v. 4, n. 20, 2024

Journal of
Engineering
Research

IMPLEMENTATION OF THE TPM METHODOLOGY IN MILITARY COMPANIES

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Abstract: The "Total Productive Maintenance" [TPM] methodology is prominent in improving industrial, operational efficiency and production volume, and can be evaluated through indicators. The objective of this study was to map the best maintenance management practices in industries in general, so that the techniques of the [TPM] methodology were applied, managed and controlled in a military company. To prepare these indicators, an "on-site" visit was carried out and data was extracted from "Systems Applications and Products" [SAP] creating a filter and identifying, among the eight pillars of TPM, the one that would immediately apply to the process. Thus, preventive and autonomous maintenance, with the establishment of monthly goals by department, proved to be the most effective. The result obtained, initially, was timid, but the elaboration of the indicators provided a general analysis of the departments within the scope of maintenance. This assessment made it possible to determine critical and strong points of the activities carried out in planned and autonomous maintenance, which was essential to begin the more detailed development of each graph. The techniques used consist of managing and focusing efforts on planning maintenance activities to make the production process more efficient.
Keywords: SAP, TPM, Planned maintenance, Autonomous maintenance.

INTRODUCTION

Maintenance can be observed as the search for improvements in the performance of equipment, products, and effectiveness in operation and profitability. Therefore, given this concept, the "Total Productive Maintenance" [TPM] methodology is necessary to guarantee this process (Ciro Yoshinaga, 1993).

The [TPM] methodology emerged in the early 1970s, shortly after the consolidation of the automobile industry in Japan, expanding into several segments in that country and, consequently, reaching other regions of the world such as the USA, Europe, Asia and South America., where they also sought and seek to apply this methodology (Takahashi, Suzuki, 1994).

[TPM] consists of a set of techniques aimed at productive excellence which, in turn, are controlled through performance indicators, productivity, absenteeism and final quality. It is a methodology aimed at the maintenance engineering department and, in addition, seeks qualification. Thus, the maintenance engineering department plays an important role in this process as one of the key factors for cost reduction, continuous improvement, increased productivity and implementation of new projects (Takahashi, Suzuki, 1994).

By knowing the importance of the maintenance department within the scope of [TPM], and seeking better efficiency, the methodology comes to carry out the necessary maintenance aimed at continuity and improvement of production, being also responsible for the implementation of new projects. However, to meet a constant production volume and avoid losses and unscheduled equipment downtime, it is necessary to include project management techniques and involvement of maintainers within the context of the methodology in question.

[TPM] mainly aims at "zero breakage" and "zero failure" of machines and processes. For Nakajima (1993), the [TPM] methodology is important in production processes because it aims to integrate man and machine, as well as participatory management and a participatory approach so that operators obtain greater operational performance.

Although the [TPM] methodology, in itself, has the role of controlling existing losses in the production and administrative process, caution is necessary at the beginning of its implementation so that the expected return is achieved in a conscious and controlled manner.

Therefore, [TPM] must be treated as an atypical implementation between industries and mainly between production departments. Therefore, it is important to initially assess the cost of implementation in each department and stipulate the objective to be achieved in small-scale stages.

The development of the monitoring plan is necessary for the maintenance engineering department to analyze and control the production departments through implementation indicators, thus controlling the level of education and knowledge of workers in relation to production processes. This control is carried out through eight pillars of the [TPM] methodology, which according to Suzuki (1994), consists of autonomous maintenance; planned maintenance; specific improvements; education and training; quality maintenance; initial control; Administrative TPM; and TPM in safety, hygiene and environment.

Therefore, to define which of the pillars is the most appropriate for the department, an analysis must be carried out regarding the level of return according to the goals and deadlines of the strategic plan, as well as the definition of efficiency, which must be one of the major factors to be considered. be analyzed. Thus, the greater the level of knowledge of operators and maintainers regarding the equipment they operate and also the processes in each department, the better the chances of implementing the [TPM] methodology.

