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EVALUATION OF MAINTENANCE MANAGEMENT OF A THERMOPLASTIC INDUSTRY USING A MAINTENANCE MATURITY MODEL: A CASE IN MANAUS INDUSTRIAL POLE

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A B S T R A C T

The present work focuses on a case study applying a maintenance management system model based on the degree of maturity in a thermoplastic industry. The system must support the decisions of the organization and promote progress in the company's continuous improvement system. The study was based on the answers to a questionnaire submitted to the maintenance, production, and process engineering sectors. The internal perception was compared with external perception in order to perform an analysis of the field of view of the three sectors on the current position of the maintenance sector in relation to the maintenance maturity model used for this analysis. From the application of the model, it was possible to develop a strategic action plan based on lean practices, so that the maintenance areas advance towards the higher levels of the maturity scale, aiming to reach and maintain performance levels recognized as excellence.

1. INTRODUCTION

Among the numerous administrative and operational functions of an organization, the most relevant are production and maintenance since. Together, they must deliver the products or services on time, with the required quality and projected quantity.

Due to this, maintenance assumes strategic importance in the structure of the companies with direct reflexes at the level of operation and logistics. Many companies are aware of the challenges and have implemented management policies or strategies aimed at giving the maintenance function equal importance to the other functions of the organization.

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The need to increase operational availability has been driven by the requirements of productivity, quality increase, competitiveness, and market opening, among others, and thus maintenance management ensures tools and techniques to improve efficiency and minimize the impact of equipment corrective failures such as Total Productive Maintenance (TPM) and Failure Mode and Effects Analysis (FMEA) based on indicators such as MTBF (Mean Time Between Failures) and MTTR (Mean Time Between Repairs).

Companies have differentiated their maintenance strategies by combining decisions made within the various activities that involve maintenance management, as there are several aspects that we must consider in order to create a consistent strategic plan for the sector. These are the issues that tend to influence decisions such as operational aspects, for example, the administrative culture of the organization and other business requirements.

This article is organized as follows. The first section introduces the lean approach to maintenance management. The second section presents the literature review, describing maintenance management, maturity models, and maturity models focused on the area. The third section deals with the application of the selected model and field studies report. Results and analysis are discussed in the fourth section. Finally, the fifth section brings the conclusion of the research.

2. LITERATURE REVIEW

The following topics cover the academic background that supports this article.

2.1 Maintenance Management

As defined by NP EN:13306 (2007), the concept of maintenance as being the combination of all technical, administrative, and management actions during the life cycle of an element intended to conserve or restore it to a state in which it performs the required function.

Maintenance management sets goals and objectives through work standards and procedures to make the best use of available resources, whether personal, equipment, or materials. In this way, it is considered strategic when it is focused on the business results of the organization, and this implies that, in addition to having to ensure the functional availability of equipment and facilities in a production or service process, maintenance management needs to combine reliability, safety, environmental preservation, and moderate cost factors.

In addition, proper management establishes maintenance performance indicators to support management in order to achieve maintenance excellence and use fixed assets in a competitive manner (NP EN:15341, 2009).

In this sense, companies differ mainly in their maintenance strategies by the combination of decisions made within the various activities involved in maintenance management, as diverse operational aspects and business requirements tend to influence these decisions, as studies by several researchers in this area (Fernandez et al., 2003; Horner et al., 1997; Hwang et al., 2007; Murthy et al., 2002; Nodem et al., 2011; Swanson, 2001; Tsang, 2002; Waeyenbergh & Pintelon, 2004).

2.2 Maturity Models

Maturity models have emerged from the need to evaluate the quality of processes applied in an organization, whether industry or institution and are currently being used to improve the services and products of organizations. Maturity levels establish levels of process evolution, characterizing stages of process implementation improvement in the organization. The maturity level of an organization allows it to predict its future performance by executing one or more processes.

According to Maier et al. (2009) and Maier et al. (2012), many maturity models have been proposed to evaluate a range of capabilities, including quality management, software development, supplier relationships, research and development efficiency, product development, collaboration, and communication that each of these assessments focus on a particular domain of knowledge.

Fraser et al. (2002) pointed out that producing a maturity model that is generic and completely rigorous is extremely complicated. In addition, they suggest that some compromise will be necessary and appropriate in the interest of producing a suitable and usable tool. However, we can cite as an example at least 30 maturity models focused on various areas, such as software engineering, process engineering, performance engineering, and quality management (Jokela et al., 2006; Tiku et al., 2007; Wilson, 2015), as shown in Figure 1.

