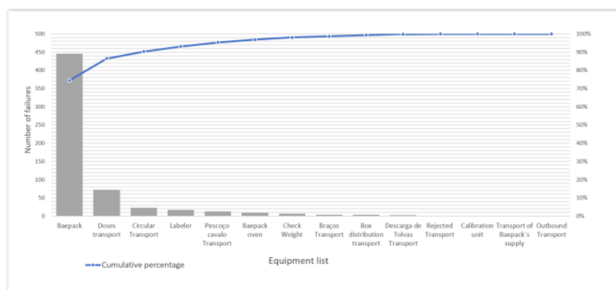


Figure 6: Pareto of the number of failures per equipment.

The analysis showed that Baepack and Dosage Transport represent 80% of the equipment with the greatest number of failures.

This new method of registration allows better equipment decisions and maintenance strategies. It is also possible to compare the initial state of the line with the improvements results, introduced in the system. Another possible benefit is the visualization of a failure pattern of a certain equipment

III. Studies of Causes of Stops

After verifying the most critical equipment in the production line, the reasons that caused the stops were analyzed, in order to eliminate or at least reduce these events.

In this way the first equipment to be studied was Baepack, due to its higher number of failures and a longer stopping time. The data from the previously developed application made it possible to carry out a study, in which the six most relevant failures were identified:

- Split particle - Characterized by the excess film if breaking;
- Split film - Characterized by ripping the film;
- Servo drive alarm - Red warning light warning on equipment;
- Rule problems - Defined as incorrect rule cut;
- Discs to be cut badly - Defined as incorrect cut of discs;
- Box fastened on the ruler - Defined when the ruler cuts the carton from the film.

The Splitting Match, Split Film and the Servo Drive Alarm were the failures responsible for 80% of the stop time on the Baepack equipment. These three failures averaged six minutes per failure at a frequency of forty-five times during the twelve weeks of analysis.

The second and third equipment to be studied was the doses transportation and the circular transport, presenting only one fault, the equipment halt. Dosing carried an average of seven minutes per stop at a frequency of forty times and the carriage circulated an average of twelve minutes of stop at a frequency of twenty-two times.

After identifying the main faults of these equipments, a collection of information about the possible causes of the failures was carried out. Therefore, brainstorming was performed with two line operators, two maintenance technicians and the production manager, who were asked some questions, such as:

- What do they understand to be the causes of failures?
- What components are involved?
- How can these failures be eliminated, or at least minimized?
- What causes do you consider to be of greatest importance in terms of time and frequency of stopping?

During brainstorming, the Ishikawa diagram was used to help analyze information on the causes of each failure. According to Pinto (2009) this methodology is widely used in brainstorming processes for problem solving. This allows to organize the reasoning in discussions and synthesize the collected information. In this way we use the Ishikawa diagram in the faults that were previously identified: split particle, split film; alarm servo drive and the stop of doses transportion and circular transport.

IV. Implementation of the TPM Methodology

The TPM methodology is supported by eight pillars and only two were developed and implemented in face of the needs of the company, namely the autonomous maintenance and preventive maintenance pillars.

Autonomous maintenance

Autonomous maintenance was addressed at an early stage of the project, allowing operators to feel part of the program.

At the beginning of the project, there was little direct involvement from operators in maintenance actions. In order to allow a greater involvement of the operators in the maintenance tasks, daily and weekly autonomous maintenance plans were created to satisfy the needs of each equipment. These autonomous maintenance plans encompassed routines such as cleanings, inspections, lubrications, checks and minor maintenance revealed to be effective in preventing equipment failure. The application developed in VBA was used, and the maintenance plans were added autonomously to the application. Figure 7 shows the application as well as the process of recording a halt on the production line.