Therefore, to consolidate the [TPM] methodology, the "status" of each of the pillars, by department, must be controlled, as well as the level of education of workers. Also, one must focus on the pillar that produces the most productive and financial return until reaching the initially stipulated objective and, after the goal is achieved, move on to the other pillars. Therefore, monitoring through indicators is necessary.

According to Suzuki (1994), the necessary basis for the development of the aforementioned pillars is the education and training of maintainers, operators and management so that it is possible to overcome the vicious cycle. However, it will only give results when the approaches increase and, consequently, the managerial, technical and practical skills of each individual involved in the process and training must be initiated on the first day of [TPM] implementation in order to consider the work environment., needs, aptitude, character and skills developed in training.

The present study aimed to map the best maintenance management practices in industries in general, so that the techniques of the [TPM] methodology were applied, managed and controlled by applying them specifically to a military company. To achieve this, the starting point was to solve the problem of how to control the efficiency of implementing the methodology, control the need for investment in the methodology, manage integration needs between methodology, productivity and whether its implementation is viable in the short and long term for two specific production departments, called A and B.

MATERIAL AND METHODS

The manufacturing productive sectors must be in cohesion for integration to occur between the pillars of the [TPM] methodology, therefore, for this to occur, efforts to improve production processes must be distributed among the pillars of [TPM], in order to so that the chances of successful results are increased.

This way, the results of implementing the [TPM] methodology are measured through indicators represented by the acronym [PQCDSM], which represents P for

Production/manufacturing; Q for Quality and environment; C for Cost; D of delivery time ("Delivery"); S for Safety and hygiene; and M for Morale, motivation and integration (Suzuki, 1994).

Thus, it is possible to detail the indicators based on the information acquired from the factory in question and determine which indicators are most important for initiating the implementation of the methodology.

The company studied is a national company founded in 1962 by Italian immigrants in the field of manufacturing hunting and shooting ammunition, located in Utinga, municipality of Santo André, state of São Paulo. In 1942, the company acquired an area of 1,888,564 m^2 in the municipality of Ribeirão Pires, also located in the state of São Paulo, where it is currently located, and in 2007 it became a multinational company, acquiring a branch in Germany that manufactures ammunition. military and police. In 2009, it further expanded its operations internationally by acquiring a branch in the Czech Republic.

The company currently has 1,800 employees and operates in 130 countries with production units in four countries and is a world leader in the manufacture of ammunition for portable weapons and one of the largest suppliers of small caliber ammunition.

The company in question, the object of study in this work, already uses one of the necessary procedures to collect data on emergency occurrences. This procedure fits into the methodology processes that correspond to the pillars of preventive and predictive maintenance, which is the use of corrective maintenance cards to control failures and breakdowns (Figure 1). Thus, the data is incorporated into the "Systems Applications and Products" [SAP] management system and based on this collected data, it is possible to generate indicators for the number of failures represented by the acronyms [MTBF] "Mean Time Between Failure", and [MTTR]" Mean Time to Repair", as well as the total number of machines stopped by department.

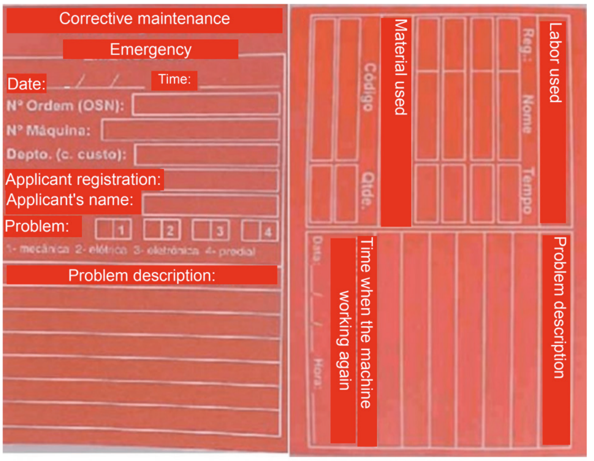

Figure 1: Corrective action emergency report card. Source: Developed by the company studied.

