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Application of reliability models with covariates in spare part prediction and optimization – A case study

Abbas Barabadi [a,*], Javad Barabady [a], Tore Markeset [b]

[a] Department of Engineering and Safety, University of Tromsø, N-9037 Tromsø, Norway
[b] University of Stavanger, N-4036 Stavanger, Norway

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ABSTRACT

The number of spare parts required for an item can be effectively estimated based on its reliability performance. The reliability characteristics of an item are influenced by different factors such as the operational environment, maintenance policy, operator skill, etc. However, in the majority of reliability based spare part provision studies, the effect of these influence factors has not been considered, and the only variable of interest is the operating time. The aim of this paper is to demonstrate the application of the available reliability models with covariates in the field of spare part predictions by means of a case study.

1. Introduction

The availability of spare parts is an important factor, which can increase the performance and effectiveness of the system. When the system fails the down-time can be significantly reduced if all spare parts needed for the repair are immediately available. On the other hand, if spare parts are not immediately available, the waiting time for them can cause costly production losses. Moreover, the overstocking of unnecessary spare parts or the obsolescence of too many stored units can lead to huge losses due to the investment costs. Hence, accurate spare parts prediction, as an important part of product support activity, has to be considered seriously in the design and operation phases [1,2].

Spare parts prediction and optimization is a complex problem and requires the identification of all influence factors as well as the selection of an appropriate model for quantifying their effect on the required number of spare parts. Some of the important influence factors are the operational conditions, including climatic conditions (temperature, wind, snow, dust, ice, etc.), the skill of the operator and maintenance crew, the history of the repair activities carried out on the machine, etc. [3,4]. Ghodrati and Kumar [5] showed that in the Kiruna Mine, Sweden, ignoring the effects of operational conditions can lead to a 20% difference in the expected number of required spares for the hydraulic jacks (lifting cylinders) in a load-haul-dump machine in one year.

The queuing theory approach has been used frequently to determine the number of spare parts required to ensure a specified availability of the system [6,7]. This deals primarily with constant failure and repair rates which are not true assumptions in many cases. Furthermore, it is not effective for modeling the effect of operational conditions as covariates on spare parts. The quantitative techniques based on reliability theory can be used for spare parts provision when the failure rate is not constant [8,9]. In reliability based statistical approaches the required number of spare parts is calculated based on the reliability performance of the item. Hence, to quantify the effect of operational conditions on the required number of spare parts, their effects should be quantified on the reliability performance of the item. However, in most of the available studies, operating time is the only variable and operational conditions have not been considered as variables [10–14]. Therefore, there is a lack of implementation of reliability regression models with covariates (RRMC) such as the proportional hazard model for spare part predictions.

The aim of this paper is to show the application of RRMC for the provision of spare parts for drill bits in Jajarm Bauxite Mine, Iran. Drill bits are among the important parts of the drilling machines and any shortage of these items can lead to the stoppage of production in the mine. The operational conditions in a mine are more severe than in most other industries. It is believed that the reliability characteristics of the drill bits are influenced by the operational conditions in Jajarm Bauxite Mine. Hence, it is

* Corresponding author. Tel.: +47 776 6 0339.
E-mail address: abbas.b.abadi@uit.no (A. Barabadi).
URL: http://www.uit.no (A. Barabadi).

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important to investigate this subject and accurately estimate the number of spare parts needed, considering the effect of operational conditions, to reduce the down-time. Moreover, considering the fact that different types of drill bits can be used for the drilling process, it is important to find the most cost-effective one to minimize the cost of the drilling process. The reliability performance of the drill bit considering the operational conditions can provide the essential information for such a type of cost analysis.

The rest of this paper is organized as follows: in Section 2 the basic concept and methodology for spare parts prediction using RRMC are discussed. In Section 3 the application of this methodology is demonstrated by a case study. Furthermore, this section shows how an appropriate RRMC can be found for specific data sets. Finally, Section 4 provides the conclusions.

2. Basic concept and methodology

Spare parts for maintenance tasks, with the exception of preventive maintenance activities, are usually required at random intervals. Hence, due to the uncertainty about the time of failure, the number of spare parts can be modeled using probability distribution illustrated by Fig. 1. The methodology is based on four main tasks:

- Data collection, identification and formulation of covariates.
- Identification of an appropriate statistical approach to estimate the number of failures in a specific time.
- Identification of the distribution of failure data considering covariate effects.
- Calculation of the required number of spare parts.

