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Maintenance Management Based on Organization Maturity Level

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Abstract

This article aims to discuss the management process of the maintenance function of companies depending on the degree of organization maturity concerning maintenance. Maintenance management makes use of some tools and techniques to improve efficiency and minimize the impacts of unplanned stoppages, such as Reliability Centered Maintenance (RCM), Total Productive Maintenance (TPM) and the Failure Mode and Effects Analysis (FMEA). The identification of the degree of maturity on maintenance, leads us to a better planning of actions to implement the more appropriate management strategy and to propose suitable computerized tools, performance indicators, technical analysis and management tools and techniques, providing a set of potential improvements necessary for the successful evolution of the maintenance process and the resulting progress in the maintenance maturity level. Understanding the aspects which define the degree of maturity of an organization may not be an easy task. In this paper, a study of the maintenance function of some companies was carried out in order to define their maturity levels regarding maintenance. A maturity model is also proposed for the maintenance function through the definition of dimensions and levels. Aspects related to maturity levels have been fairly dealt with in various segments of the knowledge and the use of the proposed models have contributed to the achievement of better results in organizations in general.

Keywords: maintenance strategy; production management; maintenance management; maturity grid.

1 Introduction

In past times, product development and manufacturing engineering were dominant in the industrial environment, and operation (production activities) and maintenance had low priority corporate strategies. Some time afterwards, both the operation and maintenance began to occupy a prominent role. Nowadays maintenance has a strategic role within organizations, it is responsible for ensuring the availability of equipment and facilities. In addition, it needs to help the production process giving reliability and appropriate security costs.

Maintenance management uses some tools and techniques to improve efficiency and minimize losses, such as the Reliability Centered Maintenance (RCM), Total Productive Maintenance (TPM), Analysis of the Failure Mode and Effects (FMEA).

According to Munk (1999), in organizations, teams can break down the traditional interdepartmental barriers and facilitate the operation of the functional structure, improving communications, coordination and integration and, above all, imposing a quicker reaction time. Teams are a powerful mechanism of integration within informal organizational structures. For individuals, teams bring more social and emotional involvement, more participation in decision making, greater penetration in the affairs of the company, greater commitment and therefore more motivation.

Clarke and Garside (1997) propose a model that combines five features for managing the maintenance function: commitment, culture, communication, tools and methodologies and conflict management. However for models to maintenance management orientation, a proper investigation and recommendation are still missing. The identification of the maturity level on maintenance allow a better planning of actions, selecting suitable computerized tools, performance indicators, management tools

and techniques. Based on the maturity level of the organization, suitable more recommendation for maintenance management can be defined.

Aspects related to maturity levels have been well covered in various segments of the practical knowledge and the proposed models have contributed to the achievement of better results in organizations in general.

The aim of this paper is to propose a maturity model regarding maintenance. This maturity model will allow in further research to define the appropriate management actions to achieve high levels of maturity for each level of the model.

Through survey, strategic points for the maintenance management will be evaluated in order to identify the current situation and generate preliminary data needed for a proposed maturity model for maintenance management.

This paper is organized as follow. The second section presents a literature review, describing maintenance management topics and maturity models concepts. The third section addresses data collection and analysis, evaluating the maintenance management of a group of organizations that act in different sectors. Dimensions and levels for maintenance maturity assessment are suggested in section 4. The last section presents the conclusion and future work.

2 Literature Review

2.1 Maintenance Management

According to Filho (2008), the maintenance management is an integral part of the company and aims to manage the maintenance in the broadest sense of the word. The maintenance management is a set of actions, rules and procedures of a maintenance system that assigns targets to the maintenance team and the organization it serves.

The maintenance management establishes goals and objectives through standards and work procedures in order to obtain a better utilization of available resources, which are staff, equipments and materials. According to Kardec and Lafraia (2007), modern management must be underpinned by a vision and governed by processes management where the full satisfaction of its customers is a result of the quality of its products and services.

In accordance with this line of thought, the maintenance management is considered strategic when it is results-driven business organization. And this implies that, besides having to assure the functional availability of equipment and facilities of a production process or service, safety and environmental factors as well as cost need to be considered.

For Kardec and Nascif (2007), the systemic view of the business and changing paradigms and concepts will lead to major innovations in the process of maintenance management.

