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Technical paper

Decision making of sourcing and order allocation with price discounts

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ABSTRACT

This paper applied a mixed integer programming approach to solve the sourcing and order allocation problem with multiple products and multiple suppliers in a supply chain. The decision process is driven by multiple objectives and a set of constraints. Two schemes of quantity discounts are used to compare the influence upon the buying decisions. An example and an experimental test are presented to demonstrate the effectiveness of the model. The computational solutions are a valuable tool to eliminate much of the subjectivity that impacts decisions under complex situations. A graphical display for the solutions is provided which can assist DMs in making decisions among criteria.

1. Introduction

Organizations have outsourced in a broad range of functions and activities formerly performed in-house to focus on value-added activities and core competencies during the last several decades. For many firms, the purchases from suppliers account for a large percentage of their cost of goods sold. Research indicates that the average purchases of raw materials and component parts can account for up to 70% of the main cost of a product in most industries; and up to 80% of total product cost in high-technology firms [1]. Moreover, supplier selection is a critical acquisition policy that has a long-term impact on outsourcing cost. Reducing the outsourcing cost to a minimum is vital to the competitiveness of most firms.

Suppliers enhance customer satisfaction in a value chain. Selecting the right suppliers can significantly reduce purchasing cost. Therefore, supplier selection is regarded as one of the critical activities in the purchasing process [2]. The decision affects the number and type of suppliers to employ as well as the order quantities to place with these suppliers. The selection of suppliers and the quantity of items to order from each supplier selected are strategic purchasing decisions.

A company must have a strong relationship with its suppliers in a supply chain to have successful outsourcing decisions. Effective relationship management in a supply chain depends greatly on the size of the supply base. Research on the optimal number of suppliers to use to fulfill product requirements is controversial. Single-sourcing strategy attempts a partnership between buyers and suppliers to promote cooperation. However, it may expose the buying firm to a greater risk of supply interruption [3]. On the other hand, multiple sourcing hedges the risks of creating a monopolistic supply base and supplier forward integration [4]. Operationally, multi-sourcing provides greater assurance of timely delivery, and greater upside volume flexibility [5]. Dealing with more suppliers reduces the risks with respect to the business disruption in the supply chain. Meanwhile, it increases the relationship management costs in terms of time and capital. Recent trends encourage the buying firm to work with fewer but better suppliers and to establish long-term mutually beneficial relationships with those suppliers [6,4,7,8]. Eliminating the excess suppliers allows the buying company to form effective partnerships with firms who look for high-quality and low-cost components [9]. Therefore, the number of suppliers used for a given product or service is an important decision in the design of an organization's supply chain [10,11,8]. In addition to the relationship focus, competitive advantages can be achieved through improved supply chain relationships and tightened links between buyers and suppliers. A properly managed supply chain will allow the organizations to focus on value-added activities and core competencies and will provide benefits for the business and its customers [12].

Determination of the order allocation is a strategic purchasing decision that will also impact the firm's relationship with suppliers. Since the purchasing decision is based on multiple suppliers, the buying firm can split its orders among suppliers to weaken the supplier's power over the buyer. Hence, the buyer firm has an opportunity to receive lower prices and shipping costs from a multiple-sourcing strategy [13]. To focus on relationship management, firms need to split order quantities to all the selected suppliers to keep secure working relationship with suppliers [14].

One major concern for supplier selection involves multi-item purchasing. Purchasing multiple items from a supplier is a standard

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business practice [15]. The problem is how much business should be placed with one supplier, especially for a small supplier where the buyer's business embodies a large portion of the seller's revenue. The purchaser does not wish to reduce flexibility by being tied to one supplier using more than a certain percentage of the total supplier's business. The decision varies widely on dividing an order among several suppliers in actual practice. In additional to divide the business equally, or based on geographical coverage, it is common to place business with various suppliers on a percentage of total requirements basis [16].

Another concern that a buying company might encounter in supplier selection is the price discount offered by suppliers. It is not always true that the unit price of an item is independent of the purchasing quantity. Quantity discounts represent another standard business custom [17]. For JIT purchasing, an ordering strategy that orders smaller quantities and more frequently as needed, suppliers are finding that it is meaningful to give discounts based on the total orders placed by a buyer. Price discounts provide a reduction in the price per unit as the number of units purchased increases. Large quantity orders lower the unit cost, but may increase inventory which conflicts with the financial department's goal of investing fewer dollars in inventories. The introduction of price discounts complicates the determination of the optimal purchasing quantities with minimum cost for an item. It is the task of the purchasing department to evaluate all of the considerations and make profitable buying decisions under different conditions.

