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A goal programming model for joint decision making of inventory lot-size, supplier selection and carrier selection

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ABSTRACT

In this paper, we address a problem in which a storage space constrained buyer procures a single product in multiple periods from multiple suppliers. The production capacity constrained suppliers offer all-unit quantity discounts. The late deliveries and rejections are also incorporated in sourcing. In addition, we consider transportation cost explicitly in decision making which may vary because of freight quantity and distance of shipment between the buyer and a supplier. We propose a multi-objective integer linear programming model for joint decision making of inventory lot-sizing, supplier selection and carrier selection problem. In the multi-objective formulation, net rejected items, net costs and net late delivered items are considered as three objectives that have to be minimized simultaneously over the decision horizon. The intent of the model is to determine the timings, lot-size to be procured, and supplier and carrier to be chosen in each replenishment period. We solve the multi-objective optimization problem using three variants of goal programming (GP) approaches: preemptive GP, non-preemptive GP and weighted max–min fuzzy GP. The solution of these models is compared at different service-level requirements using value path approach.

1. Introduction

Firm can accomplish competitiveness by reducing total logistics costs through integration of its various internal activities of purchasing process. The purchasing function of a firm consists of three activities: lot-sizing decision, supplier selection decision, and carrier selection decision. While a lot-sizing decision aims to minimize inventory and shortage costs by optimizing timings and order sizes. The intent of supplier and carrier selection decisions is to minimize inbound logistics costs and to attain a high degree of quality and delivery performance. Due to the inherent interdependency among these three decisions, a firm cannot optimize them separately (Aissaoui, Haouari, & Hassini, 2007; Choudhary & Shankar, 2013).

The value of scheduling orders over the multi-period horizon along with the supplier and carrier selections can be significantly higher than planning over a single period. In practice, suppliers offer price discounts for large order quantities. Per unit transportation cost also reduces with long shipment distances and/or large freight quantity (Russell & Krajewski, 1991; Swenseth & Godfrey, 2002; Mansini, Tocchella, & Savelsbergh, 2012). By considering multi-period horizon, a firm can aggregate orders to take advantage of economies of scale in procurement and transportation costs. In such a situation, however, inventory costs increase as excessive products need to be carried forward to future periods. The firm can sometime allow shortages with backordering to reduce inventory costs and increase order sizes, especially when a few customers are ready to wait.

While purchasing functions need to consider cost minimization objective, yet in doing so one cannot compromise on quality and delivery related criteria. Nowadays, even quality and delivery related objectives are getting higher priority than cost criterion during purchasing decisions (Ho, Xu, & Dey, 2010). Suppliers' performance on quality and delivery criteria has significant influence on the lot-sizing and total logistics costs (Choudhary & Shankar, 2011, 2013).

In this study, we take into account above observations and then develop a multi-objective integer linear programming model for an integrated inventory lot-sizing, supplier selection and carrier selection problem. We investigate a problem in which a single product is procured from multiple suppliers in multiple periods considering suppliers' capacity limitations, rejections and late deliveries. We also incorporate economies of scale concepts in purchasing and shipping costs. The model considers three important goals that

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need to be minimized. The intent of the model is to determine the timings, lot-size to be procured, and supplier and carrier to be chosen in each replenishment period. We solve this model using preemptive GP, non-preemptive GP and weighted max–min fuzzy GP approaches. Furthermore, the sensitivity of the GP methods with respect to each goal is assessed using value path approach.

The paper is further organized as follows. Section 2 presents a brief literature review of the existing quantitative approaches related to supplier selection and lot-sizing problem. In Section 3, a multi-objective integer linear programming formulation is developed for inventory lot-sizing, supplier selection and carrier selection problem. A brief description of three GP methods: preemptive GP, non-preemptive GP and weighted max–min fuzzy GP is also provided in this section. To demonstrate the effectiveness of the proposed approach, Section 4 presents an illustration. Finally, conclusions are drawn in Section 5.

2. Literature review

In the supply chain literature, while lot-sizing is considered as a tactical decision, supplier selection is regarded as a strategic decision. The lot-sizing problem deals with determining order quantity and its timing by striking a tradeoff between ordering and storage costs. A comprehensive classification of the lot-sizing models can be found in Ben-Daya, Darwish, and Ertogral (2008) and Robinson, Narayanan, and Sahin (2009).