According to Cuignet (2006), the objectives of maintenance must be connected to the overall objectives of the company once maintenance affects the profitability of the production process through its influence on the volume and quality of production and associated cost. If, on the one hand, there is a concern with improving performance and availability of equipment, on the other we have the cost factor associated with the management process.

Still to this author, the search for a balance between benefit and cost to maximize the positive contribution of maintenance to the overall profitability of the company is the secret of this step, so that all the actions necessary to achieve this equilibrium is the management of maintenance itself.

Currently, to manage the maintenance, excluding the complexity factor, large numbers of activities are necessary and should be known by the manager, namely: general knowledge in maintenance, planning, people management, assets and equipments knowledge, lubrication and calibration, material

management, maintenance techniques, knowledge in computers and computerized processes, basic of production management and basic of quality management.

Some parallels can easily be made between maintenance management and certain tenets of quality management. Crosby (1990), states that quality is defined as conformance to product requirements.

He also shows that quality is achieved through prevention and not through inspection and the optimal performance standard of quality is zero defects. He also states that quality is measured by the price of non-compliance.

In the view of maintenance, quality is closely associated with the systematic prevention of events that result in the stoppage of an asset and this prevention is strongly linked with the adopted management strategy. The quest for zero defects in the maintenance, as well as a paradigm to be broken, it is a goal to be achieved through the use of modern techniques of management activities in line with the organization's strategy. The standard of maintenance performance is associated with the absence of assistance and not by running out of acceptable standards.

From the standpoint of management, the most appropriate maintenance is one that combines different methods and techniques, according to the nature and criticality of the equipment for maintenance, in order to obtain operational efficiency and economic.

2.2 Maintenance Policies and models

Maintenance policies applied correctly aimed at preventing and/or eliminating the occurrence of failures. Lack of fulfillment of what was previously defined as "proper performance" is defined as *failure*. According to Kardec (2002), fault is "an abnormal physical state in a system that is a threat to the operation thereof". "Abnormal" is defined as the deviation of some measurable parameter beyond the limits considered desirable for the normal operation.

For Smith (2004), maintenance aims to "preserve the functional capabilities of equipment and systems in operation". According to Moubray (2000), the purpose of maintenance is to "ensure that physical assets continue to do what the users want them to do".

SAE JA1011 states that maintenance should ensure that "physical assets continue to perform their planned functions".

The maintenance really only fulfils its role when it comes before and can predict possible events that can paralyze and damage production, with consequent loss of volume, increased of operation expenses and reduction of the business margins.

To achieve what it is called World Class Maintenance (WCM), it is necessary to improve adopted maintenance processes.

According to Kardec (2002), plants coexist with certain types of maintenance (or maintenance policies) and progress of organization's management will allow the application of the most convenient such as corrective, preventive, predictive and maintenance engineering.

Various tools available today have adopted the word maintenance. It is important to note that these are not new types of maintenance but tools that allow the application of the main types of maintenance mentioned above. Highlighted among them are: Maintenance Engineering; Lean Maintenance; Total Productive Maintenance; Reliability Centered Maintenance; Reliability Based Maintenance and Condition Based Maintenance.

2.3 Maintenance Indicators

For Weber and Thomas (2005), performance measurement is fundamental for management once it identifies the difference between the actual performance and the performance intended to be achieved. According to Kardec and Lafraia (2002), maintenance indicators are developed and used by managers in order to achieve the goals set by companies.

The literature, in the context of maintenance, provides various expressions and terminology for performance indicators, once they eventually adapt to the reality of companies (Tavares, 1999). Indicators are usually grouped into:

- Asset management;
- Costs management;
- Manpower management;
- Maintenance activities;
- Maintenance organization.

The pursuit of World Class Excellence involves the identification and adaptation of best practices. This means changing the way of acting which obviously requires some time, from planning to implementation and evaluation of practical results.

EN15341 (2009) Standard highlights that maintenance performance is the result of complex activities, which can be evaluated by appropriate indicators to measure actual and expected results. Performance indicators are necessary to ensure stability and predictability of the maintenance process.

In general, indicators are measures or numerical data set about processes that we want to control, and maintenance, generally include: availability, costs, production losses due maintenance activities, Rework, Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR) and Overall Equipment Effectiveness (OEE).

Maintenance costs are linked to the adopted practices. In a unit where maintenance is performed in a reactive way, setting an unplanned corrective maintenance, costs are higher.

