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Joint decision of procurement lot-size, supplier selection, and carrier selection

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ABSTRACT

The joint decision making of procurement lot-size, supplier selection, and carrier selection has potential to reduce buyer's purchasing expenditures. Furthermore, the total logistics cost can also come down through economies of scale in the purchasing and transportation costs, and reduction in supply chain disruptions such as rejections and late deliveries. We study a procurement setting in which a buyer needs to purchase a single product from a set of suppliers over finite discrete time periods to satisfy service level requirements. The suppliers offer all-unit quantity discounts, and transportation cost depends on carrier capacity as well as geographical location of suppliers. This paper proposes an integer linear programming model to simultaneously determine the timings of procurement, lot-sizes, suppliers and carriers to be chosen so as to incur the least total cost over the planning horizon. A numerical example is included to demonstrate the effectiveness of the proposed model in establishing tradeoffs among purchasing cost, transaction cost, and inventory holding cost. Sensitivity analysis has been carried out to understand the effects of the model parameters on the purchasing decisions and total cost. Managerial insights of this study serve as a reference for decision makers to develop effective procurement strategies.

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1. Introduction

In today's competitive market, the products are to be procured and managed in the most effective manner to minimize costs while satisfying service level requirements. The purchasing strategies of a firm have potential to reduce purchasing and transaction costs and inventories by integrating various internal activities of purchasing process. The purchasing department is completely responsible for supplier selection process, procurement decision process, and sourcing evaluation (Aissaoui et al., 2007). In the supplier selection process, a pool of suppliers is chosen for procurement according to a predefined set of criteria. Based on current academic literature, Ho et al. (2010) have reviewed 78 related articles appeared in the period from 2000 to 2008. They noted that quality is the most popular criterion (68 papers or 87.18%) in the supplier selection process. The second most popular criterion is delivery (64 papers or 82.05%). The price/cost is the third most popular criterion (63 papers or 80.77%). Further, they observed that there was a trend in the supplier evaluation and selection problem to use the multi-criteria decision making approaches from the first five years (2000–2004) to the recent four years (2005–2008). The procurement decision process is concerned with the problem of lot-sizing and other inventory related issues. Finally, in the sourcing evaluation process, overall efficiency and effectiveness of procurement process is assessed.

In multi-period horizon, products could be purchased from one or more suppliers in each period. Alternately, excessive products could be carried forward to a future period. Sometimes shortages with backlogging may also be allowed to take advantage of economies of scale in purchasing cost and transaction cost (i.e., ordering cost plus transportation cost) by procuring a few large size lots when suppliers offer discounts for large order quantities. In practice, large quantity of freight or long distance of shipment may reduce per unit transportation cost (Shinn et al., 1996). Considerations like economies of scale concept may be advantageous to incur the least total cost over the decision horizon by optimizing the cost of ordering and transportation as well as purchasing cost when suppliers offer discounts. Indeed, the frequent procurement of small size lots reduces inventory holding cost but increases purchasing and transaction costs. The buyer can reduce purchasing and transaction costs by procuring a few large size lots, less frequently, but this may lead to higher inventory cost or shortage cost.

The supplier selection and lot-sizing are two important decisions any purchasing department has to make. In the literature, supplier selection is considered as a strategic decision while lot-sizing is considered as a tactical decision. With regard to supplier

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selection, the buyer needs to consider the objectives such as cost minimization, and quality and service level maximization. With regard to lot-sizing problem, the buyer needs to consider inventory cost and shortage cost minimization. However, due to the inherent interdependency between these two decisions, a purchasing department cannot optimize them separately (Aissaoui et al., 2007; Rezaei and Davoodi, 2011). Further, a few studies have reported that a firm can benefit by integrating purchasing quantities and inbound transportation decisions (Russell and Krajewski, 1991; Swenseth and Godfrey, 2002; Mansini et al., 2012). The buyer can select an appropriate size carrier or negotiate the discounts rates with third party logistics providers (3PL) to reduce the inbound transportation cost. Hence, incorporating the decision to schedule orders over time with the supplier selection and appropriate transportation carrier selection may significantly reduce total cost over the planning horizon. In spite of many advantages, the models that have been proposed in the literature on inventory lot-sizing with supplier selection, have not sufficiently considered economies of scale in the purchasing and transportation costs. Nowadays, disruptions have become more common in supply chains, which lead to supply chain risks (Giannakis and Louis, 2011). Supply chain disruptions such as rejections and late deliveries also affect the procurement decisions (Choudhary and Shankar, 2011). If buyer includes quality and delivery related performance aspects in purchasing decisions then suppliers may be motivated to increase their performance on these criteria in subsequent periods.

