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Design of BOM configuration for reducing spare parts logistic costs

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Abstract

This paper proposes an approach to reduce the total operational cost of a spare part logistic system by appropriately designing the BOM (bill of material) configuration. A spare part may have several vendors. Parts supplied by different vendors may vary in failure rates and prices – the higher the failure rate, the lower the price. Selecting vendors for spare parts is therefore a trade-off decision. Consider a machine where the BOM is composed of s critical parts and each part has k vendors. The number of possible BOM configurations for the machine is then k^s. For each BOM configuration, we can use OPUS10 (proprietary software) to calculate an optimum inventory policy and its associated total logistic cost. Exhaustively searching the solution space by OPUS10 can yield an optimal BOM configuration; however, it may be formidably time-consuming. To remedy the time-consuming problem, this research proposes a GA-neural network approach to solve the BOM configuration design problem. A neural network is developed to efficiently emulate the function of OPUS10 and a GA (genetic algorithm) is developed to quickly find a near-optimal BOM configuration. Experiment results indicate that the approach can obtain an effective BOM configuration efficiently.

Keywords: Bill of material; Spare parts; Stocking policy; Genetic algorithm; Neural network

1. Introduction

Machine availability is very important in capitally intensive industries. The higher the machine availability, the higher is the capacity. The level of machine availability partly depends on the inventory level of its spare parts. At a lower inventory level, the time required to repair a machine would be longer due to having higher possibility of lacking spare parts. A higher inventory level by contrast would increase machine availability at the expense of paying more inventory cost. Since spare parts in capitally intensive industries are quite expensive, much research investigated the stocking policies for spare parts to resolve the trade-off decision (Sherbrooke, 2004).

Spare parts are typically replenished through a *multi-echelon* supply chain system, which is a hierarchical structure comprising multiple layers of facilities (Fig. 1). A facility has two main functions: *storing* and *repairing* spare parts. Facilities in the lowest layer directly supply parts to machines, whereas those at a high layer supply parts to its succeeding lower layer facilities. Facilities at a higher layer are generally equipped with higher repairing capability. That is, a part that cannot be repaired by a particular facility would be sent upward to its parent facility. In this paper, the information for characterizing such a supply chain system is called BOS (bill of stations).

A machine is typically composed of several modules; each module comprises several assemblies that are assembled by subassemblies/parts (Fig. 2). The hierarchical representation for modeling the materials of a machine is called BOM (bill of materials), where a layer in the BOM structure is usually called an *indenture* in literature. In the BOM, each part is defined with several BOS-independent attributes such as cost and failure rate, and some BOS-dependent attributes such as eligible stations for repairing the part.

At a globalization era, a part tends to have multiple vendors who may provide parts that are functionally identical but with various failure rates and costs. The lower the

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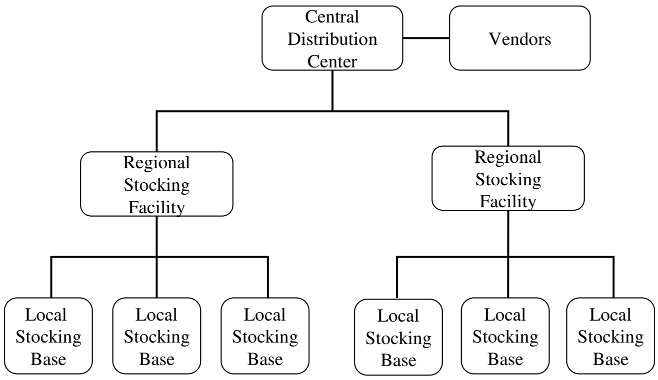

Fig. 1. BOS of a multi-echelon logistic system.