Paradoxically, it is important to note that not always the minimum cost is the best value. Strategic vision and proper planning for the functions related to training teams and operational resources (parts, equipment and tools) need to be considered. According to Filho (2008), performance measurement becomes useless if it is not accompanied by a group of actions. The maintenance policies and associated prevention strategy must ensure balanced improvement of performance indicators, as suggested in figure 1(Semitan, Oliveira & Maciel, 2009).

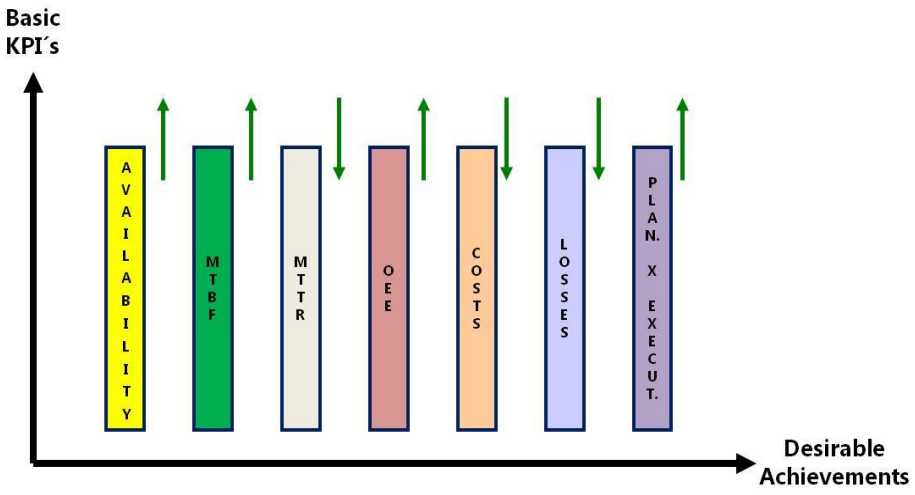

Figure 1 - Proposed Indicators Model

In addition to the identification process of managing more suitable indicators, Norton and Kaplan (1996) suggested the use of the scorecard Balance (BSC) as a methodology for performance management, where the strategy could be translated in operational terms, so that past performance measures serve to direct the value of performance measures for the future. Alsyouf (2006) proposes to use this tool to measure performance in the maintenance area of an organization.

2.4 Maturity Models

Nunes (2008) highlights the Maturity Theory of Argyris, presented in Personality and Organization, which is one of many theories that attempt to explain nature and human behavior. According to this theory, the development of a person takes place over a continuous range of an immature state to a state of maturity. A mature person is characterized by being active, independent, self confident and controlled. On the other end, an immature person is passive, dependent, lacks confidence and feels the need to control others.

In his studies of process maturity, Smith (2008) gives the basic concept, under the term maturity, the aspect that mature organizations do things in a systematic and that the immature reach their results thanks to the heroic efforts of individuals using approaches that they create more or less spontaneously. Mature organizations achieve their quality objectives, timelines and costs consistently and efficiently. Immature organizations create goals, but too often lose their targets by wide margins of error. The term maturity is introduced in various segments of knowledge, such as project management, Quality management and computerized systems development. Crosby (1979) structured a model, designated by Quality Management Maturity Grid, based on five levels of maturity for the incremental adoption of quality concepts in an organization. The proposed model considers the following maturity levels:

I. Uncertainty
II. Awakening
III. Enlightenment
IV. Wisdom
V. Certainty

Maturity levels are assigned to the following categories of dimensions:

I. Management understanding and attitude
II. Quality organization status
III. Problem Handling
IV. Cost of quality as a percentage of sales
V. Quality improvement actions
VI. Summary of company quality posture

Often, the proper functioning of organizations (in terms of work specialization, chain of command, the degree of delegation, the degree of control, etc.) is in itself an obstacle for officials to achieve a naturally high degree of maturity.

In addition, organizations expect that their employees are passive, dependent and have a short term perspective, producing without requiring a high degree of control.

In accordance with Clarkson, Maier and Moultrie (2009), a large number of maturity models have been proposed to assess a range of capabilities, including quality management, software development, supplier relationships, efficient research and development, product, collaboration and communication. These evaluations focus on a particular domain of knowledge that can result in several practical approaches confusing or contradictory. However, their study does not direct specific recommendations for the type of maintenance management of an organization.

