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An evaluation system of the setting up of predictive maintenance programmes

M[a]Carmen Carnero *

Technical School of Industrial Engineering, University of Castilla-La Mancha, Avda. Camilo José Cela s/n, 13071 Ciudad Real, Spain

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Abstract

Predictive Maintenance can provide an increase in safety, quality and availability in industrial plants. However, the setting up of a Predictive Maintenance Programme is a strategic decision that until now has lacked analysis of questions related to its setting up, management and control. In this paper, an evaluation system is proposed that carries out the decision making in relation to the feasibility of the setting up. The evaluation system uses a combination of tools belonging to operational research such as: Analytic Hierarchy Process, decision rules and Bayesian tools. This system is a help tool available to the managers of Predictive Maintenance Programmes which can both increase the number of Predictive Maintenance Programmes set up and avoid the failure of these programmes. The Evaluation System has been tested in a petrochemical plant and in a food industry.

Keywords: Predictive maintenance; Decision making; Analytic hierarchy process; Bayesian tools

1. Introduction

The implications in production and maintenance suggest the need to change the focus of maintenance policies, traditionally centred on short-term issues (use of resources, cost, etc.) towards the consideration of longer-term goals (competitive, sustainability and strategy) [41].

Predictive Maintenance is a maintenance policy in which selected physical parameters associated with an operating machine are sensored, measured and recorded intermittently or continuously for the purpose of reducing, analyzing, comparing and displaying the data and information obtained for support decisions related to the operation and maintenance of the machine [11].

Different questions related to set up a Predictive Maintenance Programme (PMP) are analysed in literature; the problems involved in setting up PMPs are presented in [53] and [54]. [74] looks at the relationship between the complexity of the production environment and the use of predictive and preventive maintenance programmes. [52] gives guidelines for using a Predictive Maintenance Programme. In [16] a control system of the set up of a PMP is developed by means of indicators. In [21] a PMP is developed by considering the lowest cost for replacing the system.

The choice of the best maintenance policy can be made by means of different approaches. One of them is Reliability Centered Maintenance (RCM) (see [64,50]) which is probably the most widely used technique [9]. RCM is a systematic methodology for the allocation of efficient predictive and preventive maintenance aimed at preventing the dominant causes of failure of critical equipment, and, in turn, towards achieving acceptable levels of equipment availability and costs by reducing corrective maintenance [51] and by so doing a structured way of making maintenance decisions is achieved [26]. RCM focuses on the use of Predictive Maintenance [82,57]. Therefore, in [85] RCM is combined with decision theory (utility functions) and [51] presents a methodology for a maintenance evaluation programme based on maintenance indicators and how it is applied to monitoring the effectiveness of the maintenance at a nuclear power station. The maintenance policies included in the methodology are conservative, modification, corrective, preventive, predictive and regulated. [25] proposes that the optimal maintenance policies should be defined in the case of military aero-engines using RCM and Monte Carlo simulation. In [33] uncertainties in the decision making of RCM can lead to non-optimum maintenance strategies, so an alternative approach is discussed to avoid this. In [28] RCM is applied to a medium size steel industry

* Corresponding author. Tel.: +34 926295300; fax: +34 926295361.
E-mail address: carmen.carnero@uclm.es

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demonstrating the features of predictive maintenance. In [27] RCM is described as a compromise between Predictive Maintenance and corrective maintenance to optimise the cost and to ensure the availability of the machines.

The subject of selecting a maintenance policy through the definition of the maintenance concept is looked at in [87] and [88]. [90] describes a model based on operational research methods to assist in generating an optimal maintenance plan for a road, considering minimisation of the Net Present Value (NPV). The discussion regarding the selection of a maintenance strategy can be appreciated in [91] where an optimum maintenance policy is described (including preventive and predictive maintenance) and corresponding maintenance systems, in order to achieve high reliability, availability, safety and productivity, are applied to a robotic car assembly line. In [71] three types of preventive maintenance are considered to select the optimum preventive maintenance time that maximizes availability.

