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ANALYSIS OF RESULTS OF A PILOT IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE IN A BRAZILIAN INDUSTRY

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A B S T R A C T

Recent studies have shown that the losses generated in the production, due to the maintenance system, have been a limiting factor in the search for the improvement of the productivity of the processes and the quality of the products. Such objectives are directly associated with the company's capacity to reduce their production costs and offer products and services that meet the client´s needs. The company is seen today as a value chain, where manufacturing, maintenance, and logistics, among other sectors, influence the organization's results. In this context, a study was developed to analyze the performance of the maintenance sector of an automotive company and its influence on the company's results. The work aimed at analyzing the results obtained with the implementation of Total Productive Maintenance (TPM), a methodology for optimizing the performance of production processes, in the body sector of an automobile industry in Brazil. For this, a follow-up and evaluation of indicators were carried out, showing the performance of the company's maintenance system and the results with the production. In this way, the gains in competitiveness obtained were made evident, including the achievement of the Organization's goals for the production line of the bodywork of one of its popular vehicles.

1. INTRODUCTION

The manufacturing industry deals with different challenges to manage complexity in a production process due to the demand for the diversity of products offered to customers (Barbosa et al., 2023; Rebolledo & Jobin, 2013; Shen et al., 2023; Silva et al., 2021; Talapatra et al. 2022). The consumer has several options to select similar products. Most consumers choose based on their overall perception of quality or value. Consumers generally want the best possible return on their money. To remain competitive, companies need to identify what is important to increase consumers' perception of the value

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or quality of a product or service (Santos &Milan, 2013; Santos & Barbosa, 2006; Rebolledo & Jobin, 2013; Sales et al., 2022; Cardoso et al., 2022). The quality area of a company is becoming the focal point and one of the biggest investments that companies have made (Cardoso et al., 2022).

The guiding principle is that Quality must begin before manufacturing begins and capital allocations are made. In practice, this means that companies should start by establishing their quality goals and develop product features that meet those goals. They must also develop processes capable of delivering those products, and establish controls that enable operations to be conducted in a consistent manner that reduces waste, thereby reducing waste generation and contributing to sustainable industrial development (Santos et al., 2017;Teixeira et al., 2022; Silva et al., 2022; Gomes et al., 2022; Hill et al., 2023; Liu et al., 2023). It is necessary to move towards the circular economy (Ramos et al., 2022; Sá et al., 2023; Sun et al., 2023) with help innovation (Figueiredo et al., 2023)

With the implementation of mass production, instituted by Ford in the United States, the factories started to establish minimum production programs and, consequently, felt the need to create teams that could perform repairs on the machine tools in the shortest time possible. Thus, an organ subordinated to the operation arose, whose basic objective was the execution of maintenance, today known as corrective (Cobas-Flores et al., 1998; Ghislain & McKane, 2006; Pathak, 2012; Vaz et al., 2021).

Originally, maintenance was established as an activity that should be carried out, in its totality, by the very person who operates the production resources. However, as technology evolved, especially equipment became larger and more complex. On the other hand, as the corporate structure grew, the maintenance function was gradually divided and allocated to specialized sectors (Arani et al., 2020; Graisa & Al-Habaibeh, 2011; Pacheco-Colcas et al., 2022).

The corporate structure grew; the maintenance function was gradually divided and allocated to specialized sectors. Total Productive Maintenance (TPM) was originally developed by the Japan Institute of Plant Maintenance (JIPM), the Japanese industrial maintenance association, and implemented in Japanese industry starting in 1971, initially in the Toyota group, Total Quality Management (TQM) and TPM have gained wide acceptance in industries. Overall Equipment Effectiveness (OEE) is a method of measuring the effectiveness of equipment usage. This method is known as an application of a TPM program. TPM is a management method that identifies and eliminates the existing losses in the productive process, maximizing the use of the industrial assets, besides guaranteeing the generation of high quality products at competitive prices (Dubey & Ali, 2011; Hama Kareem & Talib, 2015; Sayuti et al., 2019).

According to the context presented, this research aims to analyze, by means of indicators, the results before and after the implementation of TPM in an automotive production process. The results of the indicators when compared may allow the identification of opportunities for improvement in the production processes of the sector, thus monitoring the evolution and behavior of each of the component indicators of TPM.

2. THEORETICAL FRAMEWORK

The concept of 5S is introduced in the Quality Circle formed in companies and is called the cornerstone of TPM implementation. It is a Japanese way of taking care of the house. Problems cannot be recognized in a workplace is disorganized. Cleaning and organizing the workplace helps to identify problems. These quality improvement and maintenance initiatives are the result of the need to prohibit bad practices in the wake of customers giving preference to quality competitive products (Hama Kareem & Hama Amin, 2017; Reis et al. (2023a); Reis et al. 2023b; Murmura et al., 2021).

