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Spare Parts Inventory Management: A Literature Review

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Abstract: Spare parts are held as inventory to support product maintenance in order to reduce downtime and extend the lifetime of products. Recently, spare parts inventory management has been attracting more attention due to the "right-to-repair" movement which requires that manufacturers provide sufficient spare parts throughout the life-cyle of their products to reduce waste so as to achieve sustainability. In this review, 148 papers regarding spare parts inventory management published from 2010 to 2020 are examined. The studies are classified based on two groups of perspectives. The first group includes the characteristics of spare parts, products, inventory systems, and supply chains, while the second group focuses on the characteristics of research methodologies and topics in the reviewed studies. The novelty of this literature review is three-fold. Firstly, we focus on analyzing the supply chain structure of different inventory networks for managing spare parts. Secondly, we classify the current literature based on analytics techniques, i.e., descriptive analytics, predictive analytics, and prescriptive analytics. Finally, the research gaps in this field are discussed from the perspective of reverse logistics, consumer durable goods, inventory network structure and policy, spare parts demand pattern modeling, and big data analytics.

Keywords: spare parts; inventory management; operations research; management science; supply chain sustainability; optimization

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1. Introduction

Nowadays, manufacturers usually advocate for a culture of planned obsolescence. The idea of such a culture is to design their products to be short-lived and make products hard to repair, so that customers are encouraged to purchase more. However, this culture contributes to wasting more natural resources and energy, further escalating global warming. For example, the carbon emissions of producing the newest iPhone account for nearly 80 percent of the total emissions during its life-cycle [1]. To discourage this culture and achieve supply chain sustainability, a movement known as "right to repair" is starting to make progress in pushing for legislation that requires companies make their parts, tools, and information available to consumers and repair shops [2]. Under this circumstance, spare parts inventory management is attracting more attention from practitioners and academia. Spare parts are stock items used in maintenance activities to keep equipment or products in operating conditions [3]. Spare parts inventory management is critical because the cost of spare parts accounts for a large share of the products' life-cycle cost: the value of spare parts annually consumed by a piece of machinery, which might have a lifetime of around 30 years, amounts to nearly 2.5% of the original purchasing price [4]. The non-availability of spare parts may induce great financial losses for product owners. In some industries where the manufacturers provide after-sales services, good spare parts inventory management can improve customer satisfaction by reducing product downtime [5]. Furthermore, spare parts often have an obsolescence problem, which leads to spare parts being discarded at a quite low value. Overall, spare parts inventory

management plays an important role in achieving the desired product availability at the minimum economic and environmental costs. However, the management of spare parts faces several difficulties. Firstly, the number and variety of spare parts are usually very large. Secondly, the intermittent demand patterns are common among spare parts, and are difficult to predict. Thirdly, the consumption of spare parts is related to the product usage, damage, and maintenance [4].

1.1. Motivations and Objectives

The goal of this review is to provide a quick guide to a variety of classification schemes to the spare parts inventory management literature and to present a big picture on spare parts supply chains to discuss the studies on spare parts inventory management. Over the last decade, a significant number of studies on spare parts inventory management have been published to provide managerial insights to practitioners, but to the best of our knowledge, there is no literature review that organizes the current literature from the perspectives of supply chain management and supply chain analytics. There have been seven literature reviews on this topic in the last thirty years. Ref [6] reviewed the studies on optimal maintenance and replacement models for multi-unit systems and classified them into five categories based on maintenance operations. In their review, spare parts inventory management was only a sub-topic. Ref [7] presented a review on the studies of repairable spare parts inventory management, and the reviewed studies were grouped based on network structure, solution methodology, and solution types. Ref [3] presented the first review which completely focused on the literature of spare parts inventory management, and the relationships between equipment maintenance and spare parts inventory were analyzed. Ref [8] gave a review on lateral transshipments within an inventory system. Ref [9] limited their literature review to models for non-repairable spare parts. Ref [10] focused on managing spare parts inventories of technical systems. The classification in their review was made based on the characteristics of the inventory network, including the network's service provider, number of echelon levels, and availability of lateral or emergency transshipment, etc. Ref [4] presented a framework for operational research (OR) in spare parts inventory management and analyzed the literature on four critical aspects of OR in spare parts inventory management, i.e., spare parts classification, demand forecasting, inventory optimization, and supply chain system simulation.

The main differences between our literature review and the aforementioned reviews are as follows. Firstly, we focus on analyzing the supply chain structure of different inventory networks for managing spare parts. Secondly, we classify the literature according to three analytics techniques, i.e., descriptive analytics, predictive analytics, and prescriptive analytics. Thirdly, we point out several new research gaps which combine spare parts inventory management with supply chain sustainability, big data analytics, and so on.

1.2. Methodology

In this review, the database used for searching publications was ABI/INFORM Collection, which is one of the most comprehensive business databases in the OR/MS field. The initial search was conducted by searching *spare* and *inventory* as keywords in the titles and abstracts in peer reviewed publications published between January 2010 and January 2020. After this initial search, 124 studies were identified. Then we used Google Scholar to search for studies citing them. In total, there were 148 studies in the review pool. After taking out the seven aforementioned reviews, 142 studies remained.

2. Typology Based on Systematic Characteristics

In this section, the reviewed papers are classified based on the characteristics of their studied products or spare parts and supply chain structures and inventory attributes for managing those products and spare parts. In the first subsection, five types of product and spare part characteristics including product system type, product life-cycle phase, spare part type, product system complexity, and performance measures are used to depict