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Measuring maintenance performance – in search for a maintenance productivity index

Hans Löfsten*

Department of Industrial Dynamics, Chalmers University of Technology, S-412 96, Göteborg, Sweden

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Abstract

A partial maintenance productivity goal is that the firm should seek to maximize its maintenance productivity in economic terms, and should aim at producing any level of output which is decided upon at minimum maintenance cost with respect to the production system's *state*. The *state* of objects or production systems is such a property, i.e., a *multidimensional property*. In this paper we amalgamate these various dimensions into a single measure of the property involved. All things considered it would seem, that in measuring partial maintenance productivity, minimization of maintenance costs is incorporated as a *subgoal*, based on the maintenance inputs called for an "optimal budget". These imputed maintenance costs do not have to be calculated separately, but emerge as a by-product of finding a high productivity index. In our *partial productivity model*, the output prices of the produced products and input prices (maintenance costs) will change over time. Expected changes in the prices of outputs and of current inputs would be built into the model. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The purpose of maintenance management is to reduce the adverse effects of breakdown and to maximize the production system availability at minimum cost. Production system breakdown causes a loss of output. Traditionally, there are two primary approaches to achieve such a purpose. The objective of *preventive maintenance* is to reduce the probability of failure in the time period after maintenance has been applied. Another is corrective maintenance, which strives to reduce the severity of equipment failures once they occur. Between these two maintenance tactics, preventive maintenance generally has attracted more attention in industry and academic research [1–5]. Previous research has shown that the use of preventive maintenance procedures may contribute to a rational way of maintaining and operating equipment.

Characteristics of the two functions *production* and *maintenance* is presented in a simple chart in Table 1 [6]. In addition to these characteristics, both functions must similarly prioritize their activities and provide the right material at the right time. In another study, involving 340 plant engineering and maintenance supervisors, approximately 42%

* Tel:. + 46 31 772 12 30; fax: + 46 31 772 12 37; e-mail: halo@mot.chalmers.se.

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Table 1
A comparison of production and maintenance characteristics [6]

Production	Maintenance
(1) Many components	(1) Many components
(2) Many inputs Labour Equipment Overhead Materials	(2) Many inputs Labour Equipment Overhead Materials
(3) Discrete outputs which can be inventoried	(3) Diverse outputs which are consumed opon creation

responded that scheduling maintenance activities is one of their three biggest problems [7].

Historically, the relationship between maintenance and production has been characterized by conflict [8]. Typically, production departments do not readily release equipment for scheduled maintenance. Hence, the firms maintenance policy may in certain cases consist of only emergency maintenance. Although a firm may utilize a maintenance policy incorporating scheduled maintenance activities, emergency maintenance cannot be entirely eliminated. In order to determine the levels of maintenance a multitude of information is required.

The costs of maintenance, estimated to be between 15% and 40% of production costs [9], and the trend toward automation has forced managers to pay more attention to maintenance. Managers have figured out, that maintenance, with its high cost and low efficiency, is one of the last cost saving frontiers in management [4]. This paper provides a conceptual framework as well as some results regarding maintenance policies and development of a maintenance productivity index.

2. Literature review

2.1. Long-run maintenance and investment planning models

For one area of maintenance, mathematical modelling and optimization, the literature is extensive. The management science and operations research journals are replete with optimization models based on statistical analysis of component failures. Traditionally, there are also many corrective maintenance policies to reduce the severity of machine failures [1,10]. Research has examined applications of these corrective maintenance policies. However, studies have primarily focused on the effectiveness of one single maintenance policy.

The research problem of maintaining industrial production systems has traditionally been modelled in the management science literature as a constrained optimization problem [2,4,11–18]. The purpose of the use of any quantitative discipline is to assist management in decision making by using known facts more effectively and by reducing the reliance on subjective judgement. But, in the context of maintenance decision making there is often little factual knowledge available. One of the first steps is to determine the objective and once the objective is determined, an evaluative mathematical model can be constructed which enables management to determine the best way to operate the system to achieve the required objective.

Two central studies on investments and maintenance are those of Boiteux [12] and of Massé [16]. The problem of determining both partial replacement or repair and the time for retirement has been dealt by Massé. The problem of how these two factors, repair and service life should be optimally determined is called by the French the "Boiteux-problem" [12]. To conclude, it can be seen that maintenance planning has been the subject of a large number of studies and a number of the reports have treated preventive maintenance and investment planning explicitly [17–26]. Some of the studies which have dealt with preventive maintenance specifically are characterized by the fact that the models are large and complicated. Any interaction between the analysis and the decision makers is thus limited. In other studies, e.g., the problem of determining the optimal service life of a machine has been discussed since a long time in the literature under the assumption that repair cost is given. The analysis of optimal replacement policy was first directed towards determining the service life in such a fashion that unit cost of production was minimized [24]. One researcher modified this view