Focusing on the pillar of preventive/ planned maintenance, which combines corrective, predictive and autonomous maintenance methods, information is used regarding equipment operating time, useful life of components and "feedback" from these maintenances. The objective of preventive maintenance is to eliminate equipment failures and breakdowns, avoiding losses due to equipment downtime, making it vital to use all available tools and technologies for small, medium and long-term maintenance.

For Takashi (1993), specific maintenance activities guarantee the reliability of the machine. Thus, a clear distinction is established between failure and maintenance, although the term "failure" means loss of the specific function of a machine and/or process (Suzuki, 1994; Takahashi, 1993).

The information provided by the company analyzed is data on equipment that had some type of mechanical, electrical, electronic or building failure and that was treated as an emergency, resulting in loss of production volume or equipment stoppage. The data is monthly, referring to the period from January to June 2017. Initial annual goals were established and can be changed according to progress in each indicator to initiate development with the aim of finding critical points and bottlenecks in occurrences.

RESULTS AND DISCUSSION

The first step to be carried out was the analysis of the data provided, referring to the critical points and needs of each production department. After this first stage, roles and responsibilities were delegated in the implementation of the "Total Productive Maintenance" [TPM] methodology between leaders and operators, in accordance with the eight pillars established by it. Thus, the profile of each of these employees was observed, allocating them rationally in order to minimize costs.

The production departments were outlined according to the analysis of data taken from corrective maintenance in conjunction with the company, and classified as A and B. Two departments were chosen, considered critical due to the amount of equipment downtime and time between failures and repairs, defined in a meeting " in-place."

The initial premise was the training of maintainers and those responsible for the production area, guiding them to properly fill out the [MC] cards as shown in Figure 1.

The development of the indicator for the number of stops due to equipment breakdown or failure (Table 1) was predominant to determine which departments must be monitored. To prepare the graphs, the number of corrective maintenance cards, as shown in Figure 1, issued by production departments requesting the intervention of system maintainers was quantified. [ANDON[1]].

Table 1 was provided by the company studied, internally defining the initial goals for the indicators in question. The amount of equipment and availability of each department per machine was also informed, with the company working in three shifts, which means that each piece of equipment works 24 hours a day, considering 20 working days. This way, the machine time of 480 hours was considered.

The first indicator to be defined was the number of equipment stops, which is the sum of corrective maintenance cards issued by the aforementioned production departments A and B. This way, the results were obtained as shown in Figures 2 and 6.

The next step was to count the number of hours that the equipment was stopped based on the information extracted from [SAP] which is counted according to the occurrences quantified in the form in Figure 1 contained in the fields that indicate the time the machine stopped and the time in which the machine resumed operation. This way, the results were obtained as shown in Figures 3 and 7.

The next step was to create the [MTTR] graph, which is the average time between repairs, which is used to measure the available production time. Thus, equation (1) measures the [MTTR] which is the total maintenance time divided by the total number of corrective maintenance or number of breakdowns, thus giving the result as shown in Figures 4 and 8.

$$MTTR = \frac{\text{Total maintenance time}}{\text{Total number of breaks}} \quad MTTR = \frac{\text{Total maintenance time}}{\text{Total number of breaks}} \tag{1}$$

Measuring the average time is necessary to visualize which equipment takes the longest to break down and which takes the longest to repair. This data is essential to determine which equipment requires more attention for the development of a preventive maintenance plan, and, in addition to this information, it is possible to make informed reliability decisions, such as repairing or replacing a component, and storing parts in the frame [KANBAN[2]].

1. Word of Japanese origin that means lamp, allows visual control and sound alert to check if there are productive occurrences.
2. Word of Japanese origin that means card or sign, allows detailed control of component breakdown and facilitates access to

Departments	Number of machines per department	Total hours available each month	Target for number of stops		Target MTBR	Target MTTR
				h		
Department A	17	480	34		220	2
Department B	43	480	86		220	2
Total	60	960	120		440	4

Tabele 1: Goal Information Table

Source: Prepared by the company studied (2017)

In parallel to the [MTTR] graph, the "Mean Time Between Failure [MTBF]" graph must also be developed, which consists of the average time between failures or breaks. Whereas [MTTR] affects equipment availability, [MTBF] affects equipment availability and reliability as shown in Figures 5 and 9.