Above observations have been used to develop an integrated model for inventory lot-sizing, supplier selection, and carrier selection problems. We investigate a problem in which a single product is procured from multiple suppliers, in multiple periods, considering economies of scale concepts in purchasing and transaction costs, and supply chain disruptions such as rejections and late deliveries. Since, logistics cost plays a key role in inventory lot-sizing, supplier and carrier selection, it is necessary to incorporate economies of scale in purchasing and transportation costs. We consider all-unit quantity discount structure for purchasing cost, and carrier size as well as geographical location dependent discount structure for transportation cost at full truck loads (FTL) capacity. We consider all realistic constraints in purchasing and inventory management such as buyer's demand, service level requirement and storage capacity, and suppliers' production capacity, discounts, rejections and late deliveries. The proposed model permits time dependent variations in problem parameters such as suppliers' quality and delivery performance, price, production capacity, and buyer's ordering cost, inventory holding cost, transportation cost, storage capacity, service level, etc. The intent of this model is to determine the right timings of procurement, appropriate lot-sizes and its supplier(s), and carrier(s) for transportation of the items.

The paper is further organized as follows: Section 2 presents a brief literature review of the existing relevant quantitative approaches related to multi-period procurement lot-sizing with supplier selection problem. In Section 3, an integer linear programming formulation is proposed for joint decision making of procurement lot-sizing, supplier selection, and carrier selection problem considering all-unit quantity discounts, transportation discounts, and supply chain disruptions. Section 4 presents a numerical example with solution to demonstrate the effectiveness of the proposed approach. Managerial implications of proposed approach are discussed in Section 5. Finally, conclusions, limitations, and directions for future research are provided in Section 6.

2. Literature review

Supplier selection problem is an important strategic decision that a buyer has to make. It has attracted considerable attention of researchers, who have looked at it from several angles. Ghodsypour and O'Brien (2001) have examined the problem in a multi-criteria framework. A mixed integer non-linear programming model is proposed to determine the optimal allocation of products to suppliers so that the total annual purchasing cost could be minimized. Sucky (2007) proposes a dynamic decision making approach for strategic vendor selection based on the principles of hierarchical planning. This approach considers interdependencies in time arising from investment costs of selecting a new vendor and costs of switching from an existing vendor to a new one.

Due to increasing importance of supply chain management, the recent approach is towards developing models that can simultaneously look at procurement lot-sizing and supplier selection problem. Basnet and Leung (2005) propose a mathematical model for integrated procurement lot-sizing with supplier selection problem. Later, Rezaei and Davoodi (2008) present a mixed integer programming model for multiple suppliers and multiple products over a finite planning horizon. They extend the work of Basnet and Leung (2005) to study the effect of suppliers' capacity and quality related performance. Furthermore, in recent years, a few researchers have proposed multi-period and multi-objective lot-sizing models (Ustun and Demirtas, 2008a, 2008b; Demirtas and Ustun, 2009; Rezaei and Davoodi, 2011, etc.). A review of articles on inventory lot-sizing with supplier selection is summarized in Table 1.

A few studies have considered the combined problem related to the inbound transportation and procurement lot-sizing so as to optimize the total logistic cost over the planning horizon. Liao and Rittscher (2007) study the integration of the supplier selection, the procurement lot-sizing and the carrier selection decisions. They consider dynamic demand situation and propose a multi objective programming model for supplier selection, procurement lot-sizing and carrier selection decisions in each replenishment cycle. The objective aims at minimizing the total logistic cost, the total quality rejected items and the late deliveries. Mansini et al. (2012) present an integer programming model to study a procurement setting in which suppliers offer total quantity discounts and transportation costs are based on truckload shipping rates. The model is used to select a set of suppliers so as to satisfy product demand at minimal total cost. Recently, Choudhary and Shankar (2011) study a multi-period purchasing problem in which a buyer procures a single product from a single supplier considering economies of scale in purchasing and transaction costs along with supply chain disruptions. They propose an integer programming model to establish tradeoffs among cost objectives and determine appropriate lot-size and its timing to minimize total cost over the decision horizon. Their study shows that lot-sizing decisions are influenced by buyer's relative importance of purchasing, transaction, and inventory holding cost objectives. Furthermore, supply chain disruptions can substantially influence the structure of solutions, and affect the buyer's total cost objective. The present study extends the work of Choudhary and Shankar (2011) for multi supplier-single buyer system.

This paper contributes to the existing literature in several ways. It provides a summary of existing quantitative models for multi-period procurement lot-sizing with supplier selection. The available literature considers only minimization of ordering cost, inventory holding cost and purchasing cost. However, it is observed that more than 50% of the total logistics cost of a product is due to transportation. In practice, products flow from supplier to buyer in the form of fixed lot-sizes, such as FTL capacity to achieve economy of scale in transportation cost. Any lot-size less than FTL capacity may mitigate discount savings. In practice, it is observed that per unit transportation cost may

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