Maturity Models	
1. Capability Maturity Model Integration (CMMI)	16. eGovernment Maturity Model
2. Capability Maturity Model for Software (SW-CMM)	17. Earned Value Management Maturity Model
3. People Capability Maturity Model (P-CMM)	18. Outsourcing Management Maturity Model
4. Software Acquisition Capability Maturity Model	19. Change Proficiency Maturity Model
5. Software Engineering Capability Maturity Model	20. Performance Engineering Maturity Model
6. Integrated Product Development Capability Maturity	21. Architecture Maturity Model
7. IT Service Capability Maturity Model	22. Information Process Maturity Model
8. Organizational Project Management Maturity Model	23. Project Management Maturity Model (PMMM)
9. Services Maturity Model	24. Programme Management Maturity Model
10. Self-Assessment Maturity Model (SAMM)	25. Learning Management Maturity Model (LM3)
11. Test Maturity Model (TMM)	26. Automated Software Testing Maturity Model
12. Web Services Maturity Model	27. Website Maturity Model
13. Security Maturity Model (SMM)	28. PM2 Maturity Model
14. Operations Maturity Model	29. Internet Maturity Model
15. e-Learning Maturity Mode	30. Usability Maturity Model

Figure 1. Maturity models developed in several areas

2.3 Maintenance Maturity Models

According to Oliveira and Lopes (2020), maturity models have been approached in various knowledge segments, and the practical characterization of their conclusions has contributed to the achievement of better results in organizations in general. As in other areas of knowledge, maturity models have been developed for maintenance management, with the aim of identifying improvement opportunities and thus improving maintenance practices and their results in line with organizations' strategic objectives. The models available for maintenance are based on process improvements, the need for computer support and performance indicators.

In the context of maintenance Antil (1991), proposed a maturity model strongly based and inspired by the maturity model developed by Crosby in 1979 for the quality area. This model was later used by Fernandez et al., (2003) in the application of a customized maintenance management system. Wireman (1992) also proposes a model like that developed by Crosby, containing five stages and seven classes. Such a model shows the progressive stages of best maintenance practices. As an adaptation to the Crosby model, although not all issues/areas are applicable in all areas of maintenance, much can be gained from comparative practical evaluations.

Campbell and Reyes-Picknell (2006) propose a model, based on field research and the use of the Pyramid of Excellence concept, containing ten classes and five stages. Cholasuke et al. (2004) from a study in British industries, proposed a maturity model for the management of maintenance activities containing ten classes and only three stages.

Maturity models developed to assess the level of maintenance management maturity in organizations were made available by different researchers (Antil, 1991; April & Abran, 2009; Chemweno, Pintelon, Horenbeek, et al., 2015; Cholasuke et al., 2004; Hauge & Mercier, 2003; IAM, 2015; Anja M. Maier et al., 2012; Xu et al., 2021).

3. METHODOLOGY

The methodology of this work consisted of applying the maintenance maturity model developed for maintenance management processes by Oliveira and Lopes (2020). The model was applied according to the current moment of the organization's maintenance area. However, improvement actions are being studied and made possible by managers, so that we can establish a comparison between the current state and the future state of the maintenance area belonging to the organization, based on the proposed maturity model.

Information regarding the company's maintenance management was obtained through an interview by the external consultant with the current Maintenance Managers. The questionnaire system developed by Oliveira (2017) was also used during the interview, so that they were analyzed, class by class, according to the order proposed by the model. Participated in this meeting: Expert advisor; Maintenance supervisor (Graduated in mechanics); Electrical engineer; Technical coordinator of electrical maintenance (Software specialist), and Maintenance Technician.

The object of study is a company in the thermoplastic sector, which has four units in operation in Brazil. The unit of this study, located in the Industrial Pole of Manaus, manufactures plastic lids for beverages, bi-oriented polypropylene films for food product packaging and overpacks, in addition to PP (Polypropylene) and PS (Polystyrene) sheets.

The maintenance sector has 72 people and is divided into electrical maintenance and mechanical maintenance, each with their respective leaders. Among the areas where the maintenance team works are the BOPP (Bi-Oriented Polypropylene) film extrusion sector, the cutting sector (primary and secondary), packaging and, finally, the plates and lids sector.

At the time of our interview, the managers did not have the number of machines under their responsibility, but they claim that the amount exceeds 100 pieces of equipment (after the interview, 104 pieces of equipment were confirmed in the entire plant). The maintenance structure consists of technicians, technical assistants, supervision, and a single manager for the three subareas.

