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Supplier selection problem for a single manufacturing unit under stochastic demand

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ABSTRACT

In this paper we consider a supplier selection problem for a single manufacturer/retailer who faces a random demand. All the available suppliers may quote different prices and may have restrictions on minimum and maximum order sizes. The objective is to find a low-cost assortment of suppliers which is capable of satisfying the demand. Properties of the problem are explored and a solution algorithm is proposed. Numerical experimentation is presented for evaluating the performance of the algorithm.

1. Introduction

Suppliers are the critical link to any supply chain and consequently sourcing decision is one of the important decisions to be taken at the planning stage—be it short term planning or long term planning. Selection of single or multiple suppliers involves several quantitative and qualitative criteria based on the type of partnership. There are plenty of advantages and disadvantages attached with single or multiple suppliers (McCutcheon and Stuart, 2000; Mohr and Spekman, 1994). Although single sourcing foster better collaboration and partnership but relying on the single supplier reduces the supply chain robustness. Moreover there are occasions when the preferred supplier may not be able to accommodate extra demand for a limited time and buyer has to source from other suppliers or make a short term partnership with external suppliers (suppliers who were not the part of current supply chain). Furthermore, relying on more than one source of supply for forming a short term partnership is sometimes inevitable because of suppliers limitations on capacity (suppliers may invest in capacity for long term partnership) and yield uncertainty (Agarwal and Nahmias, 1997; Anupindi and Akella, 1993) particularly in forestry and agricultural based industries.

There are several industries where a product or raw material is needed for a short duration and in this situation a long term commitment with suppliers is not desirable. Either due to the absence of long term commitment (consistent demand) or probably due to technical constraints suppliers may not want to invest in the production capacity or cannot at all augments the capacity. The best example is the forestry industry. Forests are owned by several contractors (suppliers) and have limited number trees for each species. A complete requirement of a particular species (quantity, quality, etc.) may not be met by a single supplier due to limited capacity or probably commitments to other clients. In this case sawmills/furniture companies have a single option—source from multiple suppliers. Similarly in the trucking industry, you may want to reserve some capacity for the next season, for which demand is still unknown, and

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a single transporter may not be able to provide the required capacity at the competitive rates.

Selection of suppliers becomes more challenging when suppliers offer interesting deal such as better price and quality while on the other hand have few restrictions such as minimum order size, limited capacity, lead time, etc. The limitation on minimum order size is basically set for economies of scale (transportation and production set ups) while upper limit is due to residual production or transportation capacities. In this paper we present a supplier selection problem where each supplier accepts the order only if the order size lies between the given minimum and maximum limits.

The supplier selection problem has attracted the attention of a number of researchers who proposed various models and solutions. In an earlier paper Pan (1989) proposed a mathematical programming model to determine the suppliers and quantities allocated to them. There were no constraints associated with suppliers and the demand was deterministic. Chauhan and Proth (2003) proposed supplier selection model for single and multiple buyers for known deterministic demands. All the suppliers in that model have limitations on order size for each buyer. Authors presented heuristic algorithms for supplier selection in both the single buyer and multiple buyer cases. Chauhan et al. (2005) consider the multiple sourcing problem for single buyer case and proposed an optimal algorithm based on dynamic programming.

In this paper we are using an approach similar to Chauhan and Proth (2003) to identify suppliers as well as corresponding quantities for a buyer facing stochastic demand. The supplier selection problem for a single buyer is a generalized version of classical newsboy problem (Gallego and Moon, 1993) (single supplier, single buyer and no restrictions on order size). Burke et al. (2007) treated a similar problem and proposed an optimal approach in the case where set of selected suppliers, with limitations on minimum order size, must supply to a buyer facing stochastic demand. The key difference between their approach and our approach is that in our approach we identify and allocate the suppliers while Burke et al. (2007) only assigned quantities to the suppliers who must supply a positive quantity.

The rest of the paper is divided into three sections. In Section 2 we describe the problem and propose a solution approach. Section 3 presents numerical study based on the proposed algorithm and finally the last section is conclusion.

2. Problem definition

A manufacturer sources raw material from a set of suppliers to face stochastic demand. We assume all the suppliers in the identified set are pre-qualified in buyer related qualitative criteria (quality, financial strength, lead time requirements, etc.) and the final allocation will be based solely on quantitative criterion (price) set by the buyer. We assume that the demand for the manufacturing unit (single) follows a known density function $f(x)$ (cumulative density $F(x)$). The manufacturer needs to decide the exact quantity to be ordered from each of the suppliers in order to maximize the expected revenue. The selling price offered by the suppliers may be different and one or more supplier may have restrictions on minimum order size and/or limited by maximum capacity.

For the simple case of single supplier and single manufacturer the expected profit of the manufacturer for an order of size Q is given by

$$T(Q) = \int_0^Q (sx - c(Q-x))f(x)\,dx + \int_Q^\infty sQf(x)\,dx - pQ \quad (1)$$

In (1) s is revenue per unit for manufacturer, c is handling charges or loss per unit on unused or unsold quantity and p is selling price per unit offered by the supplier. $T(Q)$ is concave (Silver et al., 1998; Winston, 1993) w.r.t. Q and since the objective is to maximize the expected revenue the optimal ordering quantity in the above case satisfies the following relation:

$$F(Q) = \frac{s-p}{s+c} \quad (2)$$

Since $T(Q)$ is concave, the following is always true.

Lemma 1. *It is optimal to order* $\min(Q, q^c)$ *where* q^c *is the capacity of the supplier.*

Now consider a set, say N, of n suppliers offering the product at price p_i and few or all of them have limited capacity. Let us define $F(q_i^*) = (s-p_i)/(s+c)$, and assume that $p_i \neq p_j$, $i,j \in N$. In the case when $p_i = p_j$ we can combine the capacity of the both suppliers and drop one of them. The following can be immediately deduced due to the concavity of expression (1).

Lemma 2. *If a supplier, i, has enough capacity,* $q_i^* \leqslant q_i^c$ *and* q_i^* *is the maximum among the supplier* i.e.

$$I = \{i | i,j \in N;\ q_i^* > q_j^*\}$$

then it is optimal to source from a single supplier i.e. ith.

The problem's complexity increases when one or more suppliers have to be selected and each of the supplier has a restriction on minimum order size. Assume that supplier i, $i \in N$ accepts a order only if it lies between m_i and M_i i.e. $m_i \leqslant q_i \leqslant M_i$. Now the problem can be formulated as follows:

Definition.

$$T(q_1, q_2, \ldots, q_n) = \int_0^{\sum_{i\in N} q_i} \left(sx - c\left(\sum_{i\in N} q_i - x\right)\right) f(x)\,dx + \int_{\sum_{i\in N} q_i}^\infty s\left(\sum_{i\in N} q_i\right) f(x)\,dx - \sum_{i\in N} p_i q_i \quad (3)$$

$$\frac{\partial T}{\partial q_i} = -c\int_0^{\sum_{i\in N} q_i} f(x)\,dx + \int_{\sum_{i\in N} q_i}^\infty sf(x)\,dx - p_i \quad (4)$$

P_1 $\quad \text{Max}\, T(q_1, q_2, \ldots, q_n)$

S.T.

$$Z_i M_i \geqslant q_i \geqslant m_i Z_i \quad \forall i \in N \quad (5)$$

$$Z_i \in \{0, 1\} \quad \forall i \in N \quad (6)$$