The maintenance management framework: A practical view to maintenance management

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ABSTRACT: The objective of this paper is to define a process for maintenance management and to classify maintenance engineering techniques within that process. Regarding the maintenance management process, we present a generic model proposed for maintenance management which integrates other models found in the literature for built and in-use assets, and consists of eight sequential management building blocks. The different maintenance engineering techniques are playing a crucial role within each one of those eight management building blocks. Following this path we characterize the “maintenance management framework”, i.e. the supporting structure of the management process.

We offer a practical vision of the set of activities composing each management block, and the result of the paper is a classification of the different maintenance engineering tools. The discussion of the different tools can also classify them as qualitative or quantitative. At the same time, some tools will be very analytical tools while others will be highly empirical. The paper also discusses the proper use of each tool or technique according to the volume of data/information available.

1 THE MAINTENANCE MANAGEMENT PROCESS

The maintenance management process can be divided into two parts: the definition of the strategy, and the strategy implementation. The first part, definition of the maintenance strategy, requires the definition of the maintenance objectives as an input, which will be derived directly from the business plan. This initial part of the maintenance management process conditions maintenance effectiveness, the fourth an fifth ensure maintenance efficiency, blocks six and seven are devoted to maintenance and assets life cycle cost assessment, finally block number eight ensures continuous maintenance management improvement.

The second part of the process, the implementation of the selected strategy has a different significance level. Our ability to deal with the maintenance management implementation problem (for instance, our ability to ensure proper skill levels, proper work preparation, suitable tools and schedule fulfilment), will allow us to minimize the maintenance direct cost (labour and other maintenance required resources). In this part of the process we deal with the efficiency of our management, which should be less important. Efficiency is acting or producing with minimum waste, expense, or unnecessary effort. Efficiency is then understood as providing the same or better maintenance for the same cost.

In this paper we present a generic model proposed for maintenance management integrates other models found in the literature (see for instance [6,7]) for built and in-use assets, and consists of eight sequential management building blocks, as presented in Figure 1. The first three building blocks condition maintenance effectiveness, the fourth an fifth ensure maintenance efficiency, blocks six and seven are devoted to maintenance and assets life cycle cost assessment, finally block number eight ensures continuous maintenance management improvement.
2 MAINTENANCE MANAGEMENT FRAMEWORK

In this section, we will briefly introduce each block and discuss methods that may be used to improve each building block decision making process (see Figure 2).

Regarding the Definition of Maintenance Objectives and KPI’s (Phase 1), it is common the operational objectives and strategy, as well as the performance measures, are inconsistent with the declared overall business strategy [8]. This unsatisfactory situation can indeed be avoided by introducing the Balanced Scorecard (BSC) [9]. The BSC is specific for the organization for which it is developed and allows the creation of key performance indicators (KPIs) for measuring maintenance management performance which are aligned to the organization’s strategic objectives (See Figure 3).

Unlike conventional measures which are control oriented, the Balanced Scorecard puts overall strategy and vision at the centre and emphasizes on achieving performance targets. The measures are designed to pull people toward the overall vision. They are identified and their stretch targets established through a participative process which involves the consultation of internal and external stakeholders, senior management, key personnel in the operating units of the maintenance function, and the users of the maintenance service. In this manner, the performance measures for the maintenance operation are linked to the business success of the whole organization [10].

Once the Maintenance Objectives and Strategy are defined, there are a large number of quantitative and qualitative techniques which attempt to provide a systematic basis for deciding what assets should have priority within a maintenance management process (Phase 2), a decision that should be taken in accordance with the existing maintenance strategy. Most of the quantitative techniques use a variation of a concept known as the “probability/risk number” (PRN) [11].

Assets with the higher PRN will be analysed first. Often, the number of assets potentially at risk outweighs the resources available to manage them. It is therefore extremely important to know where to apply...
available resources to mitigate risk in a cost-effective and efficient manner. Risk assessment is the part of the ongoing risk management process that assigns relative priorities for mitigation plans and implementation. In professional risk assessments, risk combines the probability of an event occurring with the impact that event would cause. The usual measure of risk for a class of events is then $R = P \times C$, where $P$ is probability and $C$ is consequence. The total risk is therefore the sum of the individual class-risks (see risk/criticality matrix in Figure 4).

Risk assessment techniques can be used to prioritize assets and to align maintenance actions to business targets at any time. By doing so we ensure that maintenance actions are effective, that we reduce the indirect maintenance cost, the most important maintenance costs, those associated to safety, environmental risk, production losses, and ultimately, to customer dissatisfaction.

The procedure to follow in order to carry out an assets criticality analysis following risk assessment techniques could be then depicted as follows:

1. Define the purpose and scope of the analysis;
2. Establish the risk factors to take into account and their relative importance;
3. Decide on the number of asset risk criticality levels to establish;
4. Establish the overall procedure for the identification and prioritization of the critical assets.

Notice that assessing criticality will be specific to each individual system, plant or business unit. For instance, criticality of two similar plants in the same industry may be different since risk factors for both plants may vary or have different relative importance.

On some occasions, there is no hard data about historical failure rates, but the maintenance organization may require a certain gross assessment of assets priority to be carried out. In these cases, qualitative methods (see example in Figure 5) may be used and an initial assets assessment, as a way to start building maintenance operations effectiveness, may be obtained. Once there is a certain definition of assets priority, we have to set up the strategy to be followed with each category of assets. Of course, this strategy will be adjusted over time, but an initial starting point must be stated.

