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Reverse logistics network design and planning utilizing conditional value at risk

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ABSTRACT

Nowadays, due to some social, legal, and economical reasons, dealing with reverse supply chain is an unavoidable issue in many industries. Besides, regarding real-world volatile parameters, lead us to use stochastic optimization techniques. In location–allocation type of problems (such as the presented design and planning one), two-stage stochastic optimization techniques are the most appropriate and popular approaches. Nevertheless, traditional two-stage stochastic programming is risk neutral, which considers the expectation of random variables in its objective function. In this paper, a risk-averse two-stage stochastic programming approach is considered in order to design and planning a reverse supply chain network. We specify the conditional value at risk (CVaR) as a risk evaluator, which is a linear, convex, and mathematically well-behaved type of risk measure. We first consider return amounts and prices of second products as two stochastic parameters. Then, the optimum point is achieved in a two-stage stochastic structure regarding a mean-risk (mean-CVaR) objective function. Appropriate numerical examples are designed, and solved in order to compare the classical versus the proposed approach. We comprehensively discuss about the effectiveness of incorporating a risk measure in a two-stage stochastic model. The results prove the capabilities and acceptability of the developed risk-averse approach and the affects of risk parameters in the model behavior.

1. Introduction

In a reverse supply chain network, used products (called return products) are collected from customers and they are tried to be reused. Fleischmann (2001) defines the Reverse Logistic (RL) in a generic form: "reverse logistics is the process of planning, implementing, and controlling the efficient, effective inbound flow and storage of secondary goods and related information opposite to the traditional supply chain direction for the purpose of recovering value and proper disposal". Dealing with End of Life (EOL) products, there are various alternative decisions, which can be undertaken such as recycling options, remanufacturing by manufacturers (in order to send to the second markets), repairing by collection or disassembly centers (in order to forward to second markets), and finally green disposing options.

Nowadays, we can mention many reasons those actuates manufacturers toward focusing on reverse supply chain issues but the most prominent reasons are the growing concern for the environment and cost reduction (Govindan & Popiuc, 2014; Kannan, Noorul Haq, & Devika, 2009). Recently, Srivastava (2008) presents an illustration of a simple reverse logistics network, which contains various processes of reverse flows (see Fig. 1). In this Figure, EOL products are collected from consumers and, after some quality tests, appropriate decisions are undertaken. Based on the quality of return products, series of minor (repair, refurbish, disassembly, and service) or major processes (remanufacturing and recycling) are the available alternatives. The remaining products should be environmental-friendly disposed.

Generally, dealing with any type of supply chain network, we have three main decision levels: Long-term (called design or configuration or generally named location), mid-term (named planning or allocation), and short-term (called operational) (Chopra & Meindl, 2010). In this paper, the design and planning decision levels of a multi-product reverse supply chain problem is considered. In the designing stage, strategic decisions on locations of all facilities are undertaken. In the planning level, we should determine a very important part of supply chain network: Quantity of flows between all reverse supply chain network entities. Besides, since design and planning levels are long and mid-term decisions so the related decisions are not simply compensable (clearly it is costly) in comparison with short-term decision levels (Chopra &

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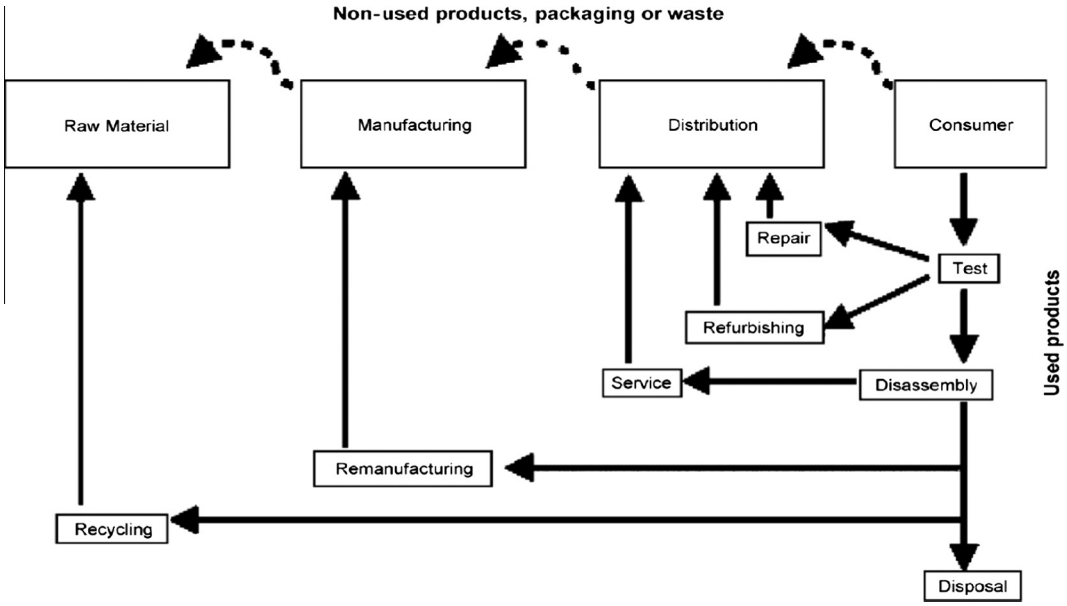

Fig. 1. A basic flow diagram of reverse logistics activities (Srivastava, 2008).

