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Disposition decisions in reverse logistics: Graph theory and matrix approach

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ABSTRACT

Reverse logistics has become an essential part of business because of legislation, environmental concerns, and corporate social responsibility. Reverse logistics activities involve the collection of returned products, inspection and sorting out into different categories, and disposition them for reuse, repair, remanufacturing or recycling. One of the important decisions is to disposition returned products appropriately for the success of reverse logistics. Disposition decision plays an important role in the performance of reverse logistics. Perusal of previous literature indicates that there are very few studies related to disposition of returned products in reverse logistics. This paper attempts to explore the various disposition alternatives and develop an approach for the selection of best disposition alternative using graph theory and matrix approach. A case of mobile manufacturing firm is discussed for the illustration of this approach. The firm has to select best disposition alternative among four identified alternatives such as returned products for repair or reuse and resell as new; or repair or refurbish and resell; or remanufacture and sell; or recycle. Different disposition attributes are identified based on literature review and experts opinion. Graph theory and matrix approach has been applied to select the best alternative. Permanent function value, referred as "Disposition Index" was evaluated for each alternative with the help of C++ program and alternatives were prioritized based on these values. The results show that firm must repair or reuse and resell the returned mobile phones as new in present business scenario in India. In addition, recycling must be preferred over remanufacturing of returned mobile phones. The study prioritized alternatives for disposition of returned products in reverse logistics appropriately. The findings of the study will provide useful insight to the supply chain managers and researchers for disposition decision-making in reverse logistics.

1. Introduction

In last few years, firms are offering more consumer friendly and relaxed consumer return policies because of business competitiveness and advent of e-commerce business. Managing product returns in supply chain is becoming more important for the success of business with the increased volume of returned products (Guide et al., 2006). Product returns may be commercial returns, service returns, distribution returns or end of life returns. The customer may return the products because of many known or unknown reasons including defects, damage, or customer dissatisfaction (Barsky and Ellinger, 2001). Products are also returned because of liberal returns policies and allowances offered by the firms as a part of business strategy for better customer satisfaction (Reda, 1998). Some firms are also forced to deal with product returns because of environmental regulations in many countries requiring remanufacturing or recycling of used products (Guide and Van Wassenhove, 2002). According to Govindan and Popiuc (2014), these returns can generate new profits in business. However, very few firms realized higher margins on remanufactured products in comparison to the new products (Stock et al., 2002). Still, product returns are eminent in a competitive business environment, and firms need to manage them efficiently. One of the ways of dealing with these product returns is to adopt and implement reverse logistics programs. Reverse logistics can manage both bad and good product returns effectively and it can make significant contributions to the sustainability efforts of an organization (Narayana et al., 2014).

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Reverse logistics activities involve all functions that start with the collection of returned products through their acquisition and end with the extraction of all possible value from those products. The customer, returning the products may expect a credit or replacement as quickly as possible while reverse logistics may be more interested in disposition of these returned products to recapture the maximum value (Hall et al., 2013). Therefore, it is important to disposition products effectively for maximum recapturing value along with customer satisfaction. According to Attia (2015), returned product disposition strategies are positively correlated with the reverse logistics performance and hence, with the performance of an organization. For disposition of returned products, various disposition alternatives are available to the manufacturers. The disposition alternatives include simply reusing the product, or repair or remanufacture or recycle the products or properly dispose them (Thierry et al., 1995; Blackburn et al., 2004; Carter and Ellram, 1998; Krikke et al., 2003). Disposition alternatives are often industry or product-specific and depend upon characteristics of the product such as price/value, transportation cost, shelf life of the product, and market demand patterns (Skinner et al., 2008). Recently, in a literature review, Agrawal et al. (2015) observed that there are very few studies focusing on the disposition decisions in reverse logistics. It is also evident from the recent comprehensive review of reverse logistics articles by Govindan et al. (2015). The objective of the proposed study is to develop an approach for the selection of best disposition alternative. Since, Graph Theory and Matrix Approach (GTMA) maintain the hierarchical structure and at the same time utilize interdependencies among attributes; this approach is well suited for the proposed study. A case of mobile manufacturing firm is discussed for the illustration of the approach. The disposition attributes were identified based on past literature review and discussion with the experts, and "Disposition Index" was determined for the various disposition alternatives. "Disposition Index" is the value of permanent function obtained through GTMA in such a way that higher the disposition index, better is the disposition alternative. The disposition index values of various disposition alternatives were compared and best disposition alternative was selected.