Planned Maintenance

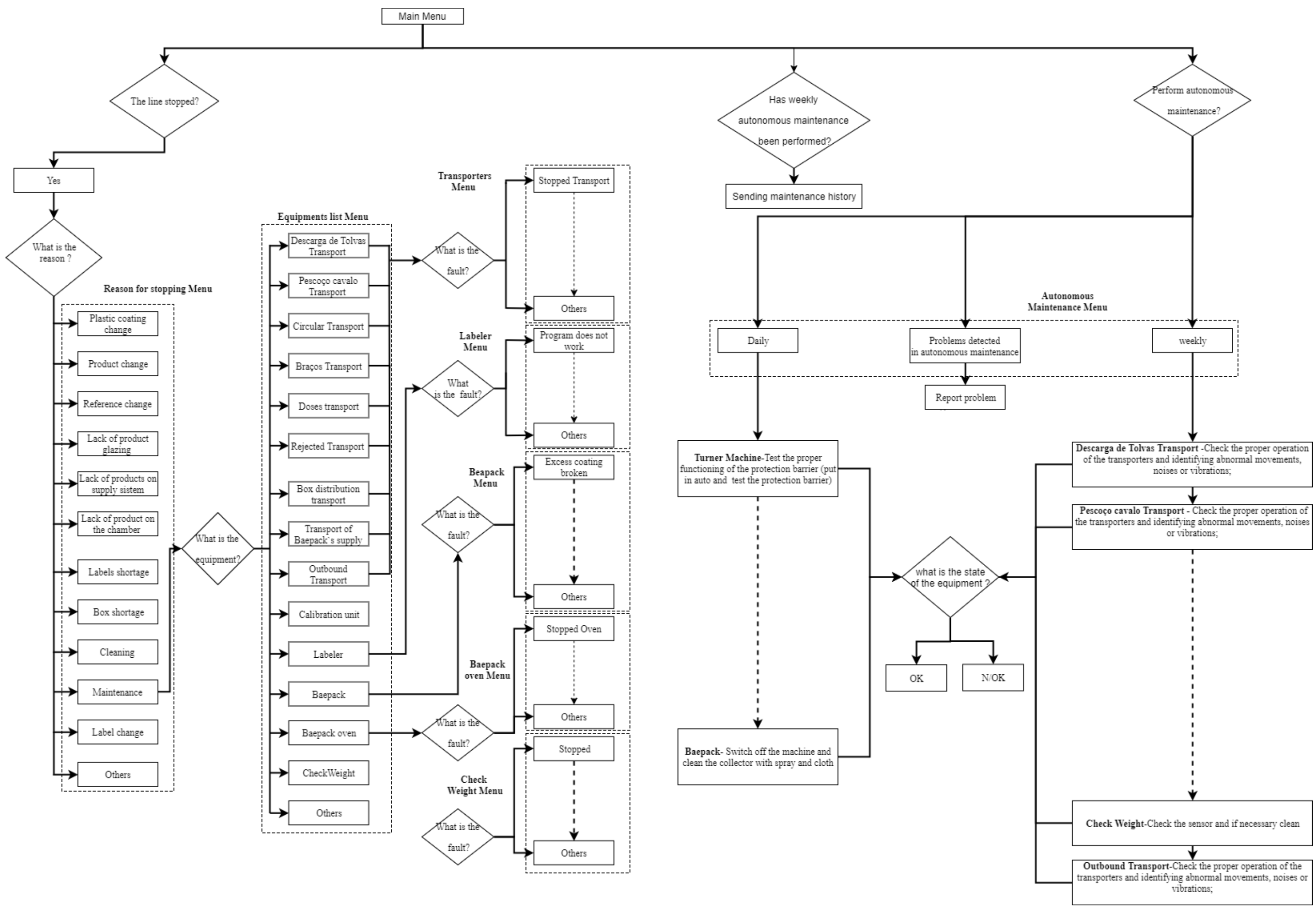
Planned maintenance ensures maximum continuous flow, preventing major damage and failure. It is of the outmost importance to the company that the maintenance plans are well implemented in each equipment and that they allow to prevent all sorts of failures that can appear, to achieve a more effective production.

For this, in a first phase, the status of the maintenance plans of line 1 was analyzed. In this analysis it was possible to verify that the maintenance plans were mismatched to the needs of the equipment and availability of technicians, taking up too much time.

After analyzing and identifying the deficiencies, it was necessary to update the planned maintenance plans, incorporating the fourteen existing equipment of the line, when previously there were only twelve equipments represented.

Finally, it was agreed with the maintenance department that planned maintenance plans for the equipment would be carried out on the first Monday of each month. According to the department, this new plan has allowed to increase the prevention and conservation of the equipment.

With this new form of registration and greater participative activity by the line operators through the autonomous maintenance, it became easier to detect component failures and to have a greater orientation for the implementation of other improvements. It is also important to motivate and involve the operator in the execution of each of the tasks.



RESULTS AND DISCUSSION

In this section we discuss the results of the study developed in the pilot line. Thus, we can verify that after the improvements introduced in the records of halts, a higher data quality and a shorter processing time were obtained.

At the beginning of this study the mean rate of availability of line 1 was 79% (Figure 7, from 1 to 12 weeks). At the end of the project, the average availability rate presented a value of 85%, that is, an increase of 6 percentage potins. (Figure 8, from the 14th to the 26th week). In week 13, the line was stopped for administrative reasons.

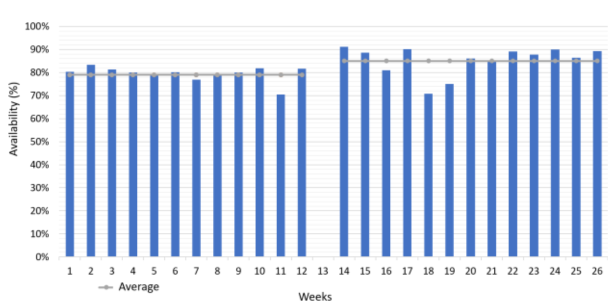


Figure 8: Availability of line 1 throughout the project.