2.1. Data collection, identification and formulation of covariates

The first step is to collect the failure data. Failure data can be collected from different sources such as maintenance and inspection reports, data from sensors on equipment, past experience with similar or identical items, manufacturer information, etc. Furthermore, in this step all factors influencing the reliability performance of the item need to be identified and formulated. The failure mechanism of the item can be used as a guideline to identify and formulate the covariates [14,15]. In the mine industry some such influence factors may include the geological characteristics of the rock, the operating history of the machine (e.g. overhauls, effect of repair, preventive maintenance), the design, material, operator and maintenance crew skills, etc.

2.2. Identification of an appropriate statistical approach to estimate the number of failures

In next stage, depending on the type of maintenance action on the item, one of the following methods can be used to calculate the number of failures [9,16].

- *Renewal processes* (*RP*): for repairable items, when maintenance action restores the items to an operating condition that is as good as new (perfect repairs) and for non-repairable items when their failure data is identical and independently (iid).
- *Nonhomogeneous Poisson processes* (*NHPP*): for repairable items when a maintenance action restores the item to an operating state that is as bad as old (minimal repairs).

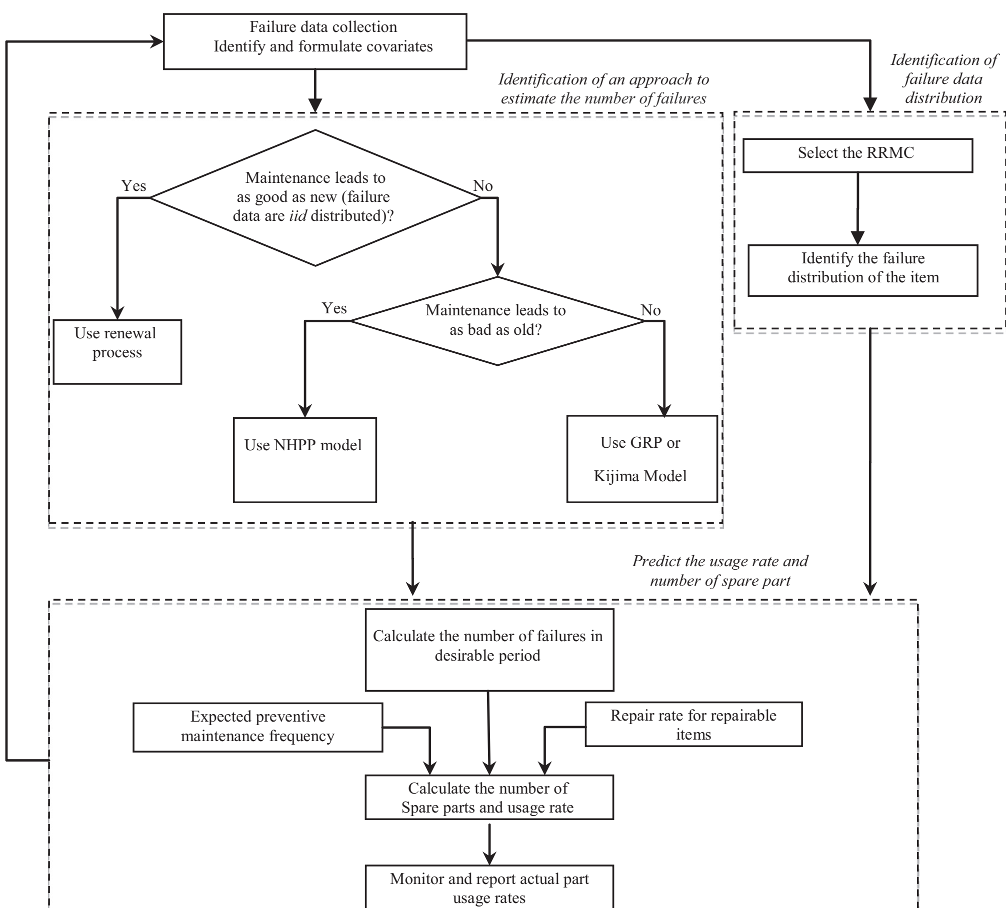

Fig. 1. A methodology for calculating required numbers of spare parts considering the effect of covariates.