The average time between failures is used to project the probabilities of a single failure within a given period, making it possible to develop a production plan for each production line, system or components. Consequently, the level of reliability is increased by determining the need for scheduled stops. Based on the availability time of the equipment, it can be highlighted that the labor factor, that is, maintainer or technician, directly influences the final result, as each employee performs this role differently.

The availability of the equipment can be calculated according to the number of hours in operation, in this study it was considered that the company works in three shifts. Understanding these factors, figure 6 can be developed with equation (2).

$$MTBF = \frac{\text{Quantity of available hours}}{\text{Total number of breaks}}$$

$$MTBF = \frac{\text{Quantity of available hours}}{\text{Total number of breaks}} \quad (2)$$

SPECIFIC ANALYZES – IMPLEMENTATION OF THE TPM METHODOLOGY

DEPARTMENT A

Figure 2 represents the number of stops in the department's months, where the horizontal line represents the target proposed by the company. A target of 34 machines stopped per month was established, which is a very audacious figure for the number of occurrences, precisely to obtain a better perspective of the development of the methodology over the months.

Therefore, with the high rate of equipment breakdowns, [KANBAN] tables were proposed to improve access to components that can be exchanged quickly and at low cost, enabling local stock and not just in the warehouse.

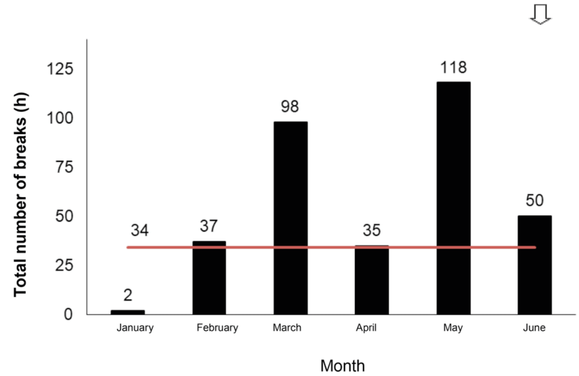

Figure 2. Quantities of downtime machines in the department A Source: Original research results (2017)

Note: The lower the values, the better the scenario

spare components for quick exchange.

Figure 3 represents the number of machines stopped throughout each current month. In this chart, no monthly goals are stipulated, as the [TPM] methodology focuses on breakage and zero failure (“0”). This information is sent to the production department to carry out a survey of production losses and estimated costs.

Therefore, for this situation, the need to develop an autonomous and planned maintenance plan was raised based on the incident card as shown in Figure 1.

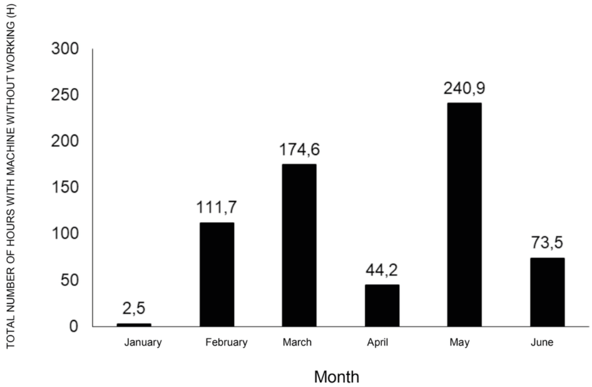

Figure 3: Quantities of downtime machines in the department A Source: Original research results (2017)

Note: The lower the values, the better the scenario

Figure 4 represents the average number of hours that are required to repair or repair the failure, that is, the time in which the equipment returns to normal operation. Based on this figure, it is possible to stipulate the system’s level of reliability in better managing production schedules. The average time depends on each type of failure, that is, when it is just a replacement due to broken components, the diagnosis is quick. But if there is a need to find a fault that is not evident, this ends up taking a lot of machine down time and at this point it is important to train maintainers on faults and operation with an adequate preventive maintenance plan for items that require manual labor. specialized work and long repair times.

