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# Information requirements for e-maintenance strategic planning: A benchmark study in complex production systems

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**Abstract**

The selection of the maintenance policy is one of the most important decisions of strategic maintenance management. It guarantees not only adequate control of the maintenance costs but also competitive performances of the production system in terms of safety, availability and quality. An optimised selection of the maintenance policy also serves the competitiveness of an e-maintenance service. This calls for fine tuning with the conditions of one plant operations, henceforth integration is required between the plant management and the e-maintenance service provider. Integration may be organised at different levels, i.e. at the strategic or operational level. The paper is concerned with the strategic planning of an e-maintenance service, to properly size the maintenance logistics support. It will present a discussion on the information required to select the policy in the case of an age based component replacement. A test will also prove the information requirements in the context of a simulated machining line wherein the most important loss is system unavailability. A benchmark study is performed therein, in order to analyse how the selection of the maintenance policy may change when information is collected with regard to the production system as a whole instead of its separate equipments. The study will demonstrate that the maintenance policy may change depending on the analysis level, i.e. from equipment level to production system level. The analysis at equipment level will reveal itself to be not so accurate, if compared with the analysis at the system level, as far as the line layout is endowed with some flexibility features and it is operated in a range of medium to high saturation rates. A more comprehensive analysis at the production system level will conversely achieve better performances though a reduced number of preventive maintenance stops during the e-maintenance service operation.


*Keywords:* Strategic planning; Maintenance policies; E-maintenance service; Simulation; Benchmarking

## 1. Introduction

E-maintenance of an industrial process offers solutions for innovative customer–supplier relationships wherein the customer not only expects high quality products from a manufacturer but also an effective service during product use. This calls for a proper integration of information and processes during the product use phase. In tele-service maintenance, the integration is reached by sharing information of a product and its actual operational conditions between different locations and partners, in order to enable the remote product diagnostics and repairing services [11]. The new working context envisioned by e-maintenance extends the tele-service maintenance to a knowledge-driven organisation where the information flows integrate diverse processes (monitoring of equipments, detection and diagnostics of their faults and troubleshooting, prognosis of their residual life), knowledge providers (technicians of the service provider, machinery builder/engineers and technicians and operators on field) and systems supporting analysis and decisions (intelligent systems based on a variety of technologies such as for degradation evaluation and prediction, knowledge learning on system failures and collaborative diagnostics and troubleshooting) [8,1]. Eventually, the integration may also regard the level wherein the strategy of the e-maintenance service is decided. This paper aims to focus at this level. It will point out the integration requirements, by means of focusing on the information sharing needed for analysis and definition of maintenance policies for the next period of service operation. An experimental proof will be provided that not only the information at the equipment level should be collected and analysed, but also a systemic approach should be adopted, for addressing the level of the overall

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production system. In the present paper, indeed, the selection of the most convenient maintenance policy for each equipment is a decision resulting from a model of the production system, where the equipment plays its role as a component.

Thereafter, the objective of the paper is to prove that the decisions resulting from the analysis at the production system level may significantly differ from decisions deriving from the analysis at the equipment level. Thus, a simulation model based analysis is proposed for this demonstration, enabling a benchmark study in order to: (i) determine if decisions at production system level differ significantly from the ones based on a model in which any equipment is modelled as a stand-alone component; (ii) identify the main features of the production affecting this shift. The simulation technique is briefly reviewed in Section 2. Focus is provided, at first, on its basic capabilities, referring to applications to maintenance planning problems in general; afterwards, a closer look is given to the selection of maintenance policies through a simulation based analysis. The two simulation models are introduced afterwards (Section 3). Then the experimentation plan is presented (Section 4) and its results are analysed (Section 5). As a result the information required to enable the selection of the maintenance policies is validated and a strategic planning practice is derived to support the selection of the maintenance policies during the use phase of a plant (Section 6). This practice is presented as a model for application at the strategic level of an e-maintenance service. Further research work is finally envisioned for future activities (Section 7).

## 2. State of the art analysis

### 2.1. Simulation modelling and analysis

Simulation modelling is a well known method to support analysis and decision over a wide range of maintenance planning problems (design for reliability, design of the maintenance logistics support, . . .).

Simulation can be used to generate and register, on a simulated time scale, the stochastic behaviours of repairable and non-repairable systems [3,20,6,14,12]. Based on a mechanism of random generation, according to well defined statistical laws (such as, e.g., for failure and repair rates), simulation results in a number of ‘‘random walks’’ – simulation histories – where the system operation state is progressively registered as a sequence of up and down times. The simulation histories are then used in order to estimate well known system characteristics of maintenance logistic operation (such as the system reliability, the point and average system availability) and, consequently, to take up further maintenance planning decisions, based also on costs derived from these system characteristics.

Simulation [10,5] is also adopted to generate and register, on a simulated time scale, both the stochastic behaviour of a system, where some entities may fail (and eventually be repaired), and the impact of these failures upon the materials flowing through the system. In this case, based again upon a mechanism of random generation, according to well defined statistical laws (for the processing, failure, repair rate of an equipment, for the loading rate of the material flowing into the system, . . .), a simulated behaviour through time is generated for two different types of entity. The so called ‘‘client entities’’ represent the material that flows through the system; in case of discrete manufacturing, these are the work orders processed into the system; their simulated time is generated as a sequence of queuing and processing times; queues may build up in case of failures or stoppages in production due to preventive maintenance activities. The ‘‘server entities’’ are, conversely, the processing stations (e.g. for machining operations), these are the entities that may fail; their simulated time is generated as a sequence of idle and processing times and other activity times including those ones that represent their failure and maintenance behaviour (e.g. the repair downtimes are generated, . . .). Beside characteristics such as the server up and down times, or the system availability, . . ., the simulation histories enable the calculation of other system characteristics.

Table 1
Selection of the maintenance policy by means of simulation (references from last decade)

| Reference | Maintenance planning problem | Case study |
|---|---|---|
| [4] | Identification of the optimal preventive maintenance period for age based component replacement | Equipment (for gas compression) |
| [13] | Identification of the optimal preventive maintenance period for age based component replacement | Continuous (chemical) process plant |
| [2] | Identification of the optimal degradation threshold for a condition based maintenance policy | Single equipment series of equipments |
| [15] | Identification of the optimal degradation threshold for a condition based maintenance policy | Series of parallel equipments |
| [19] | Optimisation of the maintenance logistic support for a given maintenance policy (determination of the maintenance crew size) | Job shop of parallel loom machines (textile sector) |
| [21] | Optimisation of the maintenance logistic support for a given maintenance policy (determination of the spare parts provisioning policy) | Manufacturing line (machining line) |
| [7] | Optimisation of selection of the maintenance policy co-ordinated with production capacity planning | Job shop of fabrication machines |
| [18] | Optimisation of selection of the maintenance policy co-ordinated with production capacity planning | Manufacturing line (machining line) (food and drink sector) |