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Simulation of service costs throughout the life cycle of production facilities

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ABSTRACT

Manufacturers of production facilities must not only be able to support their customers actively throughout the life cycle by optimizing machines and productivity but also by establishing a profitable environment for product-accompanying services. Therefore, a method has been developed which allows for the calculation of the costs of service contracts during the offer phase. Subject to different influencing variables which are deposited with stochastic distributions, the costs will be determined by the Monte Carlo method. The Monte Carlo method is used to estimate uncertain forecasts.

1. Motivation

Ensuring an economically viable and productive production process represents one of the major challenges nowadays. An optimum use of technical investment leads to a change in requirements for maintenance and servicing activities. It is expected of new maintenance concepts that the reaction time in the event of failures is shortened and that technical novelties and changes are rapidly implemented [1]. The aims of increasing availability while using less resource and, at the same time, ensuring high process quality lead to tensions that are to be solved by new service and maintenance concepts. Product-accompanying services are becoming increasingly important in this context, which offers manufacturers the possibility to gain an advantage in competition by excelling in the areas of efficient production and customer satisfaction [2,3].

Whenever a customer purchases these product-accompanying services, he expects to save costs on his production equipment [4]. It is necessary to take all the costs incurred into account when calculating an offer in order to estimate the benefits to be expected compared to the costs arising from product-accompanying services. This step is necessary to assess the risks arising from making performance promises when offering product-accompanying services. There are various scientific approaches taking these aspects into consideration, e.g. the mathematical modelling of the failure rate of technical systems which, in this case, is directly linked to maintenance and service costs.

The following methods can offer possible mathematical solutions: the Boolean model, the Markov model, the fault tree analysis and the Monte Carlo method [5]. Thanks to its flexibility, the Monte Carlo method is the most promising one in this context. It is defined as a method to assess the solution of mathematical problems by using random numbers [6]. The Monte Carlo method employs statistical distribution functions at component level as well as input parameters and provides mean values [6–8]. Statistical distributions can be used to illustrate unstable environmental conditions and to provide information about future developments. Existing assessment procedures for cost planning have so far neglected these uncertainties in forecasts [9,10].

2. Challenges

The challenge for the machine tool manufacture is to provide product-accompanying services over a certain time of the life cycle for his products or production systems. Thereby, the product-accompanying service focuses mainly on the startup and the utilization phase of the life cycle of machines. It is therefore important to provide the costumer a measurable benefit of services and additionally to predict potential costs of service for the machine tool manufacture. These day machine tool manufactures offers a wide range of product-accompanying services (e.g. 24 h free part replacement). For all these different kind of services special costumer requirements, for example individual maintenance programs, must be considered and include in the calculation of the service costs. Often machine tool operators are not able to fulfill the total spectrum of maintenance for a machine for the reason they do not have the knowledge our capacity for specific maintenance procedures. In this case the machine tool manufacture carries out these procedures. Moreover, uncertainties have to be taken under consideration while calculate service costs.

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Uncertainties in this case can be unpredictable occurrences such as machine down times or reparation times. Therefore, the challenges in the research are in the development of a method which allows future calculation of service costs regarding special costumer requirements and uncertainties alongside.

3. Literature review

Focusing on the major challenges described in chapter 3 the literature review will cover the topics of methods for the estimation of costs and the description of uncertainties. Whereas it must be declared that existing method in the estimation of costs and the description of uncertainties are too numerous to count. The literature on this subject can be found in a wide range of disciplines, including economics, organization, decision, management, IT and engineering. Hence, the authors limit the literature review to representative studies that addresses to general methods and stochastic.

3.1. Estimation of costs

The estimate of costs tries to measure coherence between costs and cost drivers [11]. In doing so two different procedures can be listed:

- qualitative procedures and
- quantitative procedures.

At the time of the application of qualitative procedures no fixed statements about the concrete figures of the service or product can be made. Qualitative procedures do not investigate what the service costs are, but indicate which cost consequences certain decisions can have. Therefore, heuristic rules can be used in the early offering stage of product-accompanying services to provide a pool of experience [12]. Furthermore, relative costs can be used to compare different services or expenses for different manufacturing procedures [13].