The supplier selection problem has been extensively studied by the researchers from several perspectives. Ghodsypour and O'Brien (2001) have studied sourcing problem in a multi-criteria framework. Supplier selection and order allocation problem usually becomes complicated under quantity discount environment. Chaudhry, Forst, and Zydiak (1993) propose a mathematical formulation for supplier selection over a single period with quantity discounts. Tsai and Wang (2010) compare the influence upon the buying decisions considering two schemes of quantity discounts: all-unit discount, and incremental discount. Xu, Lu, and Glover (2000) develop a mathematical model for multi-item dynamic lot-size problem with joint business volume discount. Dahel (2003) proposes a multi-objective mixed integer programming model to determine order allocation of multiple products to multiple supplier considering volume discounts. Ravindran, Bilsel, Wadhwa, and Yang (2010) study supplier selection and order allocation considering incremental price breaks. Kokangul and Susuz (2009) apply an integrated AHP and non-linear integer programming approach considering quantity discounts to determine the best suppliers and optimal order quantities among them. Hassini (2008) studies a lot-sizing and supplier selection problem when supplier capacity reservation and price discounts are both dependent on lead time. Burke, Carrillo, and Vakharia (2008) analyse the impact of linear discounts, incremental unit discounts, and all-unit discounts as well as capacity limitations on the optimal sourcing policy for a single period. Ebrahim, Razmi, and Haleh (2009) formulate a multi-objective mathematical model for a purchasing problem which considers different types of discount schemes such as all-unit discount, incremental discount, and total business volume discount.

In the last decade, several researchers propose models that can simultaneously deal with lot-sizing and supplier selection decisions (Basnet & Leung, 2005; Demirtas & Ustun, 2009; Rezaei & Davoodi, 2008, 2011; Ustun & Demirtas, 2008a,b). A comprehensive discussion of these studies can be found in Choudhary and Shankar (2013). Liao and Rittscher (2007) propose a multi objective programming model for supplier selection, procurement lot-sizing and carrier selection decisions. Jolai, Yazdian, Shahanaghi, and Khojasteh (2011) proposed a two-phase approach for supplier selection and order allocation problem under fuzzy environment for multiple products from multiple suppliers in multiple periods. Razmi and Maghool (2010) propose a fuzzy bi-objective model for multiple items, multiple period, supplier selection and purchasing problem under capacity constraint and budget limitation.

The literature review confirms that integrated lot-sizing and supplier selection problem has been studied sufficiently. But, in practice, it is observed that almost half of the total logistics cost of a product is due to transportation. Moreover, per unit transportation cost decreases for large quantity of cargo and/or long distance of shipment. Suppliers' performance on delivery and rejection criteria has a significant influence on lot-sizing and total logistics costs. For example, in order to meet service-level requirement, a firm has to order larger quantity due to presence of defective and late delivery. Also, per unit purchasing and transportation costs increase when defective items in a procured lot go up. In other words, while higher rejection rate of the supplier eats up the savings obtained through economies of scale in purchasing and shipment costs, late deliveries result in increasing transportation costs and stock-outs. These realistic aspects of a purchasing process have not been adequately addressed so far in the literature. Our study aims to incorporate these aspects of a purchasing process by integrating lot-sizing, supplier and carrier selection decisions so as to minimize total logistics costs while attaining desired levels of quality and delivery performances.

3. Model development

Consider Fig. 1 where a buyer procures a product from multiple suppliers. Buyer's demand of the product in each period is deterministic and known in advance. Each supplier has limited production capacity and a different unit price of the product. In addition, each supplier offers all-unit quantity discounts to motivate the buyer for procuring large quantity. Products could be shipped by using different size carriers. A particular size carrier can ship any lot-size up to its full truck load (FTL) capacity. The transportation cost will be different for different carriers as well as for different suppliers because of carrier size and geographical distance of the buyer's premises from sourcing locations. Over finite discrete time periods, shortages are allowed and backlog is permitted when available inventory plus procured lot-size for a period is less than buyer's demand during that period. Alternatively, excessive products could be carried forward for use in subsequent periods, incurring storage cost. Both shortage and inventory are restricted by the service-level requirement and available storage space, respectively. The buyer needs to select one or more suppliers as well as carriers, and determine procurement timings and lot-sizes in these periods. The total procurement from the selected suppliers should satisfy the demand considering rejections and late deliveries, and allowing shortages with backlogging while minimizing net rejected items, net costs and net late delivered items.

The following sub-sections provide model notations and a mathematical model. Assumptions considered in this study are the same as in Choudhary and Shankar (2013).

3.1. Model parameters and decision variables

Indices

i	set of suppliers, $i = 1,\ldots,I$
m	set of all-unit price break levels, $m = 1,\ldots,M$
t	set of discrete time periods, $t = 1,\ldots,T$
j	set of transportation carriers, $j = 1,\ldots,J$