Int. J. Production Economics 135 (2012) 209–221

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Designing a reverse logistics network for optimal collection, recovery and quality-based product-mix planning

Kanchan Das [a,*], Abdul H. Chowdhury [b,1]

[a] Technology System Department, East Carolina University, Greenville, NC 27858, USA
[b] North South University, Bashundhara R/A, Baridhara, Dhaka 1229, Bangladesh

ARTICLE INFO

Article history:
Received 19 October 2010
Accepted 13 July 2011
Available online 26 July 2011

Keywords:
Closed loop supply chain
Modular product design
Quality level of products
Recovery of modules
Collection of returned products
MIP model

ABSTRACT

This study proposes an integrated, reverse logistics supply chain planning process with modular product design that produces and markets products at different quality levels. A mixed integer programming (MIP) model formulates the overall planning process required to maximize profit by considering the collection of returned products, the recovery of modules and the proportion of the product mix at different quality levels. This paper proposes the collection of returnables (end-of life, defective, product under warranty) through retail outlets combined with the recovery of modules from the collected products using a network of recovery service providers. The proposed modular product design approach would create a design criterion that provides an improved recovery process at a lower cost. This study uses a total supply chain view that considers the production, transportation and distribution of products to customers, while a numerical problem illustrates the applicability of the models.

1. Introduction

Most of the companies currently involved in manufacturing and marketing of products have been incorporating reverse logistics (RL) in their supply chain (SC) planning as a way of complying with environmental regulations and sustainability expectations, as well as gaining a business advantage from the recovered products. The integration of RL has received significant attention from recent studies; please see the review studies, Ilgin and Gupta (2010), Subramonium et al. (2009) and Pokharel and Mutha (2009).

The ability to plan for the collection of returned products, the component/product recovery process, the proportion of products to be manufactured at different quality levels and product design for recovery remains a significant challenge for SC managers; despite the fact that several companies have pursued RL, and some state-of-the-art RL research models have been published. In RL, returned products can include the following: after use (end of life or before end of life); returned under warranty; defective; obsolete products returned by the retailer (obsolescence due to emergence of new model or new technology) and products returned by consumers under exchange programs. This research does not address products that have been returned under an exchange program. The literature addresses the collection of returned products in three ways: third party logistics (Cruz-Rivera and Ertel, 2009; de Figueiredo and Mayerle, 2008; Krikke et al., 2008; Webster and Mitra, 2007), the opening of collection centers by the remanufacturer/manufacturer (Aras and Aksen, 2008; Tagaras and Zikopoulos, 2008) and the use of retailers (Savaskan et al., 2004; Wojanowski et al., 2007).

The collection of end-of life, returned or defective items should be driven by reasonable profit if third party logistics is to be involved. Most of the returned products do not have any value in terms of functionality (Schultmann et al., 2006), but they do offer materials that can be reprocessed. For short life cycle products like copiers, computers and cell phones, several components can be recovered to obtain functional values if the condition of the product permits. Conditions, however, are often unknown—and the same can be said for the mix of returned items. It is also crucial to address the fact that consumers do not typically have any motivation to return products (Guide et al., 2003). As such, logical planning should set collection options that provide consumers with the motivation to return products without any extra hassle like finding a collection center. Based on these two vital collection-related factors, successful development would involve retailers and selling outlets in the collection of returnables through appropriate promotional steps that would include reasonable incentives for motivating consumers (Guide, 2000). The consumer should know from the moment of purchase that the product may be returned at any outlet or retail

* Corresponding author. Tel.: +1 252 737 1905.
E-mail addresses: dask@ecu.edu (K. Das), hannan@northsouth.edu (A.H. Chowdhury).
[1] Tel.: +88 02 8852000x1702.

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doi:10.1016/j.ijpe.2011.07.010

centers with a call to company representatives or carrying the product to the retail centers. Using retail outlets in this way will provide a collaborative network of collection centers when more than one company chooses to use the same retail outlets.

Retailers and selling outlets usually market several products from several suppliers/businesses. The proposed collaborative approach would make the collection of returnables a viable business component for retailers. Savaskan et al. (2004) compared third-party (3P) logistics, retail outlets and the manufacturer's own channels for collecting returnables, and concluded that collection through retailers was the best option. This paper proposes to involve retail outlets through contractual costs and benefit-based agreements with retailers for the collection of returnables. The approach would be to motivate the retailer by taking promotional steps that would ensure the collection of returnables—an approach that has the potential to develop long-term partner relations with retailers while generating a collaborative approach among several other organizations and retailers. Involving the retailer in the business of collection makes this approach practical and may be considered more viable than Wojanowski et al.'s (2007), which considered the collection of returnables using retailers under a deposit refund scheme. This study has taken into account the conclusions of Savaskan et al. (2004), which suggest considering retail outlets as collection centers.

