Transportation Research Part E 105 (2017) 1–17

Contents lists available at ScienceDirect

Transportation Research Part E

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

A two-stage stochastic programming approach for value-based closed-loop supply chain network design

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ARTICLE INFO

Article history:
Received 24 February 2017
Received in revised form 26 May 2017
Accepted 26 June 2017

Keywords:
Closed-loop supply chain network design
Value-based management
Two-stage stochastic programming

ABSTRACT

The ultimate goal for almost all companies in the current business world is to increase their value; therefore, managers concentrate their efforts on the control of value drivers. This research develops a two-stage stochastic programming model for the value-based supply chain network design, where all parts of a supply chain are configured and controlled in such a way that the total value of the company increases. The proposed model is a three-echelon, multi-commodity, and multi-period model for the tactical and strategic decision making. Also, a comprehensive computational analysis is conducted to evaluate the performance of the proposed approach.

1. Introduction

Decisions in the Supply Chain Management (SCM) are categorized in three levels as operational, tactical, and strategic (Simchi-Levi et al., 1999). Operational decision making addresses problems with short term impacts on the performance of a supply chain, such as scheduling (Talebi et al., 2009; Moon et al., 2002; Fazlollahtabar and Olya, 2013), routing (Asgari et al., 2016; Olya and Fazlollahtabar, 2014; Olya, 2014; Olya et al., 2013), and pricing (Christopher and Gattorna, 2005; Vidal and Goetschalckx, 2001; Shen et al., 2016). Tactical decisions have a medium term effect on the performance of a supply chain. Inventory management (Lee and Billington, 1992; Cachon and Fisher, 2000; Waller et al., 1999) and distribution planning (Olya, 2014; Bashiri et al., 2009; Olya et al., 2013) are classified in the tactical level. Decisions with a long term effect are called strategic decisions; one of the most important strategic decisions is the Supply Chain Network Design (SCND) which has been studied from different aspects (Santoso et al., 2005; Bashiri et al., 2012; Pishvaee et al., 2011; Khatami et al., 2015; Badri et al., 2013; Badri et al., 2016; Farahani et al., 2014; Rezapour et al., 2015; Bashiri and Badri, 2010; Asgari et al., 2015). SCND is the configuration of the supply chain network in which locations and capacities of facilities are determined. There are two possible logistics in a supply chain: 1- forward logistics, which involves all operations on raw materials, semi-products, and finished products starting from suppliers and ending to final consumers, and 2-reverse logistics, which involves all operations on cores starting from final consumers and ending to remanufacturing/recycling facilities. When both types of logistics (i.e. forward and reverse) are studied in an integrated approach, it is called Closed-Loop Supply Chain (CLSC) management. In recent years, an increasing attention has been given to CLSC, for the environmental, economic, and social importance of the reverse logistics (Govindan et al., 2015).

Based on a new definition, closed-Loop Supply Chain management is defined as the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types

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http://dx.doi.org/10.1016/j.tre.2017.06.012
1366-5545/

and volumes of returns overtime (Govindan et al., 2015; Daniel et al., 2009). According to this definition of CLSC, value creation is introduced as the ultimate goal in the design and planning of a CLSC.

Different firms may have different objectives for the network design, but the ultimate objective for all companies is to increase their value. This is why the concept of Value-based Management (VbM) has been applied in the supply chain management during the last decade (Brandenburg, 2013; Wang et al., 2003; Christopher and Ryals, 1999; Hahn and Kuhn, 2012; Shapiro, 2006; Schenkel et al., 2015). This field is known as Value-based Supply Chain Management (VbSCM). In this approach, the value of a firm is calculated by its ability to create future cash flows which in turn are driven by profitability, capital efficiency and cost of capital (Damodaran, 2010; Damodaran, 2011; Seuring et al., 2005). From this point of view, supply chain management aims at increasing value of the company by controlling four financial drivers, i.e. sales, cost, working capital and fixed assets (Brandenburg, 2013; Rappaport, 1998).