TPM in Japan involved all the organization's employees, although at first it was only implemented in the departments directly involved with the equipment and production, starting to be effectively applied after the introduction of preventive maintenance. This concept involves the whole organization, to obtain efficiency in its activities (Demiralay et al., 2023; Pacheco-Colcas et al., 2022; Zlatić, 2019).

TPM was originally developed by the Japan Institute of Plant Maintenance (JIPM), the Japanese industrial maintenance association, and implemented in Japanese industry starting in 1971, initially in the Toyota group. This concept can be divided into short-term and long-term elements (Demiralay et al., 2023; Hama Kareem & Hama Amin, 2017; Hara & Yokono, 2004).

The long-term elements are focused on developing new equipment and eliminating sources of wasted production time (Félix et al., 2018). The short-term elements focus on autonomous maintenance programs for the production department, planned maintenance for the maintenance department, and special skill development for equipment operation and maintenance personnel (Aadithya et al., 2023; Guha et al., 2023; Shah & Ward, 2003).

TPM is a popular management system approach that aims to analyse equipment downtime through complementary maintenance methods and techniques. TPM gained more attention during the 1990s as an approach to maximize resource utilization through basic maintenance and stability practices. In the context of emerging economies, where capital spending levels are low, and the purchase of new machinery requires greater effort, equipment utilization, and maintenance are crucial to improving the shop floor (Ajiboye et al., 2012; Chaurey et al., 2023; Samadhiya et al., 2023).

TPM is a management method that identifies and eliminates losses in the production process, maximizing the use of industrial assets, and ensuring the generation of high-quality products at competitive prices. Furthermore, it develops knowledge capable of re-educating people for preventive actions and continuous improvement, ensuring the increase in equipment reliability and process quality, without additional investments (Gurumurthy & Kodali, 2008; Shah & Ward, 2003; Santos et al., 2014; Doiro et al., 2017; Vieira et al., 2019; Silva et al., 2020; Valamede & Akkari, 2020).

3. RESEARCH METHOD

In this work, action research was developed because it refers to a process of change, based on the systematic collection of data, followed by the selection of an action for change, based on what the analyzed data indicate. Its importance lies in providing a scientific methodology for the management of a planned change (Araujo et al., 2021; Al-Zubaidi et al., 2022; Kothari & Garg, 2019; José Salvador da Motta Reis et al., 2021).

The company studied is a multinational company that assembles popular cars and is in the south of the state of Rio de Janeiro. Because it is a global company, there is a constant search through benchmarking between its plants, to improve processes to reduce costs and ensure business viability. Data collection and processing were used as one of the most important steps to support indicators for monitoring and analysing the results. These indicators were established so that structured information could be obtained, allowing the identification and analysis of TPM impacts on the sector and the company itself. In this sense, in communion with the objectives proposed for the work, seven performance indicators were defined and analysed for the referred production line. The methodological flow used is shown in Figure 1. The methodology of monitoring results through indicators is of vital importance to visualize the performance of a production system. This is because it allows us to see the variations in the process, whenever they exist over time.

These indicators were established so that one could obtain structured information enabling the identification and analysis of TPM impacts on the sector and the company itself. In this sense, in communion with the objectives proposed for the work, seven performance indicators were defined and analyzed for this production line, namely Synthetic Yield; Operational Yield; Own Availability; Operational Availability; Direct Good; MTTR; and MTBF.

The names of these indicators follow the standards commonly used in the global automotive industry, except for the synthetic performance indicator. This in the form presented constitutes a tool developed for exclusive organization applications. Nevertheless, the content of each indicator, the focus of the analysis developed, will allow us to visualize the effects of applying PMS on the indicators analyzed in this study. These indicators and their parameters will be detailed in this section, according to the methodology described.

The analysis focus indicators are easy to understand and apply, are directly related to the performance of the Total Productive Maintenance implantation and make possible the comparison between different units of the organization when you want to measure their effectiveness.

The Synthetic Yield is the technical tool for measuring the overall performance of TPM sites, through which one can see all the losses that occurred in the production lines where TPM was implemented. This indicator only finds its meaning in the analysis of the 6 families of non-performance. The calculation of the Synthetic Yield, as performed in the company, used an electronic spreadsheet to facilitate the organization and statistical treatment of the data.

The Operational Yield indicator demonstrates the overall performance level of a production line, during the product realization time by the operators added to the process. The Own Availability indicator shows the time that the equipment is available to perform its function satisfactorily. Only losses due to equipment stoppages are considered. Neither quality losses nor losses in the cycle, nor losses due to stoppages induced by external causes are considered.

