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Industrial Maintenance Management: Methods and Tools for Increasing Reliability

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Abstract. *This article aims to apply and present a bibliographic review by demonstrating methods and tools to increase reliability, basing its relationship with concepts of availability and maintainability in industrial maintenance management, contributing for competitiveness increase in organizations. It starts by reviewing concepts related to definition of maintenance, methods and tools applied to increase the reliability in maintenance management, explain what is reliability, availability and maintainability and its relation with the maintenance function, finally, it is conceptualized the good practices of maintenance and FMEA, relating the competitiveness of an organization and its maintenance function.*

Keywords: *Industrial Maintenance, Reliability, Availability, Sustainability.*

INTRODUCTION

In the current national scenario, there is a great concern of organizations to remain competitive, however few understand indeed how the maintenance function contributes directly to this goal.

Maintenance within organizations must be considered a critical point for increasing competitiveness, by contributing to success before their customers. For a long time it was considered a "necessary evil," when one spoke about maintenance in industries, the idea that used to be formed in people's minds was that of repairing something, repairing some failure, but not involving interruption of production and the use of service providers, it was something that was done reactively, that is, after the problems had appeared.

Prevention was an expression that hardly applied in factories in general, nonetheless with the increase of competitiveness among companies, it was concluded that keeping equipment available is one of the pillars to improve its competitiveness due to increased availability and reliability and reduced maintenance time of equipment, achieved with an effective and efficient maintenance function will improve competitiveness.

The present article aims to demonstrate how the use and application of methods and tools can increase reliability and availability of equipment and contribute to increase productivity, directly and decisively influencing the competitiveness of companies in an extremely demanding and globalized market.

2. INDUSTRIAL MAINTENANCE

The Brazilian Association of Technical Standards - ABNT (in Portuguese), in standard TB-116 of 1975, defined maintenance as the set of all actions necessary that an item can be preserved or restored in order to remain in accordance with a specified condition. In a revised version of 1994, designated NBR-5462, maintenance is indicated as the combination of all technical and administrative actions, including supervisory actions, designed to maintain or relocate an item in a state in which it can perform a required function.

Maintenance can be defined as a set of measures and technical care indispensable for conservation and regular and permanent functioning of a company fixed assets**.**

3. METHODS AND TOOLS FOR INCREASING RELIABILITY

Reliability: It is the probability that an item can perform its required function, for an established time interval, under defined use conditions.

1- Probabilility: Relation between number of favorable cases and number of possible cases, it is practically considered that reliability is the statistical probability of not occurring failures, of a certain type, for a certain mission, with a given level of confidence;

2- Function Required: Admissibility limit of which the function is no longer satisfactory. It is the same as fulfilling a mission;

3- Defined conditions of use: It is the operational conditions that the equipment is submitted, the same equipment submitted to two different conditions will present different reliabilities;

4- Time Interval: The time period defined and measured is fundamental as long as reliability varies over time;

5- Performance and Failure: Every equipment is designed according to specifications, every equipment is designed according to the basic function it will perform;

6- Failure rate: For most parts of an operation, failure is a time function.

At different stages of life span of anything, the failure probability will be different, the curve describing this failure probability is called "tub curve" as shown in the following figure:

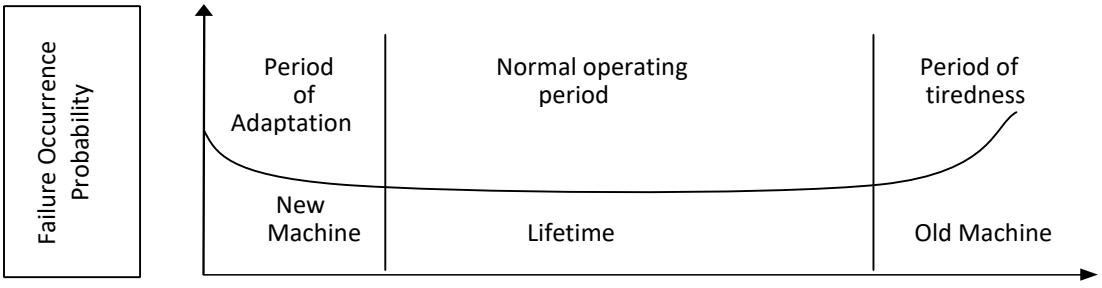

Figure 1- Tube Curve

For Slack et al. (2001), this figure represents a typical curve of an equipment life; it is comprised three different stages in it:

- ✓ "Infant" mortality, or the "early life" stage, when initial failures occur due to defective parts or improper use;

✓ The "normal life" stage, when the failure rate is normally low, reasonably constant and caused by normal random factors;

✓ The "wear" stage, when the failure rate increases as the part approaches the end of its useful life, and failures are caused by aging and parts deterioration.

Availability: It is the time in which the equipment, system or installation is available to operate or in conditions to produce. Availability is the main goal of maintenance and there are some important variables in it as in the table below:

Table 1. Variables

Total Time	It is the time that equipment could be available for operation.
Operation Time	It is the portion of the total time in which installation or equipment was running.
No-Run Time	It is the total time portion in which installation, though available, was not used by the production and stood still (did not work).

And these variables can be represented in the following way, as shown in table 2:

Table 2. Variables Representation

TOTAL TIME		
AVAILABLE TIME FOR T-PRODUCTION		TIME ON MAINTENANCE - t
TIME OF OPERATION	TIME OF NON-OPERATION	In Repair

Throughout the total time, it is obtained the available production times (T) and times in which the equipment is in maintenance (t), that is, unavailable for production. Thus, it becomes possible, for the time analyzed, to calculate the average available time (producing or not) and the mean time in repair.

The average time of good running is known worldwide as *MEAN TIME BETWEEN FAILURES* – MTBF.

$$MTBF = \frac{T1+T2+T3+T4+...+TN}{N}$$

The average time without production is associated to the failure, being known as *MEAN TIME TO REPAIR* – MTTR.

This time includes what was spent on the repair and all waits that delay the putting the equipment back into operation.

$$MTTR = \frac{t1+t2+t3+t4+...tN}{N}$$

The MTBF and the MTTR are two globally adopted indicators and together they will define availability that is nothing more than the ratio of the time the equipment or installation became available to produce in relation to the total time (PINTO E XAVIER, 2001).

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

Availability is a function of reliability and maintainability. To increase availability it is necessary:

✓ Increase MTBF (Medium Time Between Failures), reducing preventive maintenance to the least possible, adopting Predictive Techniques and practicing the development of Maintenance Engineering;

✓ Minimize ATTR (Average Time to Repair), improving personnel capacity, practicing good service planning and coordination, and also practicing development of Maintenance Engineering.

Maintainability: It is the probability that a defective item can be put back into its operational state in a predefined period of time when Maintenance is performed under determined conditions and is performed with the established means and procedures (SOUZA, 2006).

Maintainability is also defined by ABNT NBR 5462-1994, as a set of characteristics of the equipment that determines the greater or lesser facility with which its maintenance can be made.

A measure of maintainability is the standstill time for maintenance, which translates not only the execution time of maintenance operations, but also the time the equipment is stopped waiting for materials, fault investigations, tests, etc.

Maintainability can be improved by means of reducing the time required to detect and locate breakdowns, reducing time required for repair and reducing time for checking maintenance actions. And only with the first initial in capital.

Good Maintenance Practices: For Pinto and Xavier (2001), good maintenance practices is the use of what is best, to manage and to execute the maintenance services. Good maintenance practices, in addition to reducing repair time and making repairs reliable, the good maintenance practice must be linked to business dynamics and should contribute to lead the company to a market leading position, such as presented by the author, as seen in table 3.