As with th availability rate, the efficiency rate of line 1 increased by 4 percentage points. This increase is illustrated in Figure 9, from the 14th to the 26th week. Therefore, we can say that there is an association between the reduction of availabiliy and the loss of efficiency of the line, that is, the number of stops occurring in the equipment, causes not only the production stop, but also small efficiency losses.

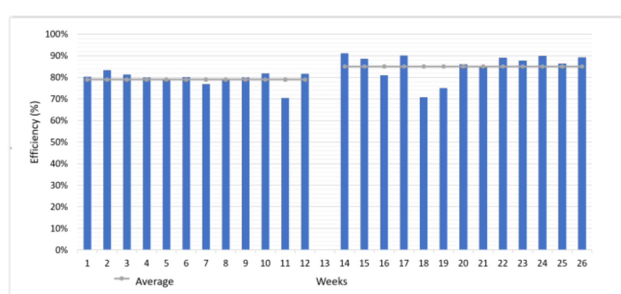


Figure 9: Line 1 efficiency throughout the project.

In relation to the production of this line, that is, the sum of kilos of packaged cod, this one presented great variability throughout the analysis. At the start of the study we found a downward trend, at around 560kg per week. After improvements were made, this trend changed, that is, an increasing trend was observed, which translates into an increase of 565 kg packaged per week.

At At the beginning of the project the unplanned maintenance stops had an average value of 37%, thus constituting a considerable fraction of the line stop time. In relation to this type of stop, the reduction to 23% was achieved at the end of the project.

CONCLUSIONS

The increasing technological development has made the production systems increasingly automated and complex. Consequently, maintenance has played a key role in ensuring the efficiency and availability of equipment. With this new concern, all organizations had to adjust their methods and processes, and Riberalves was no exception.

The main reason for the stoppage of the unit's lines at Riberalves is unplanned maintenance, accounting for about 31% of the total stoppage time. As one of the lines with the lowest availability, efficiency and highest economic impact indicator, we selected line 1 as a pilot line in order to test solutions that meet our objectives.

Then, we analyzed the company Riberalves maintenance situation, where a collection of information was performed, which allowed us to identify the various problems that exist in the company, highlighting the way information was registered and treated.

In order to address the problem of information processing, the records were initially modified to make them thorougher and easier to complete. However, after the change of the record sheet, data processing continued to be delayed. To solve this problem, an Excel application has been developed and installed on the computer next to the production line, to convert the records into automatic ones.

The new information processing allowed the Baepack, Dosage Transport and Circular Transport equipment to have a significant frequency and stop time on line 1. The most significant failures in the Baepack equipment include split particle, split film and servo drive alarm. The maintenance performed on these equipments allowed a 58% reduction of the breakdowns in the starter, 73% in the split film and 85% in the servo drive alarm.

In the Dose Transport and Circulation Transport equipment, the failures were reduced to 60% and 78%, respectively. These improvements provided favorable conditions for line 1 to function optimally.

Simultaneously, a weekly and monthly standalone maintenance plan was created, accompanied by line operators training. Through this plan, it was possible to redistribute some tasks, previously performed by the maintenance technicians, allowing an increase in their availability to perform tasks with greater relevance.

In sum, line 1 increased about 6 percentage points in availability, 4 in efficiency and 20% in production. Although the improvements achieved do not show a high growth in availability and efficiency, it is necessary to consider that the TPM methodology implies a change of mentalities, from the employees to the heads of the different departments. Therefore, greater collaboration between maintenance and production will lead to more noticeable improvements in the medium and long terms.

REFERENCES

[1] Ahuja, I. P. S. and Khamba, J. S. (2008) 'Total productive maintenance: literature review and directions', International Journal of Quality & Reliability Management.

[2] Amaral, F. D. (2016) Gestão da Manutenção na Indústria., Lidel. Lisboa.

[3] Boris, S. (2006) Total Productive Maintenance: Proven strategies and techniques do kees equipment running ate maximum efficiency. McGraw-Hill. New York.

[4] Cabral, J. P. S. (2006) Organização e Gestão da Manutenção. 5.a Edição. Lidel. Lisboa.

[5] Instituto Português da Qualidade (2007) 'Terminologia da manutenção: Norma Portuguesa NP EN 13306'.

[6] Jornal Público (2011) Um grupo com vinhos, café e imobiliário | PÚBLICO. Available at: https://www.publico.pt/2011/12/18/jornal/um-grupo-com-vinhos-cafe-e-imobiliario-23637661 (Accessed: 30 September 2018).

[7] Pinto, C. V. (2002) Organização e Gestão da Manutenção. 2.a Edição. Monitor. Lisboa.

[8] Pinto, J. N. F. (2012) João Nuno Ferreira Pinto Implementação da metodologia TPM numa empresa de produção de elevadores. Universidade do Minho.

[9] Pinto, J. P. (2013) Manutenção Lean.Lidel. Lisboa.

[10] PINTO, J. P. (2009) *Pensamento Lean- A filosofia das organizações: Vencedoras.*Lidel.Lisboa