The Good Direct indicator shows the quality level of the production line. The mathematical calculation is characterized by the total amount of parts produced, subtracting the number of parts out of specification, and dividing by the total amount of parts produced, thus presenting the ratio between the good parts and the total amount of parts produced. The indicator Average Time to Repair indicates the reactivity level of the Maintenance in the correction/intervention of the production line failures. The mathematical calculation shows the average time that maintenance takes to repair a failure.

The indicator Average Time Between Failures indicates the ability (time) of the equipment of a production line to operate continuously, free of breakdowns. It is not considered the equipment repair time, but the time between occurrences between any breakdown. The indicators detailed above were then applied and generated the results presented and discussed in the following chapter.

4. RESULTS AND DISCUSSIONS

The analysis of each of the performance indicators of that line indicated incontestably the significant gains obtained with the adoption of TPM methodology, as shown below.

To facilitate the analysis of the evolution of results, Table 1 was used with consolidated values for each of the indicators used, focusing on the results before and after the application of TPM on the production line1. Thus, it was sought to highlight the improvements obtained in the production results.

Table 1. Review of the main elements for the Business Strategy implementation.

Indicators	Abbreviations	nov/03 (Before)	nov/04 (After)	Gain	Unit	Behavior
Synthetic Performance	SP	45,18	68,09	22,91	%	Improved ☺
Operational Performance	OP	74	89,6	15,6	%	Improved ☺
Self Availability	SA	66,8	86,3	19,5	%	Improved ☺
Good Straightforward	GS	98	100	2	%	Improved ☺
Average Repair Time Between Failures	ARTBF	14,71	9,87	4,84	Time (min)	Improved ☺
Average Time Between Failures	ATBF	185,36	440,56	225,2	Time (min)	Improved ☺

It is observed from Table 1 that all indicators applied for the analysis demonstrate significant improvements in their indexes, especially the SR indicator, which demonstrates the overall performance of the production line and, consequently, the reduction of losses. As can be seen in Figure 27 there was an improvement of 22.91%, between November 2003 and November 2004, i.e., after twelve months of implementing the TPM methodology.

This result represents an evolution of more than 100%, over the initial established goals of 10.21%. The operational yield, which reflects the performance level of the production line, during the time effectively used by the operators, grew 15.6% in the analysis period. This result was mainly due to the decrease in breakdowns and micro breakdowns and quality losses.

The indicator of Own Availability, which shows the percentage time that the equipment is available to perform its function satisfactorily, experienced an evolution of 19.5%, exceeding the goal set by the organization. For the Good Direct indicator, which represents the production obtained without any kind of rework (free of defects), the percentage evolution can be understood at first as small, of only 2%. However, this figure reflects a gain over the November 2003 figures, which were already considered very good.

For the average time to repair between failures that, as already described, refers to the visibility of the average time that maintenance is making repairs on the production line, the gain obtained was 4.84%, reflecting a better performance (skills and competencies) of the maintenance teams during the corrective interventions on the production line. The average time between failures, which represents the capacity (time) that the equipment of a production line operates continuously (free of breakdowns), had a very expressive evolution, with gains of 225.2%. This was due to the improvement and time availability of the maintenance team, due to the fact that the production operators took over the simplest aspects of equipment maintenance.

4. CONCLUSION

As characterized in the body of this work, a TPM analysis was performed in the bodywork sector, referring to one of the production stages of the company's popular vehicle. For this, data was collected over twelve months, which enabled the evaluation of the behaviour of the production line performance indicators with the application of the TPM tools. As a result of the results presented and discussed in Chapter 6, a significant improvement of all performance indicators in the bodywork sector, related to the production line of this vehicle, can be observed with the implementation of the TPM methodology. Easy-to-interpret indicators, commonly found in the industrial maintenance literature, were used. These made possible a reliable analysis, showing the benefits of implementing the TPM methodology.

It was possible to prove the improvement in the production line performance of the T1-206 Rolling Base production line when comparing the previous years, i.e., before and after the TPM implementation. The synthetic yield, respectively RS 45.18% and RS 68.09%, obtained significant gains, due to the decrease of the loss family times (NRS - non-performance) around 22.91%. With this, the body shop sector of this company in the south of Rio de Janeiro state demonstrated its ability to identify and treat process losses, thus ensuring the daily achievement of the production plan and becoming a reference within the company's production in Porto Real, a pilot area in the implementation of the TPM methodology. It was perceived during the development of the work that the results achieved, resulting from the implementation of TPM in the company's body sector, were in part made possible by the change in culture obtained at all levels of the organization, involved, directly or indirectly, with the implementation of TPM.

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