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A dynamic pricing approach for returned products in integrated forward/reverse logistics network design

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ABSTRACT

During the last decade, the stringent pressures from environmental and social requirements have spurred an interest in designing a reverse logistics network. In this paper, we address the problem of designing and planning a multi-echelon, multi-period, multi-commodity and capacitated integrated forward/reverse logistics network. Returned products are categorized with respect to their quality levels, and a different acquisition price is offered for each return type. Furthermore, the reservation incentive of customers, the expected price of customers for one unit of used product described by uniform distribution, is applied to model the customers' return willingness. Due to the fact that the remaining worthwhile value in the used products is the corporation's key motivation for buying them from customers, a dynamic pricing approach is developed to determine the acquisition price for these products and based on it determine the percentage of returned products collected from customer zones. The used products' acquisition prices at each time period are determined based on the customers' return willingness by each collection center.

A novel mixed-integer linear programming is developed to consider dynamic pricing approach for used products, forward/reverse logistics network configuration and inventory decisions, concurrently. The presented model is solved by commercial solver CPLEX for some test problems. Computational results indicate that the effect of a dynamic pricing approach for used products versus a static pricing one, and the linearization of pricing concept for this model have the acceptable solution. In addition, sensitivity analysis is conducted to show the performance of the proposed model.

1. Introduction

Logistics network design problem that takes into account the facility locations and the shipment of product flows has gained considerable attention in both practice and academia. Since opening and closing facilities is both a time-consuming and expensive process, changing the network design is impossible in the short run. Moreover, due to the fact that after conducting the strategic decisions, the tactical and operational decisions are made, the design of logistics network will become a restriction for tactical and operational decisions. Considering these facts, the logistics network configuration is a very complex location problem and it is also required to be efficiently and effectively optimized for a long time [1].

During the last decade, growing attention has been paid to reverse logistics, which refers to activities, such as collection, recovery, repair, recycling, remanufacturing and disposal of the used products. An increasing number of companies such as

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Dell, General Motors, Kodak and Xerox have focused on these activities and achieved significant success [2]. The main causes of this increasingly attention are named environmental and business factors. The former relates to the used products' environmental impacts, environmental legislation, waste management, customers' increasingly careful attention to environmental issues, and pollution reduction. The latter includes economical advantages of using returned products, improving customer satisfaction, increasing market share, reducing costs, and adding value to logistics network [3]. Efficient and appropriate design of the logistics network leads to meeting these objectives. Therefore, the configuration of logistics network is considered as a significant subject within logistics and supply chain management that has an indispensable influence on the total performance of the supply chain.

The literature dedicated to the logistics network design problem can be divided into three parts, namely forward logistics network design (FLND), reverse logistics network design (RLND), and integrated forward/reverse logistics network design (IFRLND). The first division only addresses the traditional supply chain network design. The reverse logistics network focuses on the backward network, known as recovery network. Given the fact that designing the forward and reverse logistic network separately leads to sub-optimal designs, the configuration of forward and reverse logistics network should be integrated as the third part of the related literature [4,5]. Most of the logistics network design models have been constructed based on the facility location theory. According to the body of literature, the primary works start with simple facility location models (e.g. [6,7]). Then, more complex models are developed by taking the real life features of logistics network into account (e.g. [8–10]). In the next section, a comprehensive literature review of logistics network is provided.

In the RLND problem, making acquisition price decisions for the returned product is one of the most interesting and challenging issues [11,12]. The reason that makes the used products attractive for many corporations is twofold. The first one is the environmental aspect of collecting used products. Nowadays, because of tightened environmental laws, manufacturers need to devise products and production processes that make the recovery of used products possible for capturing the remaining advantages value. The second one is economical. Recovery and remanufacturing can reduce the unit cost of production by 40–60% by reutilizing the product components [13]. In this issue, Guide et al. [14] proposed a method to calculate the optimal acquisition price and the optimal selling price for remanufactured products. Based on anticipated demand, Liang et al. [11] presented an option model for acquisition pricing for the returned products. Choi et al. [15] and Yalabik et al. [16] also developed some strategies to calculate the optimal acquisition price. However, as suggested by Pokharel and Mutha [12] for future researches, the researchers do not explicitly consider network design and pricing for the acquisition of used products based on their quality. Therefore, in the context of the IFRLND problem, there is not any research containing determining the acquisition price for used products and location-allocation decisions at the same time, which is considered in this paper as the main contribution.

With regard to the matters enumerated, this paper develops a novel model for a multi-stage, multi-period, multi-product and capacitated integrated forward/reverse logistics network design including two echelons in forward direction (i.e., production/recovery centers, and distribution centers) and two echelons in backward direction (i.e., collection centers, and disposal centers). The goal of IFRLND model is to minimize its logistics cost. Furthermore, a complete sensitivity analysis is presented to investigate this model from different perspectives. To differentiate our efforts from those already published on this issue, the main innovations of this paper could be summarized, as follows:

- Designing and modeling a novel integrated forward/reverse logistics network as a mixed-integer linear programming (MILP) model to integrate both strategic and tactical decisions.
- A dynamic pricing approach is used to make the acquisition price decision for the used products with different quality levels returning from customer zones.
- The concept of transshipment among stages of IFRLN is considered to reduce the cost of logistics network.
- The IFRLN is designed based on a push–pull strategy in such a way that the periodic review inventory policy is used for the forward logistics of IFRLN.
- Based on product life cycle, the IFRLN is defined in which three return-recovery pairs: recoverable, scrapped and commercial returned products are considered.

The rest of this paper is organized, as follows. In the next section, we review the related literature and provide a comprehensive table. The concerned problem and its characteristics are defined in Section 3 in detail. The proposed MILP model for IFRLND and also the dynamic pricing approach are presented in Section 4. Sections 5 and 6 provide the computational results and sensitivity analysis for some test problems, respectively. Finally, Section 7 concludes this paper and offers guidelines for further research.

2. Literature review

The vast majority of existing literature in respect to designing the logistics network is comprised of diverse facility location models most of which is based upon the MILP. These studies encompass a wide scope of models range greatly from simple uncapacitated facility location models to complex capacitated multi-stages, multi-product, multi-period or multi-objectives ones. Melo et al. [17] and Klibi et al. [18] present comprehensive reviews on the logistics network design problem to support a wide variety of future research streams. In the following, we will review the literature of represented models concerning the logistics network design problem dividing into forward logistics network (FLN), reverse logistics network