In order to collect the necessary information for the application of the model, after the interview with the managers of the maintenance area, in order to deepen the items covered by the model and considering the proposed classes, some considerations were made regarding the organization and management of the company's maintenance area by the Consultant.

The company's maintenance team participated in the interview phase and in the application of the maturity model, according to their point of view. At this stage of the research, a meeting was requested for feedback after the specialist's visit, with the production, maintenance, and process engineering sectors, to jointly assess the view of internal maintenance customers.

Therefore, the internal analysis was carried out with the managers of the production, maintenance, and process engineering areas. According to them, the view that internal customers have of the organizational level of maintenance management is quite distorted from the view that maintenance has of itself, and the presence of superior managers was necessary to collect more complete data on the relationships. between sectors.

4. CASE STUDY

More recently, Oliveira (2017) proposed a maturity model for maintenance management. The author evaluated the existing models in this area and considering opportunities for improvement, suggested the model that served as the basis for this work.

For the present work, besides the adoption of the maturity model developed by the mentioned author, a questionnaire, including questions related to all maintenance management processes was applied to the managers and other professionals working in the maintenance and production areas of the company.

As part of the methodological process used, in contrast to this, an external evaluation was conducted by a maintenance specialist in all processes of the organization's maintenance area, as well as the performance of its managers and production areas (Oliveira and Lopes, 2020). During the interview, it was evaluated: the posture of the maintenance sector in the area management; organization of activities; performance measures; team management; adoption of tools and methodologies for failure analysis; adoption of maintenance management supports methodologies; computer systems; subcontracting (outsourcing); main difficulties encountered by managers.

The use of this maturity model aims to help the maintenance sector of the company of the thermoplastic sector specializing in bi-oriented polypropylene films (BOPP) to identify the main points of improvement from the recognition of their weaknesses. This was due to an external analysis performed by a specialist in the area of maintenance management, to be confronted with an internal analysis of the application of the same maturity model. Thus, a concise action plan was elaborated seeking to reach higher levels within the given model.

The model has five levels of progression and ten classes for coherent assessment of maturity status in organizations, and was applied according to the current moment of the organization's maintenance area. However, improvement actions are being studied and made possible by managers, so that a comparison can be made between the present state and the future state of the organization's maintenance area, based on the proposed maturity model.

The information related to the maintenance management of the company obtained from the skilled interview with the current maintenance managers was given according to the classes proposed in the model. It attended this meeting: skilled consultant; maintenance supervisor; electric engineer; maintenance technicians and technical coordinator of electric maintenance. The result of applying the model, in relation to the team's self-assessment and that performed by the external consultant, is shown in Table 1.

Assuming that the external view is the most realistic according to our studies, but still considering the internal view as essential, a projection proposal was generated with the commitment to create an action plan to advance to the higher levels proposed by the model. For each of the model classes, a set of actions were defined, namely:

- Organizational Culture: implement actions related to the development of Kaizen Projects (Continuous Improvement);
- Maintenance Policy: define a clear maintenance policy for the organization, involving all sectors;
- Performance Management: adopt Cost Performance, Production and Equipment indicators such as OEE, MTBF, MTTR, General Maintenance Costs, Availability, Downtime;
- Failure Analysis: adopt a systematic use of failure analysis methodologies / tools such as 8D's, FMEA, FTA;
- Planning and Scheduling of Preventive Maintenance Activities: adopt the systematic use of TPM and RCM to discipline maintenance actions;
- CMMS: adopt a CMMS to discipline all maintenance activities, track assets, generate reports, generate indicators, parts control, maintenance activity planning, maintenance schedule;
- Spare Parts Inventory Management: systematize in the team the use of the SAP system, involving all those responsible for planning maintenance activities and purchasing parts/consumables;
- Standardization and Document Control: organize and adopt a document control system in the maintenance sector;
- Human-Resource Management: create a technical, operational, and behavioural training and development plans for each team member, respecting individual and departmental needs;
- Results Management (Costs and Quality Maintenance): discipline maintenance actions to prevent recurrence of problems, through a good control of the activities being developed, through a strong and consolidated maintenance plan.

The results are shown in the Figure 2.

