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Review

System-oriented inventory models for spare parts

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HIGHLIGHTS

- We survey the literature on models for spare parts inventory control.
- Our focus is on models using system-oriented service measures.
- We link the models to two archetypical types of spare parts networks in practice.
- Both the single-location and multi-echelons models are treated.
- We discuss various extensions, including the use of lateral and emergency shipments.

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ABSTRACT

Stocks of spare parts, located at appropriate locations, can prevent long downtimes of technical systems that are used in the primary processes of their users. Since such downtimes are typically very expensive, generally system-oriented service measures are used in spare parts inventory control. Examples of such measures are system availability and the expected number of backorders over all spare parts. This is one of the key characteristics that distinguishes such inventory control from other fields of inventory control. In this paper, we survey models for spare parts inventory control under system-oriented service constraints. We link those models to two archetypical types of spare parts networks: networks of users who maintain their own systems, for instance in the military world, and networks of original equipment manufacturers who service the installed base of products that they have sold. We describe the characteristics of these networks and refer back to them throughout the survey. Our aim is to bring structure into the large body of related literature and to refer to the most important papers. We discuss both the single location and multi-echelon models. We further focus on the use of lateral and emergency shipments, and we refer to other extensions and the coupling of spare parts inventory control models to related problems, such as repair shop capacity planning. We conclude with a short discussion of application of these models in practice.

Contents

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1. Introduction

In this survey, we discuss models and literature on spare parts inventory control. We focus on spare parts inventories for technical systems that are used in the primary processes of their users. Examples are trains, radar systems, MRI-scanners, wafer steppers, and baggage handling systems. Upon failure of such a system, tests are performed to isolate the failure to a specific Line Replaceable Unit (LRU) and this LRU is then replaced by a functioning spare part. This repair-by-replacement policy enables quick repair of the technical system so that the disruption of the primary process of the user is kept within certain limits. This is important, since such disruptions can be very costly; for instance, in the semiconductor industry, downtime costs of the bottleneck machines are estimated to be tens of thousands of euros per hour [1, p. 17]. Obviously, having adequate numbers of spare parts is of key importance for this repair-by-replacement policy to be effective. However, spare parts stocks may tie up a lot of capital: commercial airlines are estimated to have over $40 billion worth of spare parts [2, p. 78], a single company such as ASML, which builds lithography equipment used in semiconductor manufacturing, owns spare parts worth tens of millions of euros [1, p. 78], and the US Coast Guard Aircraft owns inventories worth over $700 million [3, p. 1028]. Stocking the right number of spare parts, not too few and not too many, is thus of key importance. However, stocking the right amounts is difficult, especially for expensive components that fail infrequently and have a long replenishment lead time. In the military world, for instance, lead times can be over a year [4, p. 17].

Spare parts are either repairable or consumable and they differ greatly in their values. In their benchmark study of after-sales service logistics systems, Cohen et al. [5, p. 630] report that the "…average part cost is $270, with some companies reporting parts that cost hundreds of thousands of dollars". Still, the impact of unavailability of a low value spare part and a high value spare part may be the same. Consider a bearing and an X-ray tube, both of which are used in a fully automated security check point in a baggage handling system. If either one of them breaks down, the check point cannot be used anymore. Since the user of the baggage handling system is interested only in whether or not the system is working, it makes sense to stock relatively more inexpensive bearings than expensive X-ray tubes. Due to the direct link between the availability of spare parts and the availability of the technical systems, it makes sense for many companies to use *system-oriented* service measures and targets. Targets can be set, for example, for the availability of the technical systems or the expected number of backorders over all LRUs (a backorder being a spare part that is requested but not yet delivered). This is a key difference with standard inventory models, in which *item-oriented* service measures, such as the fill rate (the percentage of requested parts that can be delivered from stock immediately), are used. In a comparison of multi-item spare parts inventory models (using a system approach) with single-item models, in a single-location setting, Thonemann et al. [6] show that costs savings of about 10%–20% are possible when using a system approach instead of an item approach. Such savings may be achieved when there are large cost differences between the various components. Rustenburg et al. [7,8] study spare parts models for a two-echelon network at the Royal Netherlands Navy and compare the item approach that was in use at that time with the system approach. Rustenburg et al. [8, p. 172] show that for one system, spare parts holding costs would reduce by about 60% under the system approach, while attaining a slightly higher spare parts availability; for another system, the spare parts holding costs would reduce by 9%, while bringing the availability up from 56% to 90%. In our survey, we focus on the system approach and we will discuss the commonly used greedy algorithm that can be used to solve such multi-item models.