The remainder of the paper is organized as follows: Section 2 consists of literature review of reverse logistics, disposition alternatives, and previous approaches utilized for the selection of best disposition alternative. In section 3, GTMA along with development of step by step approach are discussed for the determination of disposition index. Subsequently, the proposed approach is validated through a case illustration of a mobile manufacturing firm in section 4, and results are discussed in this section. Finally, section 5 summarizes all the findings and concludes the study along with future scope of research.

2. Literature review

According to Rogers and Tibben-Lembke (1999), reverse logistics is defined "*as the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal*". Srivastava (2008) clarified reverse logistics as the process of planning, implementing and controlling the efficient, effective inbound flow, inspection, and disposition of returned products and related information for recovering value. Products after acquisition are supposed to be collected and delivered to the facilities for inspection, sorting, and disposition. Rogers and Tibben-Lembke (1999) observed that the customer may return the products because of many known or unknown reasons and the condition of returned products may differ greatly. Therefore, a separate inspection of each item is required for sorting the products. Its overall appearance and state of the constituting elements need to be evaluated. Products and components are sorted into the different categories based on such evaluations (De Brito and Dekker, 2002). Once products are sorted out into different categories, diagnostic tests are performed to determine that what action may recover the most possible value from the returned products, and products are disposition accordingly. Khor and Udin (2012) examined the impact of disposition decision on the economic and environmental performance of the organizations. They collected the data through survey of electronics industry in Malaysia and found that disposition decisions significantly influence the performances of the organizations. Thierry et al. (1995) illustrated three disposition alternatives as product reuse, product recovery, and waste management. Krikke et al. (2003), and Tibben-Lembke and Rogers (2002) further modified these alternatives as reuse, product upgrade, material recovery and waste management. Norek (2003) stated that firms mostly have five recovery alternatives including sell as new; repair or repackage and resell as new; repair or repackage and resell as used; resell at a lower value to a salvage house; and sell by the weight to a salvage house. Previous studies discussed about number of alternatives available for the disposition of returned products. Each study emphasized slightly different alternatives and definitions of disposition. Five common disposition alternatives, which are frequently discussed in the past literature are direct reuse; repair; remanufacture; recycle; and disposal (Fleischmann et al., 1997; Thierry et al., 1995; De Brtio and Dekker, 2002; Hazen, 2011; Agrawal et al., 2014; Govindan and Soleimani, 2016). These disposition alternatives are explained as follows.

(i) Reuse

When a customer returns the new product as it is, product is reinserted back into the supply chain. Reuse of returned product requires only minor inspection, cleaning and minor maintenance; and products are generally returned back to the forward logistics chain for redistribution (Fleischmann et al., 2000). This process includes unused product, packaging, bottling etc. If product requires any upgrade then it may go for other alternatives.

(ii) Repairing

If a product cannot be directly reused then the next alternative is repairing. It is concerned with repairing and servicing of products and retuning those products to the customers (Krikke et al., 2004).

(iii) Remanufacturing

It is generally concerned with product/module/component recovery from high value products (Blackburn et al., 2004). In most of the cases, the manufacturers carry out remanufacturing because they know the product better. Uncertainty in terms of quality, quantity and timing of product returns are important factor for the success of remanufacturing (Rogers and Tibben-Lembke, 1999).

(iv) Recycling

It is generally concerned with the material recovery from rather low value product/module/component (Blackburn et al., 2004). If a product, module or component cannot be reused in any form then there is alternative of extracting material through recycling and use of it as raw material. In many cases, investment cost is high due to requirement of advanced technological equipment for recycling. Low recovery value and high investments require higher processing