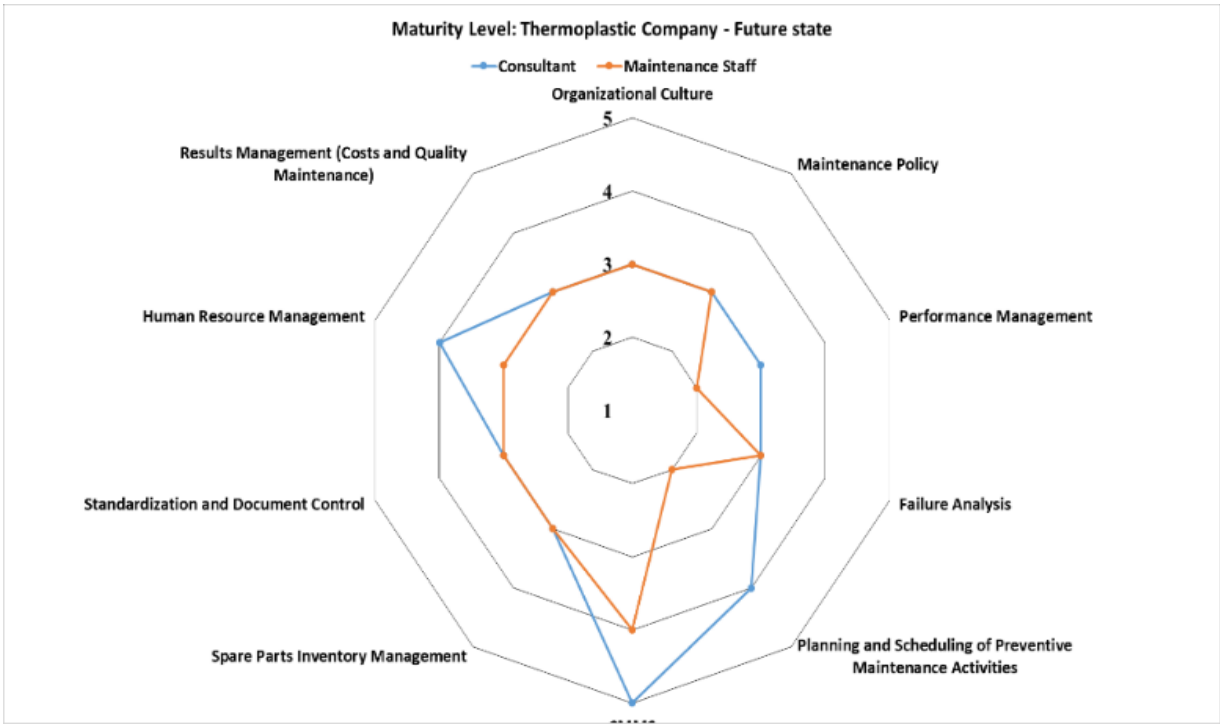

Figure 2. Maturity level analysis perceptions.

Table 1. Consultant x Maintenance staff evaluation.

Class	Consultant & Score		Maintenance & Score	
Organizational Culture	Improvement actions are isolated within the organization and between areas, with emphasis on the area of cap manufacturing. However, clearly the relationship between the areas, and between the managers, does not contribute to a peaceful coexistence, with many points of friction and nonexistent collaboration and team spirit. Collaboration occurs when there are extreme demands.	2	Limited teamwork and lack of team spirit due to differing opinions between the sectors that make up the process and, mainly, between the mechanical and electrical maintenance divisions. Due to lack of knowledge of the process, sometimes one team ends up holding the other responsible and the service takes time to be performed.	2
Maintenance Policy	Although the team of managers who participated in the interview affirmed the organization's commitment to maintenance, clearly the activities are performed according to the needs of each area of the company, since they are organized in different areas: plates, covers, films of bi-oriented polypropylene - BOPP. The orientation to act in the shortest possible time prevails.	3	Maintenance is seen as a necessary evil. This perception is due to the lack of confidence that the production team has in the maintenance. Even so, it is recognized the need to act in a preventive manner, which is even charged by production managers, although the availability to carry out preventive is conditional on the decision of the production area, in order to meet its objectives and goals.	2
Performance Management	In fact, the maintenance area adopts a single performance indicator: Availability. There is no clear understanding of indicators such as OEE, MTBF, MTTR, for example, but they intend to adopt at least MTBF.	1	There are no indicators, and during this activity, it was agreed to hire a team to study time and methods in certain sectors in order to project the use of main maintenance management indicators, such as MTBF, MTTR and OEE.	1
Failure Analysis	Punctual actions and highlighted the lack of training and lack of knowledge of analysis tools / methodologies.		The fear of the organization is that the maintenance industry ends up becoming a parts replacement industry with no significant technical functions. No troubleshooting tools are used effectively. Training on problem analysis and troubleshooting (MASP) and Failure mode and effect analysis (FMEA) training was proposed as a way to adapt the maintenance team to effectively use both tools to act preventively in the production process.	1

Table 2. Consultant x Maintenance staff evaluation (Continued)

