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An improved model for supplier selection under capacity constraint and multiple criteria

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ABSTRACT

Ghodsypour and O'Brien [2001. The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint. International Journal of Production Economics 73(1), 15–27] study multiple sourcing problem with multiple criteria and capacitated suppliers. Considering the buyer's quality requirements as a constraint, they develop a mixed integer non-linear programming model to find the least-cost cyclic ordering policy for the buyer. They propose to solve the model by enumerating over all possible supplier combinations. Although the problem is interesting and their analysis is correct, we point out two issues with their assumptions, namely, capacitated suppliers and cyclic ordering policy. We discuss two different capacitated supplier settings: (i) long-run average annual capacity, and (ii) exact annual capacity. First, under long-run average annual capacity assumption we propose a model which provides the same or a better solution and is much easier to solve than their model. Then, we discuss how to modify our and their models to handle exact annual capacity assumption.

1. Introduction

Most companies procure raw materials or component parts from outside vendors/suppliers where there is a number of competing suppliers with different capacities, pricing schemes, cost structures, service and quality levels. The cost of raw materials and component parts represent a significant portion of the total costs in many industries (Aissaoui et al., 2007; Burke et al., 2007). Thus, procurement decisions play a key role in a company's overall efficiency and effectiveness.

One of the most important decisions related to procurement operations is supplier evaluation and selection. There are several factors involved such as price offered by the supplier, lead time, the quality of items, the capacity of supplier and the geographical location of supplier while making supplier evaluation and selection decisions (Ho et al., 2010; Minner, 2003).

Ghodsypour and O'Brien (2001) study supplier selection problem while taking into account both the quality of procured items and total annual cost which includes fixed ordering cost, inventory holding cost and variable purchasing cost. Assuming there are multiple capacitated suppliers with different pricing schemes and quality levels (also called perfect rate), they focus on the ordering decision of a buyer who faces a deterministic constant demand for a single item. The buyer has a minimum required quality level (perfect rate) for the incoming parts which should be satisfied as an aggregate performance measure (Chaudhry et al., 1993; Rosenthal et al., 1995). The authors assume that fixed ordering costs from suppliers are independent and incurred every time an order is given. They try to determine how much to order in each order cycle and how to allocate total order quantity to the suppliers. In the first part of the paper, they consider the buyer's perfect rate requirement as a constraint and look for a solution with minimum total annual cost. In the second part, they modify the model to consider both quality and cost in the objective function. They develop a multiple objective programming model where they penalize deviations from cost and quality goals by certain weights. The authors look for a cyclic ordering policy where quantity allocated to each supplier is same in each cycle, and the next supplier's order is received when the current supplier's lot is finished. They propose a mixed integer non-linear programming model. In order to find an optimal solution to the mixed integer non-linear programming model with n suppliers, they solve 2^n pure non-linear programs by considering all different combinations of supplier selection variables (0/1 variables).

In this paper, we point out two important issues with the assumptions and model in Ghodsypour and O'Brien (2001) and propose a model to address these issues. The first issue is about how supplier capacities are handled. Supplier capacities are provided as annual capacities, and based on the analysis in the

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paper, we understand that capacities are actually considered as long-run average annual capacities (Rosenblatt et al., 1998). That is, total order quantity from a certain supplier in a given year in the proposed model can be greater than capacity, but the long-run average annual order quantity does not exceed capacity. We illustrate this phenomenon in the next section using the example provided by Ghodsypour and O'Brien (2001) and discuss the differences between "long-run average annual capacity" and "exact annual capacity". The second issue is about the proposed cyclic ordering policy. Although cyclic ordering policy is easier to implement, it is not necessarily optimal especially since buyer incurs a fixed ordering cost every time places an order with any supplier. That is, instead of ordering from a certain supplier in each cycle, the buyer may prefer ordering a higher quantity in every other cycle in order to decrease fixed ordering costs if inventory holding cost does not increase significantly. Moreover, the proposed model is not easy to solve since it is a mixed integer non-linear programming model. The authors propose solving 2^n pure non-linear programs by considering all different combinations of suppliers which requires an exponential effort. First, assuming a long-run average annual capacity on the suppliers we demonstrate that cyclic ordering policy proposed by authors does not provide an optimal solution in general by providing a model for the most general ordering policy. The proposed model is a linear program which can be solved in polynomial time (Karmarkar, 1984). Any solver including Microsoft Excel, as mentioned by the authors, can be directly used to determine the ordering policy instead of enumerating all possible combinations of suppliers. This is especially important when the number of suppliers is large. Second, we discuss how to modify our and their models to make sure that total annual order quantity from each supplier does not actually exceed the capacity in each year.

