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A genetic algorithm approach to developing the multi-echelon reverse logistics network for product returns

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Abstract

Traditionally, product returns have been viewed as an unavoidable cost of doing business, forfeiting any chance of cost savings. As cost pressures continue to mount in this era of economic downturns, a growing number of firms have begun to explore the possibility of managing product returns in a more cost-efficient manner. However, few studies have addressed the problem of determining the number and location of centralized return centers (i.e., reverse consolidation points) where returned products from retailers or end-customers were collected, sorted, and consolidated into a large shipment destined for manufacturers' or distributors' repair facilities. To fill the void in such a line of research, this paper proposes a nonlinear mixed-integer programming model and a genetic algorithm that can solve the reverse logistics problem involving product returns. The usefulness of the proposed model and algorithm was validated by its application to an illustrative example dealing with products returned from online sales.

Keywords: Reverse logistics; Location-allocation; Genetic algorithm

1. Introduction

As of 1999, the total value of returned merchandise was \$62 billion, representing \$10–\$15 billion in losses to retailers in the United States, while the cost of handling these product returns was estimated to be \$40 billion [1]. Faced with the mounting costs of managing product returns, some companies have begun to consider mapping the process of reverse logistics involving product returns and creating opportunities for cost savings and service improvements. These companies include e-tailers that have grown with increases in online sales, but were often overwhelmed by the scope and complexity of sending returned products back to their distributors or manufacturers for credit. According to ReturnBuy [1], return rates for online sales are substantially higher than traditional bricks-and-mortar retail sales, reaching 20–30% in certain categories of items. In an extreme case, Rogers and Tibben-Lembke [2] reported that an average return rate for the magazine publishing industry was 50%.

With ever-rising costs of product returns and dwindling profit margins, the optimal handling of product returns can be a competitive differentiator since a firm can save a substantial amount of transportation, inventory, and warehousing costs associated with product returns. Indeed, Shear

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Table 1
Comparison between reverse logistics and forward logistics

	Reverse logistics	Forward logistics
Quantity	Small quantities	Large quantities of standardized items
Information tracking	Combination of automated and manual information systems used to track items	Automated information systems used to track items
Order cycle time	Medium to long order cycle time	Short order cycle time
Product value	Moderate to low product value	High product value
Inventory control	Not focused	Focused
Priority	Low	High
Cost elements	More hidden	More transparent
Product flow	Two way (“push and pull”)	One way (“pull”)
Channel	More complex and diverse (multi-echelon)	Less complex (single or multi-echelon)

Source: Adapted and modified from Shear et al. [3], “The warehousing link of reverse logistics.”

et al. [3] noted that handling costs associated with product returns could reach $50 per item and could be three times higher than outbound shipping costs. In addition, they observed that product returns often reduced current assets due to lower inventory values for returned products, increased short-term liabilities due to required repairs and refurbishment, lengthened order cycle time due to reshipment of ordered items, and decreased sales revenue due to lost sales. As such, those firms that are willing to implement an optimal strategy of handling product returns can bring in millions of dollars of potential cost savings. Poirier [4] recently observed that firms in the optimal (or efficient) supply chain network enjoyed 40% more cost savings, 33% more inventory reductions, and 44% higher customer services than those in the inefficient supply chain network.

Typically, a product return involves the collection of returned products at designated regional distribution centers or retail outlets, the transfer and consolidation of returned products at centralized return centers, the asset recovery of returned products through repairs, refurbishing, and remanufacturing, and the disposal of returned products with no commercial value. The product return process entails the determination of the number and location of initial collection points for returned products and the location/allocation of centralized return centers in such a way that total reverse logistics costs (e.g., inventory carrying and transportation costs) are minimized, capacity of initial collection points and centralized return centers are fully utilized, and the convenience of customers who return products is maximized. By nature, the product return process is more complicated than forward logistics operations due to the presence of multiple reverse distribution channels (direct return to manufacturers versus indirect return to regional collection points or centralized return centers), individualized returns with small quantities, extended order cycles associated with product exchanges, and a variety of disposition options (e.g., repair versus liquidation). Recognizing the inherent complexity of the product return process, this paper develops a mathematical model and its solution procedure that can optimally create the reverse logistics network linking initial collection points, centralized return centers, and manufacturing facilities.

2. Relevant literature

In a broader sense, reverse logistics refers to the distribution activities involved in product returns, source reduction/conservation, recycling, substitution, reuse, disposal, refurbishment, repair and remanufacturing (e.g., [5]). As shown in Table 1, reverse logistics differs significantly from forward logistics. Despite its differences, reverse logistics has drawn little attention from researchers and practitioners alike until recent years. For the last decade, increasing concerns over environmental degradation and increased opportunities for cost savings or revenues from returned products prompted some researchers to formulate more effective reverse logistics strategies. These researchers include Min [6] who developed a multiple objective mixed integer program that was designed to select the most desirable shipping options (direct versus consolidated) and transportation modes for product recall. Although he considered a tradeoff between transportation time and cost associated with reverse logistics, his model could not handle multi-modal situations. Caruso et al. [7] proposed a multiple objective mixed integer program and a heuristic solution procedure for solving the location-allocation of waste service users, processing plants, and sanitary landfills with capacity constraints. Considering a multiple planning horizon, Melachronoudis et al. [8] also developed a multiple objective integer program for the dynamic location of capacitated sanitary landfills. Del Castillo and Cochran [9] presented a pair of linear programs