In this study, a Mixed-Integer Linear Programming (MILP) model is developed for the value-based closed-loop supply chain network design. The proposed model, is a three-echelons, multi-period, and multi-product model whose objective is to increase the value of a company in a given planning horizon. To measure the value, Economic Value-Added (EVA) concept is used. The main outputs of the developed model include location of the re-manufacturing facilities (strategic level), production, distribution, and inventory planning (tactical level). Also, from financial point of view, debt management is the most important output of the developed model. In our proposed approach, sales growth, supply chain costs, fixed assets, and working capital are considered as the main value drivers.

Remaining parts of this paper are organized as follows. In the next section, a comprehensive literature review on the closed-loop supply chain network design problem, as well as the value-based supply chain network design is presented and the position of this study in the current literature is highlighted. Section 3 is devoted to problem definition in which the proposed mathematical model is described. In Section 4, the proposed solution is described, and a computational study is presented to illustrate the performance of the proposed model. Finally, conclusions and directions for future studies are given in Section 5.

2. Literature review

In this section an extensive literature review is conducted to highlight the position of this study in the current literature. Since the main idea of the current research is to apply the value-based concept in the CLSC network design, we review the studies in two fields: closed-loop supply chain network design, and value-based supply chain management.

2.1. Closed-loop supply chain network design

In recent years, many studies have been made on closed-loop supply chain planning, due to the environmental and economic importance of reverse logistics. Network design is considered as a strategic problem and one of the most critical decisions in CLSC, because of the long term effects on the performance of the supply chain. Therefore, integration of the design and planning decisions in closed-loop supply chains is of high importance. One of the first integrated models in reverse and CLSC networks was developed by Fleischmann et al. (1997). This study considered distribution planning, inventory control, and production planning in reverse and CLSC networks. Jayaraman et al. (1999) proposed a mixed integer programming model for the location of re-manufacturing and distribution facilities, transshipment, production, and inventory. The proposed model in this paper is a single period, multiple products model whose objective function is to minimize the total cost including location, production, transportation, and the inventory costs. Fleischmann et al. (2001) considered CLSC in photocopier re-manufacturing and paper recycling. The results of this case study show that there is a potential for cost savings if one adopts an integrated approach rather than a sequential design of forward and reverse distribution networks.

Min et al. (2006) developed a mixed integer nonlinear programming model for a CLSC network design considering both spatial and temporal consolidation of returned products. The authors also developed a solution method based on the genetic algorithm to solve the proposed model. A new model for CLSC network design was proposed by Yang et al. (2009) considering suppliers, manufacturers, retailers, customers and recovery centers. In this study, different partners have conflicting aims; and to tackle the problem, they used the theory of variational inequalities. Wang and Hsu (2010) developed an integer linear programming model for the operations of 3R (Reduce, Recovery and Reuse) in green supply chain management. To solve the developed model, a solution approach based on the genetic algorithm and spanning trees was proposed. Kannan et al. (2010) proposed a multi-period, multi-product CLSC network design model, taking procurement, production, distribution, recycling, and disposal into consideration. Qiang et al. (2013) considered a CLSC network involving suppliers, retailers, and the manufacturers that collect the recycled product directly from the demand market.

Amin and Zhang (2013) developed a mixed-integer linear programming model for a CLSC network which includes multiple plants, collection centers, demand markets, and products, in which the objective is to minimize the total cost of the network. Özceylan et al. (2014) proposed a nonlinear mixed integer programming model which jointly optimizes the strategic and tactical decisions of a CLSC. In this study, decisions regarding the amounts of goods flowing on the forward and reverse chains are considered as the strategic level decisions; and decisions on balancing dis-assembly lines in the reverse chain are considered in the tactical level. The objective of the proposed model is to minimize costs of transportation, purchasing, refurbishing, and operating the dis-assembly workstations. Kannan et al. (2014) developed a multi-objective mixed