Table 3 - Action and condition of good maintenance practices/consequences

Action/Condition	Consequences
Organizational structure; Organization of maintenance teams; Integration with materials area; Integration with areas of operation and engineering.	High productivity of own and contracted personnel; High levels of security; Improvement in level of availability and reliability; - Proactive environment.
Work processes; Planning and control of processes; Continuous process improvement; Integration of technological processes with business; Use of managerial tools to support improvement.	Reliability of services; Costs reduction of services and contracts; Increase in MTBF - Mean Time Between Failures; Optimization of procedures; Definition of control items and goals to overcome.
Management of materials and equipment; Maintenance history; Updated project documentation.	Reliable materials and spares; - Reduction of inventory in stocks – Standardization, shared recovery policy with suppliers; Consolidated database for consultation and control.

FMEA: Failure Mode and Effect Analysis - Seeks in principle to avoid that it occurs failures in product or process design by means of analyzing potential failures and proposals for improvement actions. The basic objective is to detect failures before a piece and/or product is produced, that is, an increase in reliability is sought (CAPALDO et al, 2007).

This technique can also be defined as an analytical and preventive method applicable to projects and processes to identify, analyze all potential failures and their effects, defining priority actions to minimize or avoid them.

Although the FMEA has been developed with a focus on design/processes of new products, the FMEA methodology, for its great use, came to be applied in several ways (CAPALDO et al., 2007).

Currently there are several types of FMEAs, stages and way of performing the analysis are the same, the differentiation between types occurs only in relation to the objective.

According to Pinto and Xavier (2001), experts indicate three levels of FMEA:

- ✓ FMEA in the project: aims to eliminate causes and failures during the design of equipment;
- ✓ FMEA in the process: focuses on manufacturing and assembly processes;
- ✓ FMEA in the system: focuses on global system functions.

For Capaldo et al. (2007), regardless of the type of FMEA and application, the technique principle is the same. The analysis basically consists of formation of a group of people who identify for the product/process in question their functions, the types of failures, effects and possible causes of this failure.

The sequence of steps for applying FMEA is: planning; Analysis of potential failures; risk assessment; improvement.

Pinto and Xavier (2001) conclude that "FMEA focuses on potential failures and their causes, thus the necessary actions can be taken in order to avoid future problems and losses before they even take place."

4. MAINTENANCE AS A STRATEGIC FUNCTION

In the modern concept, strategically thinking about the maintenance function effectively contributes to the company progress toward excellence, this new attitude before a scenario and a globalized and highly competitive economy are fundamental activities because nowadays there are no more spaces for improvisations and arrangements, factors such as competence, creativity, flexibility, speed, change culture and teamwork are basic features in modern business conduct.

In the current view, intervention exists so that there is no maintenance, it is necessary to keep the equipment available, reducing the probability of unplanned shutdown, it is increasingly necessary to adopt methods and tools to avoid failures and not to correct them, the correct definition of maintenance mission, its concepts and paradigms, will surely elevate the organizations to new levels of competitiveness.

5. FINAL CONSIDERATIONS

Considering the current environment, highly competitive, where flexibility, speed of response and innovation are the foundation for sustaining competitive advantage, becoming essential for companies that intend to stay in business, have methodologies and tools to support decision-making and monitoring of results.

In the past, the maintenance function was only remembered in the occurrence of equipment failures and that generated direct impacts in the process, that is, remembering the maintenance only during the process stoppage and very little in its stability. With the society evolution, concepts such as quality, price and meeting deadlines are fundamental characteristics that companies to answer the needs of their customers, transforming the maintenance function within organizations.

Failure to perform a maintenance or lack thereof may make the business unfeasible, for example in the aeronautics sector, where an accident by lack of maintenance would drive customers away and would most likely lead the company to be discontinued in the industry. The correct use of information and indicators of reliability, availability and maintainability, as well as the adoption of tools to increase reliability, will aid in the diagnosis of maintenance performance and in decision making, each manager is responsible for the management and application of process improvements, market share, customer satisfaction and loyalty, guaranteeing the survival, competitiveness and constant evolution of the company.

Modern maintenance management must be supported by a future vision and managed by management processes aimed at continuous improvement, productivity and competitiveness, making the maintenance function a strategic factor for organizations in what refers to competitiveness.

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