Based on Crosby's maturity grid for Quality, Fernandez et al. (2003) propose a maintenance maturity grid. However, the authors only emphasize quality management criteria for maintenance.

3 Data collection and Analysis

A survey was undertaken in some industrial plants of the industrial pole of Manaus, in Amazonas state (Brazil), in order to study different processes and identify their management strategies.

The maintenance management of companies in the plastic industry, manufacturing of mobile phones, modems, set top boxes, televisions, laptops, audio, CD and DVD manufacturing, motorcycles, air conditioners, cameras, alarm and protection systems, car alarms, naval industry, metallurgical industry and support activities of IT infrastructure in government departments were analyzed (see figure 2).

About the companies, nine of them are considered small companies, eight, medium companies and three, large companies. All companies of this survey have ISO 9001 certification. Besides, large companies have ISO 14000 certification.

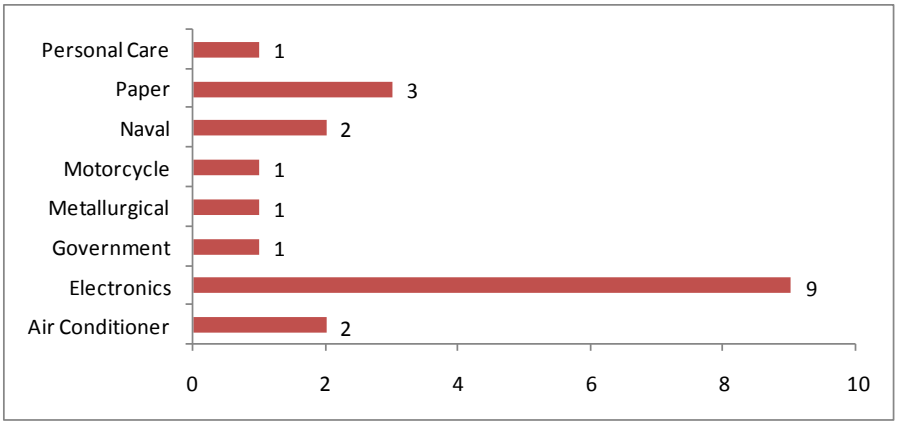

Figure 2 – Surveyed Company

Through field research using semi-structured interviews, data related to the management aspects of the strategies and maintenance activities of the company were collected. In the survey, information about maintenance management function was gathered, such as:

- Use of key process indicators;
- Management of maintenance costs;
- Qualification of the maintenance team
- Application of management support.

The collected information in the companies was analyzed and classified in the following management dimensions:

- Maintenance Policies: to identify the current maintenance type;
- Maintenance Planning and Organization: to identify CMMS utilization;
- Maintenance KPI Management: to identify the current KPI and their management;
- Maintenance Training Strategy: to identify the training level and knowledge of maintenance crew.

Table 1 presents the results for each company and also shows how maintenance activities are organized and how each company manages them according to their own policies and strategies.

The results reveals that most organizations adopt corrective policy, have low competence investment (personal and technical training), no performance indicator and have poor maintenance activities planning.

According to the data obtained in the investigation and displayed in Figure 3, only 45% of companies have adopted a preventive policy or rather merge preventive and corrective policies. The majority focuses on correction, which can result in a strategy focusing on production rather than productivity and efficiency, which usually increases the probability of equipment downtime.

