Chapter 15
An Integrated Bi-Objective Reverse Logistics Network Design for Remanufacturing

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ABSTRACT
Growing environmental and economical concern has led to increasing attention towards management of product return flows. An effective and efficient reverse logistics network enables companies to gain more profit and customer satisfaction. Consequently, the reverse logistics network design problem has become a critical issue. After a brief introduction to the basic concepts of reverse logistics, the authors formulate a new integrated multi-stage, multi-period, multi-product reverse logistics model for a remanufacturing system where the inventory is considered. Two objectives, minimization of the costs and maximization of coverage, are addressed. Since such network design problems belong to a class of NP-hard problems, a multi-objective genetic algorithm and a multi-objective evolutionary strategy algorithm are developed in order to find the set of non-dominated solutions. Finally, the model is tested on test problems with different sizes, and the proposed algorithms are compared based on the number, quality, and distribution of non-dominated solutions that belong to the Pareto front.

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1. INTRODUCTION

Reverse logistics can be defined as the process of moving goods and products from their usual destination to other locations and facilities in order to obtain value, or to manage safe disposal (Du & Evans, 2008). Environmental protection along with economic and service reasons has pushed a growing number of companies to consider product recovery and reverse flows within their logistics systems (Du & Evans, 2008; Lu & Bostel, 2007). Proper and effective implementation of reverse logistics can lead to savings in costs associated with inventory, transportation and waste disposal. It can also improve customer loyalty and future sales (Ko & Evans, 2007).

Product recovery options fall into different classes: refurbishing, cannibalization, repairing, recycling and remanufacturing (Thierry, Salomon, Van Nunn, & Van Waasen, 1995). Based on the condition and age of the returned product and economic considerations, the right option can be chosen (Guide, Jayaraman, Srivastava, & Benton, 2000). Common activities in product recovery systems can be grouped as follows (Aran & Aksen, 2008; Fleischmann, Krikke, Dekker, & Flapper, 2000):

- **Collection:**
  - Moving returned products physically from locations of product holders (customer zones) to some point for further treatment such as consolidation and storage.

- **Inspection/Separation:**
  - Determining if the returned products are in fact recoverable. Disassembly, testing, sorting and storage are some of the operations related to inspection/separation.

- **Reprocessing/Reconditioning:**
  - Transforming the returns into usable products once more. Repair, recycling and remanufacturing are common forms of reprocessing/reconditioning.

- **Disposal:**
  - Discarding products that cannot be reused due to economical and/or technological reasons. Landfilling and incineration are the usual steps of discarding the unrecoverable returns.

- **Redistribution:**
  - Directing and physically moving the reusable products to potential markets and future users. Sales and storage are the prevalent activities related to redistribution.

Remanufacturing is known as the main option of recovery in terms of its feasibility and benefits (Lu & Bostel, 2007). It can return the used product to ‘as new’ condition through disassembly and inspection of all modules. Parts or modules that cannot be salvaged are replaced and tested. Sometimes it is even necessary to include technological upgrades. Remanufacturing is usually performed in-house by manufacturers, since they own the specific product knowledge (Beamon & Fernandes, 2004). Over the past decade, some firms such as Dell, General Motors, HP, Kodak and Xerox have focused on remanufacturing activities and carried out related operations successfully (Pishvaee, Kianfar, & Karimi, 2010a; Üster, Easwaran, Açali & Çetinkaya, 2007).

Obviously, the operational profitability of the underlying supply chain plays a key role in the financial success of product recovery practices. One of the main issues in this context is designing and establishing an effective and efficient infrastructure through optimal network design (Açali, Çetinkaya, & Üster, 2009). The product return recovery usually entails the determination of the number and location/allocation of different facilities involved in the product recovery practice. Necessary decisions must be made in such a way that total reverse logistics costs (e.g., opening cost of facilities opened along with storage and transportation costs) are minimized and service level is maximized (Min & Ko, 2008).
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