Therefore, a general target of 0.8 hours was set to repair each fault, being considered a low target by knowing number of productive equipment in the department, which is 17, as shown in Table 1.

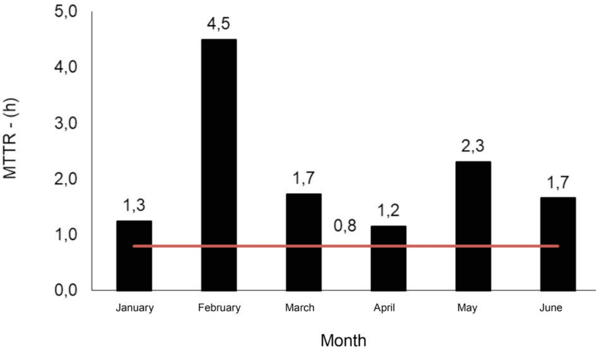

Figure 4. Quantities of downtime machines in the department A Source: Original research results (2017)

Note: The lower the values, the better the scenario

Figure 5 represents the mean time between failures, that is, it is the average between a failure and the start of another failure, and this measurement must be made in units of time and the unit adopted was in hours (h). Therefore, these data are applied in parallel to the [MTTR] graph, and for this analysis, it is important to develop an autonomous and predictive maintenance plan so that it is possible to predict failures before they even happen, avoiding increase in equipment breakdowns and carrying out scheduled maintenance.

This way, a tangible short-term goal of 220 hours between failures was set, and this goal must be achieved by optimizing the time between failures.

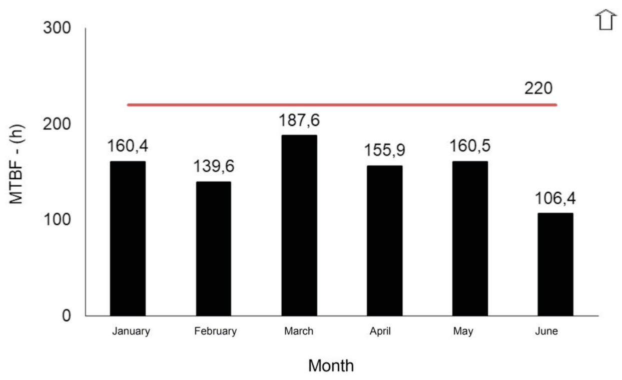

Figure 5: Chart of quantities of stopped machines in department A

Source: Original research results (2017)

Note: The higher the values, the better the scenario

DEPARTMENT B

Figure 6 represents the number of stops over the months in department B, where the horizontal line represents the target proposed by the company. A target of 86 emergency stops was established, following the similarity of department A, but double the amount of equipment.

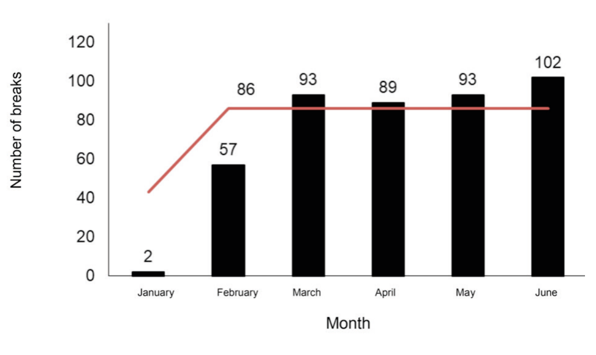

Figure 6. Quantities of machines stopped in department B Source: Original research results (2017)

Note: The lower the values, the better the scenario

Figure 7 represents the amount of machine downtime throughout each current month. In this graph, no monthly targets are stipulated, because, as previously highlighted, the [TPM] methodology focuses on zero breakage and failure ("0"). This information is sent to the production department to carry out a survey of production losses and estimated costs.