Table 1 – Maintenance Strategy Organization

Company	Sector	Maintenance Policie Prevailing	Maintenance Organizational & Planning	Maintenance KPI Management	Maitenance Training
1	Paper	Corrective	Spreadsheet	Not Available	Low
2	Electronics	Corrective	Spreadsheet	Not Available	Low
3	Electronics	Corrective and preventive	Spreadsheet	Basic KPI's: MTBF, Costs and Availability	Medium
4	Electronics	Corrective and preventive	Spreadsheet	Not Available	Low
5	Air Conditioner	Corrective	Spreadsheet	Not Available	Low
6	Naval	Corrective	Spreadsheet	Not Available	Low
7	Naval	Corrective	Spreadsheet	Not Available	Low
8	Electronics	Corrective and preventive	Spreadsheet	Basic KPI's: MTBF, Costs and Availability	Low
9	Electronics	Corrective	Not Available	Not Available	Low
10	Paper	Corrective and preventive	Spreadsheet	Not Available	Low
11	Electronics	Corrective and preventive	Spreadsheet	Basic KPI's: MTBF, Costs and Availability	Low
12	Motorcycle	Corrective and preventive	Spreadsheet	Not Available	Medium
13	Electronics	Maintenance Engineering	CMMS	Basic KPI's: MTBF,MTTR, Costs and Availability	Medium
14	Paper	Corrective	Spreadsheet	Not Available	Low
15	Personal Care	Corrective and preventive	Spreadsheet	Basic KPI's: MTBF, Costs and Availability	Medium
16	Government	Corrective	Not Available	Not Available	Low
17	Air Conditioner	Corrective and preventive	Spreadsheet	Not Available	Low
18	Electronics	Corrective	Spreadsheet	Not Available	Low
19	Electronics	Corrective and preventive	Spreadsheet	Basic KPI's: MTBF, Costs and Availability	Medium
20	Metallurgical	Corrective	Spreadsheet	Not Available	Low

A percentage of 5% adopt management models based on engineering maintenance, although initiatives to implement TPM (Total Preventive Maintenance) and RCM (reliability centered maintenance) have been implemented without success.

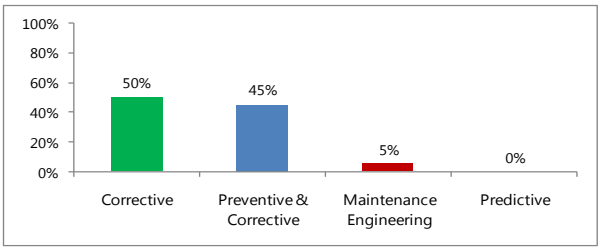

Figure 3 – Maintenance Policies

Furthermore, regarding planning of maintenance activities, a percentage of 85% companies use spreadsheets to support the management and control of maintenance activities as indicated by figure 4.

This ongoing research aims in the future to propose a simple and economical information system to make the maintenance management processes equally simple, objective and efficient, a system enabling the user to use 100% of its operating capacity. The management system will support the manager in more responsive decision-making based on results presented for a certain period of time.

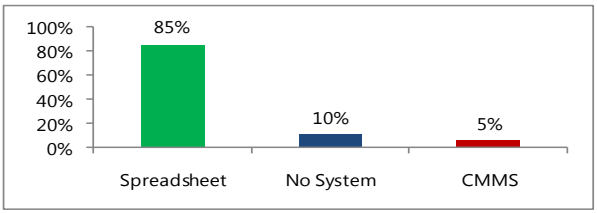

Figure 4 – Maintenance Organization & Planning

Concerning the application of maintenance indicators, to better define maintenance strategies, the study reveals a reduced utilization which can point to a lack of skills and knowledge of the team about concepts related to management and control activities of maintenance (see figure 5).

Besides, companies that have any kind of indicators use MTBF, MTTR, Availability and Costs for maintenance management.

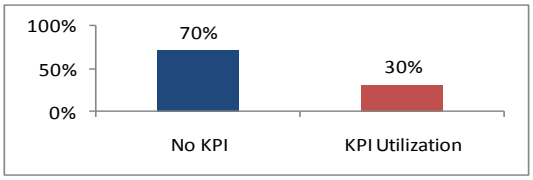

Figure 5 – Maintenance KPI

Nevertheless, most companies show a little investment in staff qualification, either in aspects related to technical activities, whether in concepts related to maintenance management, as shown in figure 6. Low level training is considered when the company maintenance crew has minimal information about maintenance activities and poor knowledge about equipment and process, with no investment in qualification. For medium level training the crew has enough concepts about process and equipment and some investment is made to qualify them. For high level training, the crew has strong knowledge about process, equipments, management tools, clear failure analyses methodologies and investment in qualification.

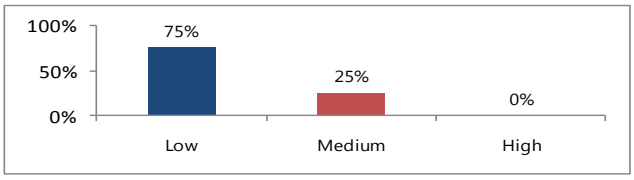

Figure 6 – Maintenance Training

4 Proposed dimensions and levels for maintenance maturity assessment

The maintenance function can be analyzed and evaluated in order to propose a gradual progress in the pursuit of world class performance, increasing the operational availability company equipment, its productivity and intellectual capital of technical teams for maintenance management.