Supplier selection is basically a multiple criteria decision making problem involving several conflicting factors such as price, quality, and delivery [18]. The joint consideration of the criteria complicates the selection decision. Mathematical programming techniques provide optimal solutions to various formulations of the problem where the criteria are formulated as the objective functions to be simultaneously considered in the selection of suppliers. Therefore, a multi-objective supplier selection model is formulated in this paper.

Kawtummachai and Nguyen [14] developed a procedure for a buying company, not a manufacturer, in a supply chain to order the required products from suppliers in its list. The factors used in their model included order price and percentage of on-time delivery. The objective for their model was to allocate orders to the selected suppliers to optimize the purchasing cost within the acceptable percentage of on-time delivery to guarantee high service levels to the retailers. This paper extends their work to a new environment where multiple-item and multiple-supplier sourcing are present. Since the allocation of order quantity depends on the number of suppliers, the optimal acquisition policy for supplier selection can be developed in this context. In addition, this paper addresses a multi-objective model to simultaneously determine the number of suppliers to employ and the order quantities to allocate to each supplier. According to the multi-criteria nature of the problem, multiple objectives and constraints are formulated in the model instead of using the single objective of on-time delivery. Another extension in this paper is that the suppliers offer discount schemes for each product on the total quantity of products purchased from them. Price discount is a common approach used by suppliers to increase business while the buyer can obtain a lower unit price.

Little attention has been addressed to this complex system in the literature. The purpose of this paper is to present a mixed integer linear programming formulation for the supplier selection and order allocation problem under multiple objectives of minimum purchasing costs, rejections, and late deliveries with constraints of demand, capacity, and price discounts. The remainder of this paper is organized as follows. The next section cites the relevant literature to the supplier selection and order quantity allocation problem. Formulation of the mathematical model is presented in Section 3. Also, discussed in this section is the development of the model. Section 4 describes the experimental design and discusses the results of the computational experiment. Finally, concluding remarks are provided in Section 5.

2. Literature review

Supplier selection is a multi-criteria decision problem that determines which supplier(s) should be selected and how much order quantity should be assigned to each supplier selected [19]. Twenty three criteria were identified as the factors used in the supplier selection process [20]. Among the criteria, it is found that price, quality and delivery were the most important factors [18].

Many papers have addressed supplier evaluation methods in literature [21–24]. De Boer et al. [25] have provided a comprehensive review of the most commonly used methodologies for solving the vendor selection problem. In this section, literature will be reviewed mainly in the mathematical programming models concerned with facilitating sourcing and allocation decisions.

Pan [26] introduced a linear programming model to minimize the total purchasing price based on constraints for satisfying the quality, lead time, and service requirements of the buyer. However, the model did not include supplier capacity constraints and only a single objective was used. Hong and Hayya [27] focused on single and multiple sourcing. They formulated and solved a mathematical programming problem to obtain the optimal selection of suppliers and the size of split orders for multiple sourcing; and provided a procedure that yields the optimal number of deliveries for single sourcing. Zeng [28] established an integrated framework of a single-objective that integrated significant factors into joint decisions of sourcing and lot sizing. An optimization procedure was developed to determine the optimal number of sources and the lot size. However, quantity discount was not included in the decision model.

Liu et al. [29] have applied a data envelopment analysis method for a vendor selection problem. Talluri and Narasimhan [30] used a max–min approach to evaluate suppliers and then allocated the order quantities based on the efficiency scores of suppliers. Yet their approaches did not consider price discount in the decision process.

Mixed-integer programming approaches have been applied to the supplier selection problem. Rosenblatt et al. [31] developed an acquisition policy for a single item in the presence of multiple suppliers, supplier relationship costs, and supplier capacity constraints. Jayaraman et al. [32] proposed a mixed integer programming approach to solve the supplier selection problem. Their model presented to minimize the single objective function of total costs subject to constraints on capacity, quality, and lead time. Tempelmeier [33] developed a heuristic approach to solve a mixed-integer linear formulation of the vendor selection and order-sizing problem for a single item under dynamic demand in the absence of supplier capacity constraints. Ghodsypour and O'Brien [1] presented a mixed integer non-linear programming model to solve the multiple sourcing, multiple criteria and capacity constraint problem, which took into account the total cost of logistics, including net price, storage, transportation and ordering costs. They extended their single-objective model to a two-objective model, however, quantity discount was not considered in their model. Basnet and Leung [34] formulated a mixed integer programming for the multi-period multi-product lot sizing with supplier selection problem where cost was the single objective considered in the model, consisting of the purchase cost, the transaction cost, and the holding cost in each period.

Authors [35–37] used the lexicographic goal programming (LGP) approach to allocate order quantities among suppliers. The LGP approach must decide the pre-emptive priority of the goals to generate solutions. The priority structure may be reorganized if the solution is unacceptable and in this manner the number of potential priority reorderings may be very large. Another limitation to the approach is that lower priority goals may not affect the solution since the analysis stops when an optimization is generated [37].