As mentioned above, once there is a certain ranking of assets priority, we have to set up the strategy to follow with each category of assets. Of course, this strategy will be adjusted over time, and will consist of a course of action to address specific issues for the emerging critical items under the new business conditions (see Figure 6).

Once the assets have been prioritized and the maintenance strategy to follow defined, the next step would be to develop the corresponding maintenance actions associated with each category of assets. Before doing so, we may focus on certain repetitive—or chronic—failures that take place in high priority items (Phase 3).
Finding and eliminating, if possible, the causes of those failures could be an immediate intervention providing a fast and important initial payback of our maintenance management strategy. The entire and detailed equipment maintenance analysis and design could be accomplished, reaping the benefits of this intervention if successful.

There are different methods developed to carry out this weak point analysis, one of the most well known being root-cause failure analysis (RCFA). This method consists of a series of actions taken to find out why a particular failure or problem exists and to correct those causes. Causes can be classified as physical, human or latent. The physical cause is the reason why the asset failed, the technical explanation on why things broke or failed. The human cause includes the human errors (omission or commission) resulting in physical roots. Finally, the latent cause includes the deficiencies in the management systems that allow the human errors to continue unchecked (flaws in the systems and procedures). Latent failure causes will be our main concern at this point of the process.

Designing the preventive maintenance plan for a certain system (Phase 4) requires identifying its functions, the way these functions may fail and then establish a set of applicable and effective preventive maintenance tasks, based on considerations of system safety and economy. A formal method to do this is the Reliability Centred Maintenance (RCM), as in Figure 7.

Optimization of maintenance planning and scheduling (Phase 5) can be carried out to enhance the effectiveness and efficiency of the maintenance policies resulting from an initial preventive maintenance plan and program design.

Models to optimize maintenance plan and schedules will vary depending on the time horizon of the analysis. Long-term models address maintenance capacity planning, spare parts provisioning and the maintenance/replacement interval determination problems, mid-term models may address, for instance, the scheduling of the maintenance activities in a long plant shut down, while short term models focus on resources allocation and control [13]. Modelling approaches, analytical and empirical, are very diverse. The complexity of the problem is often very high and forces the consideration of certain assumptions in order to simplify the analytical resolution of the models, or sometimes to reduce the computational needs.

For example, the use of Monte Carlo simulation modelling can improve preventive maintenance scheduling, allowing the assessment of alternative scheduling policies that could be implemented dynamically on the plant/shop floor (see Figure 8).

Using a simulation model, we can compare and discuss the benefits of different scheduling policies on the status of current manufacturing equipment and several operating conditions of the production materials flow. To do so, we estimate measures of performance by treating simulation results as a series of realistic
experiments and using statistical inference to identify reasonable confidence intervals.

The execution of the maintenance activities—once designed planned and scheduled using techniques described for previous building blocks—has to be evaluated and deviations controlled to continuously pursue business targets and approach stretch values for key maintenance performance indicators as selected by the organization (Phase 6). Many of the high level maintenance KPIs, are built or composed using other basic level technical and economical indicators. Therefore, it is very important to make sure that the organization captures suitable data and that that data is properly aggregated/disaggregated according to the required level of maintenance performance analysis.

A life cycle cost analysis (Phase 7) calculates the cost of an asset for its entire life span (see Figure 9). The analysis of a typical asset could include costs for planning, research and development, production, operation, maintenance and disposal. Costs such as up-front acquisition (research, design, test, production, construction) are usually obvious, but life cycle cost analysis crucially depends on values calculated from reliability analyses such as failure rate, cost of spares, repair times, and component costs. A life cycle cost analysis important when making decisions about capital equipment (replacement or new acquisition) [12], it reinforces the importance of locked in costs, such as R&D, and it offers three important benefits:

- All costs associated with an asset become visible. Especially: Upstream; R&D, Downstream; Maintenance;
- Allows an analysis of business function interrelationships. Low R&D costs may lead to high maintenance costs in the future;
- Differences in early stage expenditure are highlighted, enabling managers to develop accurate revenue predictions.

Continuous improvement of maintenance management (Phase 8) will be possible due to the utilization of emerging techniques and technologies in areas that are considered to be of higher impact as a result of the previous steps of our management process. Regarding the application of new technologies to maintenance, the “e-maintenance” concept (Figure 10) is put forward as a component of the e-manufacturing concept [14], which profits from the emerging information and communication technologies to implement a cooperative and distributed multi-user environment. E-Maintenance can be defined [10] as a maintenance support which includes the resources, services and management necessary to enable proactive decision process execution.

This support not only includes etechnologies (i.e. ICT, Web-based, tether-free, wireless, infotronic technologies) but also, e-maintenance activities (operations or processes) such as e-monitoring, e-diagnosis, e-prognosis … etc. Besides new technologies for maintenance, the involvement of maintenance people within the maintenance improvement process will be a critical factor for success. Of course, higher levels of knowledge, experience and training will be required, but at the same time, techniques covering the involvement of operators in performing simple maintenance tasks will be extremely important to reach higher levels of maintenance quality and overall equipment effectiveness.

3 CONCLUSIONS

This paper summarizes the process (the course of action and the series of stages or steps to follow) and the framework (the essential supporting structure and the basic system) needed to manage maintenance. A set of models and methods to improve maintenance management decision making is presented. Models are then classified according to their more suitable utilization within the maintenance management process. For further discussion of these topics the reader is addressed to a recent work of one of the authors [2].
REFERENCES