Unlike the qualitative procedures, the quantitative procedures calculate the expected costs for example in correlation to the manufacturing procedure or the material costs [14].

3.2. Method for the estimation of costs

To consider uncertainties of initial parameters a multitude of approaches exist. Besides, uncertainty stands for a problem formulation which is based on stochastic information [15]. The focus within in this review will be on the probabilistic theory. Within the probabilistic theory the first step exists in the choice of a most suitable distribution function which describes the uncertainties. After the definition of the type of distribution its characteristic parameters must be determined. If empirical information is available, classical methods of the statistic can be used. Otherwise questioning of experts must be carried out [16,17]. The challenge, therefore, exists in the right description of uncertainties through a distribution function.

As the given challenges deal with uncertainties service costs cannot not be calculated in a deterministic way. As stochastic model rendering forecasting comparatively easy can be generated. The advantage over static simulation, which relies on fixed values instead of random figures, is the ability to estimate the service costs for machines and production systems and the risks entailed in its application [18].

4. Objectives

This article uses the example of a machine tool to illustrate a general approach to assessing the life cycle costs for service contracts. Within the framework of the project called LICMA—*Life Cycle Performance for Manufacturers of Production Facilities*, a method to assess and calculate service contracts has been developed. As part of this project, stochastic cost elements are forecast and deterministic cost elements are calculated. The result of this method enables the machine manufacturer to determine the costs incurred by service contracts.

5. Approach

The approach to calculating service costs is divided into four steps (Fig. 1). As a first step, the deterministic cost elements of the life cycle are calculated, such as service, maintenance and material costs. As a second step, stochastic distributions will be determined which represent a specific scope of service and maintenance activities. As part of step 3, the life cycle performance (LCP) matrix establishes a link between deterministic and stochastic elements. As a fourth step, the Monte Carlo method is used to calculate the stochastic and deterministic cost elements of the service costs.

5.1. Deterministic cost elements

Among deterministic cost elements figure service costs, costs for servicing activities and material costs.

5.1.1. Service costs

The costs arising from service contracts are determined in accordance with the services agreed on in the contract. The costs for individual services are divided into costs incurring once for every single machine (X_i). In addition, every machine incurs machine specific one-off costs (Y_i) and annual costs (Z_i). Among the one-off costs for all machines figure, for example, the costs for purchasing a camera equipment or for customer training. Machine specific one-off costs are, for example, a modem for remote diagnosis systems. Royalties are an example of annual costs per machine. Depending on the services that were agreed on the share in the total costs $C_j = (j = 1,2,3)$ is calculated as follows (for all of the services agreed on i):

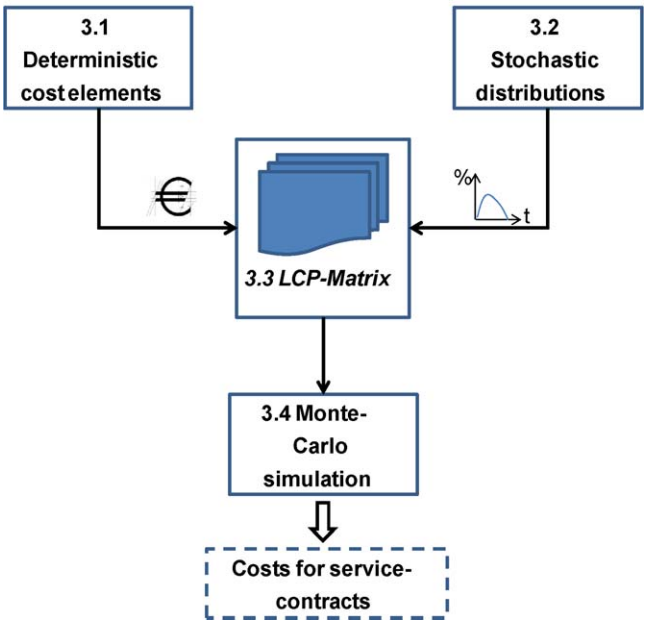

Fig. 1. Flow chart of how deterministic elements and stochastic distributions influence each other.