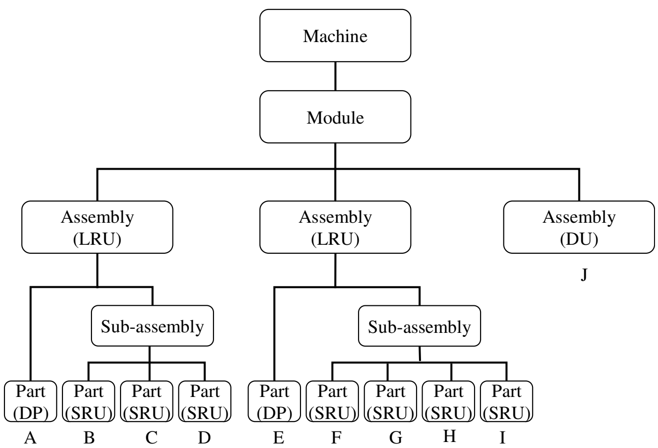

Fig. 2. BOM of a multi-indenture machine.

failure rate, the higher is the price of a part. Purchasing more reliable parts (i.e. with lower failure rates) would reduce the inventory level of spare parts required to maintain the target machine availability. As a result, this would reduce the holding cost of part inventory at the expense of increasing its purchasing cost. Choosing an appropriate configuration of BOM is therefore a very important way to reduce the total operational cost of a spare part supply chain system. Yet, this idea has been rarely noticed in literature.

This paper proposes the idea of choosing appropriate BOM configurations, formulates the decision problem, and develops an efficient approach to solve the problem. Suppose a machine has s critical parts, each of which has k vendors. The possible number of BOM configurations may be quite huge (k^s). It might take a formidable computation time if we exhaustively evaluate the performance of each BOM configuration by using the evaluation methods developed in literature. To efficiently solve the problem, we propose a GA-NN approach. The NN (neural network) technique is used to efficiently emulate the function of an existing method for evaluating BOM configurations, whereas the GA technique is used to efficiently identify a near-optimal BOM configuration from the huge solution space.

The remainder of this paper is organized as follows. Section 2 reviews the literature on stocking spare parts for a supply chain system. Section 3 introduces OPUS10 (proprietary software), which can be used to evaluate the performance of a BOM configuration. That is, OPUS10 can yield the optimal stocking policy and its associated total operational cost for a BOM configuration. Section 4 describes the procedure for establishing the neural network that could emulate the function of OPUS10. Section 5 presents the genetic algorithm. Section 6 illustrates the experimental results and concluding remarks are placed in Section 7.

2. Related literature

The inventory policy for a multi-echelon repairable item (spare part) system has been a research issue for several decades. Much literature has been published and some of them have included a comprehensive survey (Diaz & Fu, 2005; Guide & Srivastava, 1997; Kennedy, Patterson, & Fredendall, 2002; Rustenburg, 2000; Sleptchenko, 2002). These previous studies can be categorized into two main streams.

The first stream addressed a scenario equipped with an *infinite repair capacity*. An early and representative study is the METRIC (Multi-echelon Technique for Recoverable Item Control) model developed by Sherbrooke (1968). Many studies that extend the METRIC model were subsequently developed (Graves, 1985; Muckstadt, 1973; Sherbrooke, 1986, 2004; Simon, 1971; Slay, 1984). With the ample-server assumption, the queue-time for repair is negligible; therefore, these METRIC-variant models have been able to deal with large and complex systems. However, a real-world problem is typically equipped with limited repair capacity. The METRIC-variant models thus tend to underestimate the stocking levels in some real applications.

The various versions of the METRIC-variant models can be characterized from three perspectives: the demand pattern of spare part, BOM, and the complexity of supply chain. In the original METRIC model (Sherbrooke, 1968), the BOM is a single-indenture system involving multi-repairable-items, the demand is a compound Poisson process, and a replenishment $(S,\ S-1)$ policy is used throughout a two-echelon supply chain. Simon (1971) developed a METRIC-variant model that uses (s, S) policy in the second-echelon facilities. Muckstadt (1973) enhanced the METRIC model by including two-indenture BOM systems. Slay (1984), Graves (1985), and Sherbrooke (1986) further developed methods in order to estimate the variances of service levels. Hausman and Erkip (1994) broadened the METRIC model by including a scenario where an emergency-ordering policy is allowed.

The second stream addressed a scenario with *finite repair capacity*, which leads to the need of modeling the machine-repair queueing behavior. The models in this stream, more realistic than the METRIC-variant models, are certainly more difficult to solve. Due to the inherent complexity, by the possible inclusion of enumeration techniques, most of these studies are computationally extensive (Gross, Miller, & Soland, 1983). Approximations to reduce the complexity have therefore been proposed in order to