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A serial inventory system with supplier selection and order quantity allocation considering transportation costs

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ABSTRACT

Given the importance of incorporating transportation costs in inventory replenishment and supplier selection decisions, this article addresses the issue of supplier selection and order quantity allocation in a multi-stage serial supply chain system with multiple suppliers considering inventory replenishment, holding, and transportation costs simultaneously. We propose a mixed integer nonlinear programming model to determine the optimal inventory policy for the stages in the supply chain and allocation of orders among the suppliers at the initial stage. Transportation costs between consecutive stages are modeled using a piecewise constant setup cost structure arising from a full truckload freight rate cost model. Vehicles of different capacities are available to transport materials from the suppliers to the manufacturing facility and between the remaining stages of the supply chain. The usefulness of the model is discussed with an example. Sensitivity analysis is carried out to determine the effect of cost parameters on supplier order allocation. The analysis shows that the selection of suppliers and the corresponding order quantities are affected by the variations in supply chain costs parameters. In addition, the advantages of using an integrated approach versus a sequential approach for inventory replenishment and supplier selection decisions are shown. Computational results show that the integrated approach yields average savings of 4.88% in total cost and 15.31% in logistics costs over the sequential approach.

1. Introduction

In today's competitive environment, companies are forced to optimize business processes and improve the performance of their entire supply chains. Successful performance of a supply chain depends on every single organization involved, and an efficient and flexible supply chain enables the firm to select the right suppliers at the right time for the right materials, not only significantly reducing purchasing cost, but also greatly improving corporate competitiveness [1]. Among the various drivers in a supply chain, ***sourcing, inventory, and transportation*** are recognized as the major ones [2]. In the first place, partnering with the right suppliers has been increasingly recognized as a strategic and crucial component of supply chain management [3]. Selecting the right suppliers can impact the overall purchasing cost (the cost of raw materials and component parts), which accounts for a large percentage of the final product cost. According to Burton [4], the cost of components

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and parts purchased from suppliers may total more than 50 percent of sales for large automotive manufacturers, and purchased material and services represent up to 80 percent of the final total product cost for high technology organizations. Heberling [5] points out that over 80 percent of the purchases in the manufacturing sector are for materials and supplies. Hence, it is essential for organizations to keep supplier-related costs to a minimum. According to Weber and Current [6], the objective of ***supplier*** selection is to identify suppliers with the highest potential for meeting demand needs. This implies not only to choose the best suppliers to do business with but also to determine the exact quantities for each order placed with a selected supplier.

In the second place, since manufacturing processes are not instantaneous and to keep up with unpredictability in businesses, ***inventory*** has traditionally been viewed as a necessity to meet customers' demand. Higher levels of inventory result in increased responsiveness of the supply chain, but decrease the cost efficiency because of the cost associated with holding inventory. Therefore, inventory management is one of the important aspects of supply chain management because the cost of inventory can represent anywhere between 20% and 40% of the total value of the product [7].

In the third place, when computing the order quantity of a product, the ***transportation*** cost is also an important aspect to be considered. However, many inventory management models in the literature assume that the transportation cost is included in the purchasing cost of the product [8]. Considering transportation costs in determining order quantities becomes imperative to improve the efficiency of the supply chain. Blumenfeld et al. [9] discussed the need for analyzing the trade-offs between inventory and transportation costs. Their model focuses on minimizing the total inventory and routing cost by simultaneously determining optimal routes and shipment sizes of vehicles.

Research on supply chain optimization has mainly focused on two problems: (1) the manufacturer has to determine its optimal production, distribution and inventory policies considering its capacity, setup costs, distribution costs and operating costs, and deliver the final products to customers; and (2) the manufacturer has to determine the suppliers/vendors from which to purchase raw materials as well as the corresponding order quantities (supplier selection). Solving these two problems separately (in sequence) may yield to sub-optimal solutions for the entire supply chain. Therefore, this article considers an integrated approach consisting of a multi-stage serial supply chain system that simultaneously addresses the problems of supplier selection and inventory replenishment considering purchasing, setup, holding, and transportation costs. We propose a mixed integer nonlinear program (MINLP) for the integrated inventory planning and supplier selection problem. The advantages of optimizing the supply chain considering inventory and transportation costs simultaneously are illustrated using a numerical example. Sensitivity analysis is carried out to determine the effect of cost parameters on supplier order allocation. The analysis shows that the supplier selection and the corresponding order quantities are affected with changes in the supply chain cost parameters. Moreover, the proposed integrated approach is compared with the sequential approach, where the inventory planning and supplier selection problems are solved sequentially. The results from the analysis show that the integrated approach yields significant savings in terms of logistics and overall supply chain costs.

The remainder of this article is organized as follows. Section 2 provides a review of the literature. In Section 3, a discussion on full truckload (TL) freight rates is presented. The vehicle selection problem in the supply chain is formulated as a minimization version of the knapsack (KS) problem. In Section 4, we provide a detailed statement of the integrated inventory planning and supplier selection problem for a serial supply chain, and propose a new MINLP model for the problem. In Section 5, we present an example to illustrate the proposed mathematical model. Sensitivity analysis is performed in Section 6 to show the effect of the echelon holding cost, setup cost at the stages, and transportation cost between consecutive stages. Section 7 compares the proposed integrated approach to the sequential approach, where the problem is solved in two stages. We also provide conditions under which the integrated approach gives better results than the sequential approach. Section 8 presents some conclusions on the work and future research directions.

2. Literature review

The supplier selection problem has been widely addressed by many researchers. Various decision models and solutions have been proposed over time. Weber et al. [10] presented a detailed review of different decision techniques and criteria used for supplier selection provided in 74 articles that appeared in the literature since 1966. Degraeve et al. [11] adopted the concept of Total Cost of Ownership (TCO) as a basis for comparing supplier selection models. The TCO approach basically considers all relevant costs involved in the purchasing process of a good or service from a particular supplier. De Boer et al. [12] studied the supplier selection literature in a more comprehensive manner. They proposed a framework that includes four main steps in the supplier selection process: problem definition, formulation of selection criteria, pre-qualification (preliminary screening), and final selection. Ho et al. [13] surveyed 78 journal articles from 2000 to 2008 related to multi-criteria decision making approaches for supplier evaluation and selection. Most recently, Chai et al. [14] provided a systematic literature review on articles published from 2008 to 2012 on the application of decision-making techniques for supplier selection.

Some of the approaches summarized in these reviews are based on mathematical models that integrate the selection of suppliers and calculation of order quantities for the selected suppliers using linear programming (LP), mixed integer programming (MIP), and multi-objective programming. Some of the papers that used LP models are summarized below. Anthony and Buffa [15] developed a strategic level single objective LP model to minimize the total purchasing cost considering limitations on purchasing budget, supplier capacity, and buyer's demand. Ghodsypour and O'Brien [16] used analytical hierarchy process (AHP) and LP to determine the best order quantity allocation while considering qualitative and