Based on the study presented in the previous section and on experience, dimensions and levels for maturity assessment was defined and presented in table 2.

Maturity grid proposed so far covers quality dimensions and this study intends to provide criteria to identify the current maturity level and the steps to move forward to high maturity levels.

Table 2 - Proposal for dimensions and levels of maturity

Dimension	Low maturity	Medium maturity	High maturity
Maintenance Strategy	Corrective strategy only	Corrective and Preventive strategy	Predictive strategy
KPI´s (Availability, MTBF, MTTR)	Not available	MTBF, MTTR, Costs, Availability	MTBF, MTTR, Costs, Availability, OEE, Reliability, Training Rate, Failure Rate
Maintenance Data System (CMMS)	No CMMS	Spreadsheet or General CMMS	Customized CMMS
Technical Competences (culture)	Corrective mind	Use preventive tools such as FMEA, 8D	Use failure analysis tools, such as FMEA, 8D, RCA, FTA, Reliability Model
Management Models	Not Available	TPM	TPM, RCM, Maintenance Engineering

Finally, this assessment allows us to establish criteria and steps to support companies to move from low performance to world class performance in maintenance management due to clear strategy and commitment, according to figure 7.

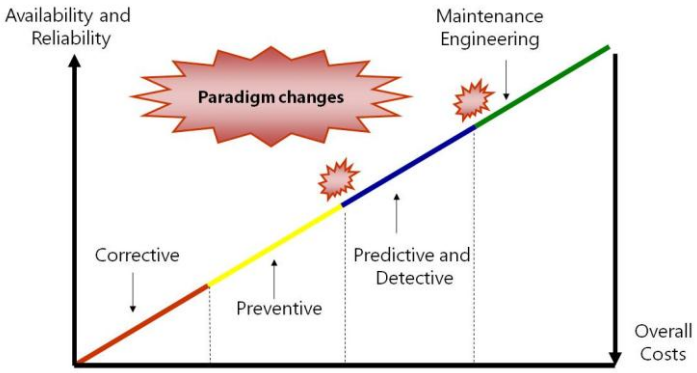

Figure 7 - Maturity level upgrade in organizations

Then, based on the research proposal, most surveyed companies can be classified as organizations that are in an initial maturity stage, as showed in figure 8.

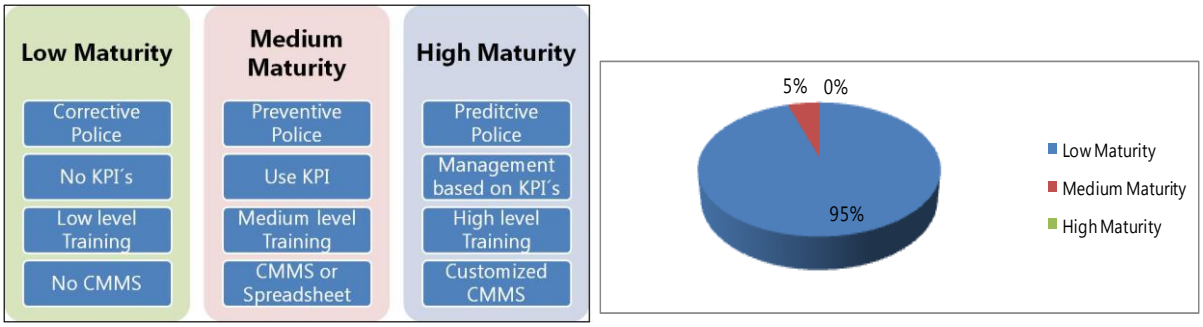

Figure 8 – Maintenance Management Strategy

5 Conclusion and future work

A systematic way to understand the steps in a process of maintenance management activities should emphasize the existence of an effective planning and monitoring of activities using the most appropriate resource and applying the more advantageous tool and techniques. The proposed maturity model will allow defining the more appropriate strategy and maintenance tool, techniques and indicators for each level.

The effectiveness of the maintenance function in an industrial unit depends on the equipment involved, the training of personnel, and mainly on the adopted strategy for maintenance management. In addition to modern equipment, it is necessary to understand the concern about flaws, in its details, in order to attack not the consequences but the causes using the most appropriate tools and techniques.

