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Using repair priorities to reduce stock investment in spare part networks

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Abstract

In this paper, we examine the impact of repair priorities in spare part networks. Several heuristics for assigning priorities to items as well as optimising stock levels are developed, extending the well-known VARI-METRIC method. We model repair shops by multi-class, multi-server priority queues. A proper priority setting may lead to a significant reduction in the inventory investment required to attain a target system availability (usually 10–20%). The saving opportunities are particularly high if the utilisation of the repair shops is high and if the item types sharing the same repair shop have clearly different characteristics (price, repair time). For example, we find an investment reduction of 73% for a system with single server repair shops with an utilisation of 0.90 that handle five different item types.

Keywords: Inventory; Queuing; Spare parts

1. Introduction

For advanced technical systems, such as engines, medical equipment, and airplanes, a sufficiently high system availability is enhanced by a distribution network for repairable spare parts. In this network, a failed item can follow two different routes through the system: either it enters the local repair facility, or it is forwarded to the next echelon upstream to be repaired there (e.g. the downstream echelon consists of frigates, the upstream echelon consists of a depot in the harbour, see Fig. 1). Usually items are sent to the higher echelon if local repair is technically impossible, i.e. if the local repair shop does not have appropriate equipment or skills. It is usually (and here) assumed that the decision whether to repair locally or not is based on such technical considerations only, and not by e.g. current repair shop workload. This is modelled by a fixed probability that the item can be repaired locally, independent of the system state. We will use the same assumption.

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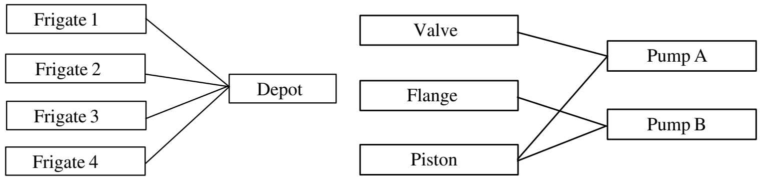

Fig. 1. The system structure (left side) and the indenture structure (right side).

It is also assumed that items have *multi-indenture* structure, which means that every item (assembly) may consist of other items (subassemblies), see Fig. 1. If an assembly fails, we assume that either the failure is caused by the failure of exactly one of its subassemblies (so the replacement of this subassembly is sufficient to repair the assembly), or there is no specific subassembly causing the assembly failure (hence the assembly as a whole has to be repaired). In the case of a subassembly failure the assembly is disassembled and the failed subassembly is sent further for subassembly repair.

Next to each repair facility there is a stock with new items and when a failed item arrives at the repair shop an order for a new item is issued. If a new item is available on stock, it is dispatched to replace the failed item. At the same time, the failed item either enters the local the repair shop or dispatched to external repair/stock facility (subassembly repair of higher echelon repair) and after repair it is added to stock (Fig. 2).

A well-known problem is to choose optimal spare part stock levels in the network, such that target system availability is attained at minimal inventory investment. Inventory levels have to be selected for each spare part, being an item in a multi-indenture product structure, and for each location in a multi-echelon distribution network structure.

The class of VARI-METRIC models (cf. Slay, 1984; Sherbrooke, 1992) has been developed to tackle this problem. Their method aims to determine initial stock levels, assuming that all failed items are either repaired or replaced by new items if repair is impossible, so that the original amount of items remains circulating through the network. A deficit of the original VARI-METRIC method is the assumption that the repair shop capacities are infinite. As has been shown by Sleptchenko et al. (2002a) this may lead to significant errors in estimating system availability and determining spare part stock levels if the repair shop utilisation is high. Therefore, they model repair shops as multi-class, multi-server queuing systems to resolve this issue. Thus, they develop a variant of VARI-METRIC with finite repair capacities. In such models, we can introduce other degrees of freedom for efficiency improvement, such as capacities of the repair facilities and repair priorities. Sleptchenko et al. (2003) use a finite repair capacity model to make a trade-off between

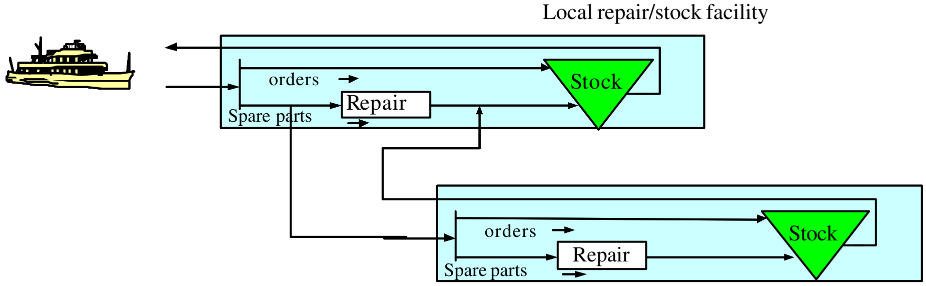

Fig. 2. Representation of spare part flows.