To be successful, a RL system must have product recovery and collection of returnable equally effective. The recovery process can be handled by the original manufacturer of the product, or 3P logistics, but since it is very difficult to pre-determine the quantity and quality of returned products it may not be feasible for a manufacturer to open a recovery facility for their returned or reverse-channeled products. Economic factors suggest that the most suitable recovery option would be a 3P recovery service provider (RSP) or a network of RSPs. It may be noted at this point that product recovery in a RL situation is both complex and time consuming. Recovery processes for different product types (Thiery et al., 1995) would involve different levels of expertise. The literature mentions modularity in RL as a way to avoid the futility of returned built-to-order type products (Mukhopadhyay and Setoputro, 2005) and sometimes to cope with the take back law (Fernandes and Kekale, 2005). Modular product design is an established approach for accelerating product development and creating a range of variation in product design.

Some of the additional benefits of modular design have been studied by Mikkola and Gassmann (2003). This paper considers using modular product design to create the original product and obtain a reduced recovery cost by decreasing lead time and making the overall recovery process easier. Since product design is a strategic decision issue, SC planning should integrate product design in the strategic planning process to acquire its advantage in production processes (Blackhurst et al., 2005). As discussed, modular design improves production lead time and recovery process of the returned products. Inclusion of modularity while integrating product design at the strategic decision process will further enhance the RL process and overall SC performances. There is no research that considers modularity as product architecture for quick recovery the way this research does. Since the quantity of the returned products, as well as the value addition in the recovery process are not certain, this research assigns RSPs for product recovery using a contractual agreement.

To obtain RL-related business advantages or even comply with the regulatory requirements, SCs should note that RL is a complex business process (Krumwiede and Sheu, 2002), and the recovered products would always be in a competing situation with new products (Horvath et al., 2005).

An RL-based SC may categorize products at three quality levels (QLs): QL1 could be products that use all new components/modules; QL2 could be products that use a mixture of new and recovered components/modules and QL 3 could be products that use only recovered components/ modules. This business provision would allow SCs to use an "if-what" analysis to decide the proportion of each QL produced as a way to optimize their profit. There is a significant gap in the literature regarding how to solve the challenges faced by SC managers who wish to collect returnables, recover products from returnables, decide the proportion of product quantities at different quality levels and make the recovery process faster, easier and cost effective. Motivated by this finding, this paper proposes an effective and practicable, closed-loop SC design that addresses most of the critical issues of this gap.

The contributions that distinguish this paper from the existing and past research include planning a customer-friendly returnable collection process using retail outlets when collection is a business option for the retailers; providing different quality-level selection options to the market for each product; considering modular product design architecture for a quicker, easier, cost effective recovery process and integrating a network of RSPs to handle product recovery. In addition, this paper takes a total SC view when assigning components to suppliers, producing modules and products for plants, assigning returnables to RSPs for the recovery of modules and allocating DCs to customers for overall profit maximization.

This paper is organized in the following way: Section 2 reviews the relevant literature; Section 3 includes the problem statement, MIP-based closed-loop SC model and model description. Section 4 illustrates an example problem to show applicability of the model and investigates model sensitivity for the change in recovered product demand, and Section 5 concludes.

2. Literature review

Consideration of RL as a significant part of overall business process has been gaining importance across the entire global market. This literature review will study recent, relevant work on the collection of returned items, recovery systems/services, RL-based SC planning and modular product design for ease of recovery.

2.1. Collection of returned items

Schultmann et al. (2006) modeled RL problems for automobile industries, specifically end-of-life vehicles (ELV) in German closed-loop supply chains (CLSCs). Their study used 3 P collection centers and evaluated network design concepts for separating and reprocessing plastic ELV components. Schultmann et al. (2006) recommended establishing a collaborative approach to the recovery network for minimizing cost in which recovery is to be done by the manufacturing companies to fulfill legal requirements. Cruz-Rivera and Ertel (2009) studied the RL problem for ELVs in Mexico using 3P collection centers in an un-capacitated facility location problem approach to determine cost and location centers that effectively consider 100%, 90% and 75% of the entire market collection coverage.

de Figueiredo and Mayerle (2008) proposed an analytical model for designing collection networks where the manufacturer, defined as the recycler, was under the regulation of using a decided percentage of recovered products or components. The model considered incentives paid to the consumer or collection agents for returned items, number of collection centers and the location of the collection centers when designing collection networks for optimal collection costs. In a similar study, Aras and Aksen (2008) proposed a model to determine optimal location distances for establishing collection centers, as well as paying incentives for returning the product. The authors categorized returned products at different quality levels and planned incentives