Meindl, 2010). Therefore, these important levels are chosen to be studies in this paper. Finally, in this paper a multi-echelon, multi-product reverse network including various possible flows between network entities is developed, formulated, and evaluated. Then, nondeterministic parameters (demand of return products and their prices) are considered in the network design problem and a new approach to deal with such uncertainties is developed.

There are various sources of uncertainties in a reverse supply chain such as quality, price, time, and amounts of return products, which are not exist in a classical form of supply chain (forward). Therefore, in the designing and planning procedure of a reverse supply chain, availability of sufficient information about parameters is the main issue. In volatile markets, considering nondeterministic parameters is unavoidable. In this paper, the network design problem with stochastic return and price is regarded. On the other side, for location–allocation problems, two-stage stochastic programming is a powerful technique. Consequently, two-stage stochastic approaches have been applied in wide range of applications (Birge & Louveaux, 1997). In the field of reverse supply chain design and planning problem, there are few two-stage stochastic programming researches. To the best of our knowledge, all of them are risk neutral in a way that they consider just expectation criterion in their two-stage objective function. For non-repetitive decision making problems under uncertainty (such as this paper), a risk-averse approach that considers the effects of the variability of random outcomes, such as the random total cost, would provide more robust solutions compared to a risk-neutral approach (Noyan, 2012).

Most earlier researches have tried to cope with the real volatile markets by regarding some stochastic parameters in one or two-stage stochastic structure (Noyan, 2012). However, all of these researches in reverse logistics have just considered expected cost or expected profit as the objective function. Therefore, they are all risk-neutral. In these studies, there is not any kind of risk parameters to cope with real volatile markets. These risk-neutral approaches are inefficient in non-repetitive decision making problems such as design and planning a reverse network (generally in location allocation problems). The studies of Ruszczynski and Shapiro (2006) and Ahmed (2006), are two popular papers dealing with risk-averse approaches. They stipulate on inefficiencies of risk-neutral approaches when just expectation is considered in the objective function. Consequently, in order to cope with real volatile markets in such problems, regarding risk criteria will lead us to solutions that are more robust. On the other hand, based on excellent background of risk measures in financial engineering, they can be utilized as risk criteria in two-stage stochastic problems. We attempt to develop the mentioned approach in the reverse supply chain and to cover this gap for reverse logistics.

In this paper, Conditional Value at Risk (CVaR) as one of the effective and well-behaved risk measures is incorporated into the objective function of the proposed two-stage stochastic framework. To the best of our knowledge, it is the first research that tries to consider a risk-measure in reverse supply chain network design and planning through a two-stage stochastic programming framework. As discussed, this extension is completely necessary in the current volatile markets specially for location–allocation problems. Indeed, in a reverse supply chain, missing of such risk-based approaches are observed and we try to cover this gap through a multi-product network.

The rest of this paper is arranged as follows: In Section 2, a complete literature review is presented. Discussing about risk-measures especially conditional value at risk and the framework of two-stage stochastic programming is illustrated in Section 3. The model characteristics and formulation is demonstrated in Section 4. A comprehensive computational analysis is undertaken in Section 5. Finally, Section 6 is assigned to conclusion and future research.

2. Literature review

The main two fundamental papers in reverse logistics are Beamon (1999) and Fleischmann, Krikke, Dekker, and Flapper (2000). Beamon studies the environmental factors toward implementing a reverse logistic and a CLSC. She offers a conceptual framework for classical supply chain, reverse logistics, and closed loop supply chain in a green structure. Popular paper of Fleischmann deals with logistic networks' characteristics in order to consist with reverse supply chain. Since then, many papers have researched on different aspects of design, planning, and utilizing reverse supply chain. Here, we consider stochastic researches specially two-stage cases.

Although we can mention some excellent two-stage stochastic optimization papers in design and planning forward supply chain such as Chen, Daskin, Shen, and Uryasev (2006), Guillén, Mele, Espuña, and Puigjaner (2006), Schütz, Tomasgard, and Ahmed