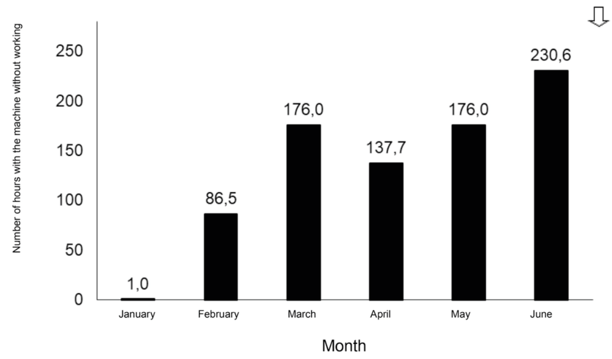

Figure 7. Quantities of machines stopped in department B Source: Original research results (2017)

Note: The lower the values, the better the scenario

Figure 8 represents the average number of hours required to fix the fault or repair, that is, the time it takes for the equipment to return to normal operation. Based on this figure, it is possible to stipulate the system's level of reliability and better manage production schedules. The average time depends on each type of failure, and when it is just a replacement due to broken components, diagnosis is quick. However, if there is a need to find a fault that is not evident, the process ends up taking a lot of time, leaving the machine stopped, and it is at this point that training maintainers on faults and operation becomes important, improving efficiency. between man and machine, so that the necessary preventive maintenance plan for the items is carried out, with the need for specialized labor and with a long repair time if necessary.

Therefore, a general target of 1 hour and 50 minutes was set to repair each fault, meaning an apparently high target, but necessary, by knowing the number of productive equipment in department B, which is 43 according to Table 1.

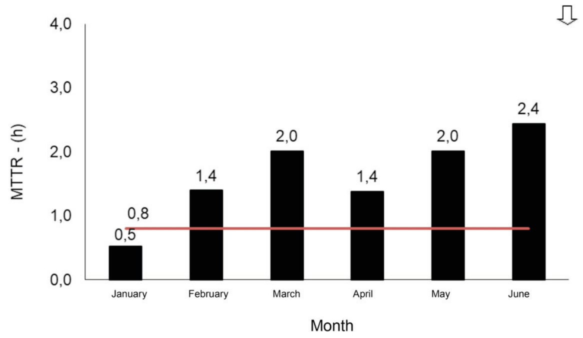

Figure 8. Chart of quantities of machines without working in department B

Source: Original search results (2017)

Note: The lower the values, the better the scenario

Figure 9 represents the mean time between failures, that is, it is the average between one failure and the start of another failure. This measurement must be made in units of time and the unit adopted was hours (h). Therefore, these data are applied in parallel to the [MTTR] graph, and for this analysis it is important to prepare the autonomous and predictive maintenance plan so that it is possible to predict failures even before they occur, thus avoiding, the increase in equipment breakdowns and carrying out scheduled maintenance.

This way, a tangible and initial target was set for the department of 220 hours between failures.

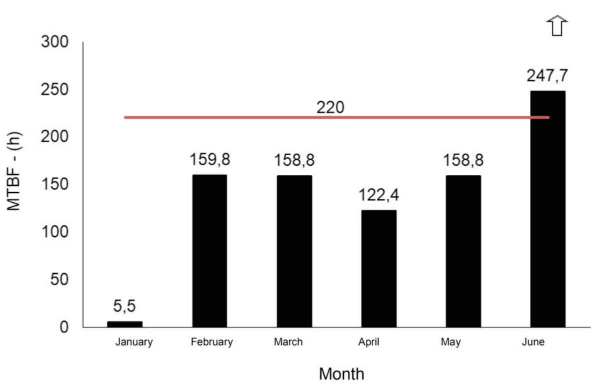

Figure 9. Chart of quantities of downtime machines in department B Source: Original research results (2017)

Note: The higher the values, the better the scenario

PRE- AND SUBSEQUENT IMPLEMENTATION ANALYSIS

The application of the "Total Productive Maintenance" [TPM] methodology was carried out for both departments (A and B). Although there was variation in the data, they reached the same initial goals for both to monitor the evolution of the application, aiming to increase productivity, minimize costs, aiming for a quick return.