Planning and Scheduling of Preventive Maintenance Activities	In practice, planning is only formal, as implementation does not always happen according to schedule. There is a high backlog, mainly because maintenance activities are performed when production releases. Some cases follow a frequency based on equipment activity hours.	1	The sector faces difficulties in carrying out scheduled preventives. The justification given by the production planning and control sector (PCP) is that the excess of correctives is high and there is no time to perform such activities, as it would make it impossible to meet the production goals.	1
CMMS	They use the SAP preventive maintenance module. However, only the area of covers uses more effectively, due to the experience gained by the person responsible for maintenance of this sector. Nevertheless, planning is limited. Other areas do not use the SAP PM module because they find it difficult, compounded by the fact that they do not dominate the system. With this, all control is being performed in spreadsheets. History is also a weakness in management. In addition, SAP is not integrated with the company's other systems and not all equipment is included in the plan registered in the system.	2	Everyone in the company is very confident in applying the maintenance control tool through the SAP system. In some sectors, the use of the same has shown satisfactory results, in other segments of the company the implementation of the system is slow.	3
Spare Parts Inventory Management	They use the SAP module for inventory control. However, there is no-good control, since not all parts are registered and there is a parallel control to the system, causing inaccuracy and inventory controls problems.	3	The fear of maintenance becoming a part changer is real, and at times it really seems to be the fact. In this industry, the main spare parts, especially the BOPP film extrusion process, are excessive. In the internal analysis, it was clear, from the opinion of many presents, that the stock is expensive and that some essential elements do not have immediate replenishment, severely hampering inventory management.	1
Standardization and Document Control	Documentation is easily accessible, but there are no systematic review and standardization of procedures adopted by the area.	2	Equipment documentation for some industries is unavailable, outdated, or difficult to access. Non-standard processes and activities. It was alleged during the internal meeting that there is no standard among maintenance technicians at the time of fault correction, where each technician acts differently in solving the same problem, which results in time variation between repairs. The existence of standard procedures is believed to lead to a more homogeneous process and a shorter time between repairs.	1
Human-Resource Management	There is no training policy in place, although management wants to implement it, but they have not punctuated the time horizon for this to happen. Managers have to machine experience, but the process is where knowledge is most deficient, causing conflict zones to be created between maintenance and production personnel to agree whether a problem is process or maintenance equipment. Anyway, there is low concern regarding conflict management, since they are more concerned with technical performance.	1	The company has undergone a major overhaul in recent years following the acquisition of other companies and the merger of departments. That is, there have been changes in its system and updating of its culture, making the highest quality workforce possible. The organization has drastically changed branches and moved from the audiovisual media sector to the thermoplastic sector, both with complex but overly distinct processes. As many maintenance technicians were accustomed to another process and were reused for this modern process, the lack of skills needed for the new scenario became more evident.	1
Results Management (Costs and Quality Maintenance)	The biggest concern of managers is related to costs, although actions to contain and eliminate waste have not been carried out. Moreover, failure recurrence is one of the main factors affecting the results and material loss is not only high since all material is reused, as it is ground and mixed again with the material. However, a lot of time is lost with equipment shutdowns as the process does not stabilize immediately.	2	High cost and no control, associated with failures in inventory management. Perception of high material waste is justified by the high amount of parts replacement listed with high recurrence of failures, due to the lack of a coherent method of analysis and problem solving.	1

5. CONCLUSION

Presenting the overview obtained from the model used in this paper, it is observed that the model proposed is easy to understand and, for those who work or have worked in the areas of maintenance management, it uses maintenance-oriented quality management concepts.

The model leads us to reflect on the path we are taking to improve corrective actions in the maintenance sector, and the production involved with maintenance. During the work, the model brought a clear view of the current situation of the maintenance sector of the company under study. There were no difficulties with using the model. Given information not compatible between maintenance and production, after internal analysis, it was noted that there is a lack of agreement between both parties.

Production attributes to the maintenance of lack of technical knowledge, claiming that even preventive workings occur sloppily while maintenance demonstrates that the huge amount of line breakage occurs due to the simple lack of availability of production lines for preventive maintenance.

Just as improvement points were identified and adjusted through this work, other points can be identified for the other units of the company, such as the application of the model in the group's petrochemical industry segment.

With the improvement actions proposed by this work, in order to be able to advance in the levels proposed by the maturity model, we seek to increase the physical availability of equipment, reduce losses due to machine defects, qualify maintenance and production teams, and decreased part replacement time.

Properly applied models of maturity are perfectly aligned with the lean strategies of organizations, by implementing the recommended actions in the studies and their continuous monitoring

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