Another option is in [19] that developed a model that provides a choice of no inspection, continuous inspection and periodic inspection for identifying the current state of a deteriorating system using Markov Chain. In [24] the problem of selecting a suitable maintenance policy for repairable systems and a finite time period is analysed using a semi-Markov decision process. In [58] a model for a multi-state semi-Markovian deteriorating system is described; the model allows one of three maintenance decisions (do-nothing, minimal maintenance or replacement) to be taken for each state of the system; the model is able to find the optimal maintenance policies that minimize the expected long-run cost rate of the system.

Another approach to selecting a maintenance policy is by means of multicriteria methods; [9] applies the Analytic Hierarchy Process (AHP) for selecting the best maintenance strategy for an Italian refinery with an Integrated Gasification and Combined Cycle plant, including the alternatives corrective maintenance, preventive maintenance, opportunistic maintenance, condition-based maintenance and predictive maintenance; a criticality index is designed to classify the machines into three groups ranging from the group where a failure can lead to serious safety problems or production losses to the group in which the failures are not relevant. [45] uses the AHP to justify the application of Total Productive maintenance (TPM) in Indian industries; The alternatives considered in this model are the application of a TPM system or a traditional maintenance system. [34] identifies the preferred maintenance policies for one specific weapon of the Norwegian Army by means of AHP; in this case four maintenance echelons are considered and Monte Carlo simulations are used to evaluate the robustness of the decision.

Some examples of effectiveness of PMPs are: in the food industry [1], the paper mill industry [2,70], buildings [3], power plants [43] and nuclear power plants [31,84], petrochemical plant [61], the manufacturing industry [49] and railway systems [62].

The selection of a Predictive Maintenance policy is considered a strategic decision [80] due to its particularities regarding cost, temporal horizon and repercussions in the Production, Quality and Safety departments. However, this strategic decision is lacking in questions related to its setting up, management and control [16].

Up until now it has been customary for large industrial plants, particularly nuclear and petrochemical plants, to apply Predictive Maintenance Programmes and in so doing achieve an increase in competitivity (as a result of improvement in availability and cost reduction), and furthermore an increase in safety in the plant. However, these technological maintenance policies are not applied uniformly in small and medium-sized enterprises, due very often to a lack of information about the benefits of a PMP. This means that plants that could benefit from this kind of maintenance policy do not adopt them and, therefore, do not have the option to improve the competitivity and safety in the plant. The aim of the decision support system proposed in this paper is to provide an evaluation system that will aid in the decision-making process regarding the implementing of PMP's, particularly in small and medium-sized enterprises, and in so doing achieve an improvement in safety levels in plants. The evaluation system of the setting up of a Predictive Maintenance Programme uses a combination of tools belonging to operation research. These tools are the Analytic Hierarchy Process (AHP), Bayesian techniques and decision rules. The AHP provides a hierarchical structure of the problem, the decision rules define the restrictions regarding the problem and the Bayesian tools contribute to reducing uncertainty, if there is not enough information in the industrial plant.

The layout of the paper is as follows. Section 2 is devoted to some notions in relation to Predictive Maintenance. Section 3 looks at the characteristics of Analytic Hierarchy Process. Section 4 presents the Evaluation System of the setting up of a Predictive Maintenance Programme. Section 5 presents the results of applying the System to a petrochemical plant and a food industry. Section 6 draws some conclusions.

2. Predictive maintenance

Predictive Maintenance consists of starting a maintenance operation only when required by the state of the system [21]. As a result continuous or periodic measurement and interpretation of an item is required to determine the need for maintenance [13].

Predictive Maintenance can be disaggregated into two specific sub-categories [32]:

- Statistical-based Predictive Maintenance. The information generated from all stoppages facilitates development of statistical models for predicting failure and thus enables the developing of a preventive maintenance policy [22].
- Condition-based Predictive Maintenance. Condition-based monitoring is related to the examination of wear processes in mechanical components. The wear process is preceded by changes in the machine's behaviour although does not cause sudden mechanical failure.