Additionally, the use of complex computer systems generally do not simplifies the maintenance management, because it takes a long time in the design, analysis and storage of information, which suggests studying the development of a more simple and straightforward system.

In the ongoing research, it is intended to develop a computer system which allow both the determination of some vital rates (such as the frequency of failure, time to resolution of a given problem, availability, cost) and the formation of action plans for maintenance improvement using tools such as FMEA's and 8D.

Most companies have a basic level of maintenance management which means that they have opportunities to make improvements and to obtain important gains. They have also the capacity to become more competitive, increasing throughput and reducing losses.

As future activities, the maturity model dimensions and levels will be validated and the steps needed to move forward to higher maturity level will be defined.

References

Assis, R. (2010). Decision support in maintenance management of physical assets. 1st edition. Portugal: Lidel Edições Técnicas Ltda.

Cabral, J. P. S. (2006). Organization and Maintenance Management: from concepts to practice. 6st edition. Portugal: Lidel Edições Técnicas Ltda.

Cuignet, R. (2006). Maintenance Management: Improve operational and financial performance of its maintenance. Portugal: Lidel Edições Técnicas Ltda.

Crosby, P. B. (1979). Quality is free: The art of making quality certain. New York, NY: McGraw-Hill Companies.

Crosby, B.P. (1990). Quality : Seriously. São Paulo: McGraw-Hill Companies.

Clarke, A., & Garside, J. (1997). The development of a best practice model for change management. European Management Journal, 15, no. 5.

Clarkson. J. P., Maier, A. M. & Moultrie, J.(2009). Development maturity grids for assessing organizational capabilities: Practitioner guidance. University of Cambridge.

Fernandez, O. & Labib, W. (2003). A decision support maintenance management system: Development and Implementation. International Journal of Quality & Reliability Management, Vol.20, No 8, pp. 965-979.

Filho, G. B.(2006). Maintenance Indicators. Rio de Janeiro, RJ: Editora Ciência Moderna.

Garg, A. & Deshmukh, S. G. (2006). Maintenance management: literature review and directions. International Journal of Quality in Maintenance, Vol.12, pp. 205-238.

Higgins, L. R., & Mobley, K. R. (2001). Maintenance Engineering Handbook. New York, NY: McGraw-Hill.

Kardec, A., & Lafraia, J. R. (2002). Maintenance: Strategic Management and Reliability. São Paulo, SP: Qualitymark Editora.

Kardec, A., & Nascif, J. (2002). Maintenance: Strategic Management. São Paulo, SP: Qualitymark Editora.

Kaplan R. & Norton, D. (1996). The balanced scorecard: Translating strategy into actions. Boston, MA: Harvard Business School Press.

Kans, M. & Ingwald, A. (2007). Commom data base for cost-effective improvement of maintenance performance. International Journal of Production Economics, Vol.113, pp. 734-747.

Lafraia, J. R. B. (2001). Reliability, Mantenability and Availability Guidance. Rio de Janeiro, RJ: Qualitymark Editora Ltda.

Levitt, J. (1997). The Handbook of Maintenance Management. New York, NY: Industrial Press Inc.

Munk, L. (1999). The effective formation of work teams: An approach in the light of organizational changes. Master Tesis, Santa Catarina federal University, 115 pgs.

Europe Standard EN15341:2009. Maintenance: maintenance performance indicators (KPI). Quality Portuguese Institute, 30 pgs.

SAE JA 1011:1999 Standard. Evaluation criteria for process reliability-centered maintenance. Consulting on 18/08/2010, available at http://www.sae.org.

Nunes, P. (2008). Concept of Argyris's Maturity Theory. Consulting on 02/06/2010, available at http://www.knoow.net/cienceconempr/gestao/teoriamaturidadeargyris.htm.

Semitan, M. C., Oliveira, M. A. & Maciel, E. L. F.(2009). 9º International Reliability Symposium: RCM: Asset effectiveness management – Case. Curitiba, PR: Reliasoft Co.

Weber, A. & Thomas, R. (2005). Key performance indicators: Measuring and Managing the Maintenance Function. Consulting on 10/08/2010, available at http://www.plant-maintenance.com/articles/KPIs.pdf.