Immediately, with the elaboration of the indicators, [TPM] already offers the possibility of a perspective view of the current scenario of the industrial equipment park, the critical points for the process, and the bottlenecks for the maintenance of critical components.

From the presentation of this scenario, it is possible to create graphs of cost per equipment stoppage, cost of labor spent on maintenance, cost of product left unproduced, being able to create indicators based on the pillars of the methodology, resulting in ideal planning maintenance and a global view of production departments. For this study, a graph of labor costs spent on corrective maintenance between departments was created, as shown in Figure 10.

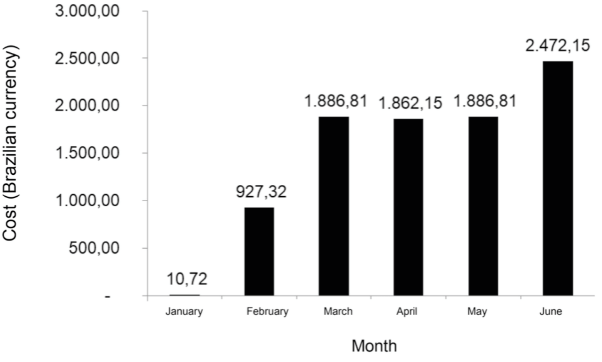

Figure 10. Corrective maintenance cost graph – Department B

Source: Original research results (2017)

CONCLUSION

The implementation of the "Total Productive Maintenance" TPM methodology enabled an initial perspective of the industrial park, analyzing two production departments, with the aim of developing new maintenance plans with the aim of reducing costs and increasing productivity.

After presenting the results to the company with the maintenance engineering planning coordination, it was generally possible to obtain support to continue the implementation in the other departments, and monitoring of these departments will also be carried out in order to improve the implementation and presentation of the costs contained, subsequently showing the advantages of implementing the [TPM] methodology.

The biggest difficulty in implementation is the initial culture that must be modified, overcoming the end client's paradigms and barriers. Such a culture will only be overcome with the direct support of department management. It is worth mentioning that, in the past, there was an initial attempt to implement the same methodology without success.

Working together with the planning department made it possible to collect data and define goals to be achieved initially and in subsequent months. Even though it is an aggressive goal, the objective is to show that the maintenance process directly affects the production process and that more attention and availability of equipment is needed for preventive maintenance.

By knowing the initial implementation, it is necessary to expand the techniques of the other pillars of the [TPM] methodology to ensure stability in the implementation.

In this sense, with the initial study it can be established that the maintenance department will be able to control the reliability of its equipment, prepare preventive and autonomous maintenance plans, and develop the kanban board to improve equipment breakdown times.

The implementation of the [TPM] methodology generates a high cost and long-term return in addition to investments with consultancy companies and extra investment in control tools, in addition to training at an operational and managerial level. Therefore, a thorough evaluation of the data obtained and the real need for long-term investment is necessary, so as not to have an unsuccessful implementation. During this study and in previous participation in implementations of the methodology, it can be seen that the implementation itself requires a pre-implementation plan for the methodology, in order to direct those responsible not only to the maintenance department, but also to also for production departments. As a result, there is an opportunity to merge the management techniques of the "Project Management Body of Knowledge" [PMBOK] for the integration of the implementation, developing a methodology implementation plan, as well as monitoring and stipulating goals for each department and pillar, including the processes and activities of each employee and their level of training. Thus, this is a basis for starting a study.

THANK

Firstly, I thank God for the blessings he has given me and for providing me with health and determination to always improve, my family for their unconditional support in overcoming all prejudice and always seeking victory. To my advisor Michel Augusto Santana da Paixão for all his dedication and commitment to helping me achieve this goal and to my friends who contributed directly and indirectly.

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