Given the high percentage of raw material and component part costs in total costs, the proposed model provides a significant improvement in procurement operations, and accordingly, in aggregate planning for industries such as apparel industry (Qi, 2007), office products industry (Burke et al., 2008) and contract manufacturing where a manufacturer outsources its parts production to multiple contract manufacturers (Aissaoui et al., 2007; Kim et al., 2002).

The remainder of the paper is organized as follows. In the next section, we provide a review of the multi-criteria supplier selection literature. We discuss long-run average annual capacity and exact annual capacity concepts in Section 3. In Section 4, we provide a more general model for supplier selection problem under long-run average annual capacity assumption, and then discuss how to modify the proposed model and Ghodsypour and O'Brien's (2001) model for exact annual capacity case. We present the results of computational experiments on randomly generated instances as well as on the instances provided by Ghodsypour and O'Brien (2001) in Section 5. We conclude the paper in Section 6.

2. Literature review

Multi-criteria supplier selection has been extensively studied in the literature since the seminal work of Dickson (1966). Weber et al. (1991) provide a review of the articles which have appeared between 1966 and 1990. Degraeve et al. (2000) propose using Total Cost of Ownership (TCO) concept (Ellram, 1995) as a basis for comparing vendor selection models and evaluate the models in the literature from TCO perspective. De Boer et al. (2001) discuss a supplier selection framework which covers different phases of supplier selection process including pre-qualification, formulation of criteria and final evaluation. They classify the models in the literature using this framework. More recently, Ho et al. (2010) and Wu and Barnes (2011) provide a review of the articles about multi-criteria supplier evaluation and selection. According to Ho et al. (2010), the three most important criteria considered while selecting suppliers are product quality, delivery lead time and price.

Various decision-making models have been proposed to address multi-criteria supplier selection problem using (i) Data Envelopment Analysis (DEA), (ii) Analytic Hierarchy/Network Process (AHP/ANP), (iii) Mathematical Programming (MP), (iv) Total Cost of Ownership (TCO), (v) Linear Weighting (LW), and (vi) Fuzzy Set Theory (FST).

Models that use DEA (Falagario et al., 2012; Wu and Olson, 2010) do not require predefined weights for the criteria considered. These models evaluate the efficiency of each supplier separately by determining the set of criterion weights that maximizes the supplier's efficiency. The efficiency of a supplier is calculated as the ratio of output (the performance of the supplier) to input (the cost of using the supplier). Then, buyer classifies suppliers as efficient and inefficient suppliers according to the calculated efficiency. The main disadvantages of DEA models are the ignored hierarchy and dependencies among criteria.

AHP models (Hou and Su, 2007; Sari et al., 2008) consider both tangible and intangible factors in a hierarchical manner. The main idea is ranking suppliers by pairwise comparisons. However, the results are highly subjective since the decision maker has to determine both the direction of relative importance (among two criteria which one is more important) and the degree of relative importance. ANP is a more sophisticated version of AHP allowing for more complex relationships between criteria. Examples of models that use ANP are proposed by Gencer and Gurpinar (2007) and Yang et al. (2010).

Decisions-making approaches that use MP require all the criteria considered to be quantified. These approaches use (i) linear (Ng, 2008; Talluri and Narasimhan, 2005), (ii) integer (Hong et al., 2005; Jayaraman et al., 1999), (iii) non-linear (Ghodsypour and O'Brien, 2001; Sharma et al., 1989), (iv) multi-objective (Feng et al., 2011; Wadhwa and Ravindran, 2007), and (iv) goal programming (Karpak et al., 2001; Ravindran et al., 2010) models.

TCO quantifies all direct and indirect costs associated with the purchasing process including net price, costs related to service, quality and delivery. Supplier selection decisions are made based on this calculated TCO values. Examples of models that use TCO concept are presented by Degraeve and Roodhooft (1999, 2000). The main disadvantage of TCO models is the required extensive accounting system to capture all the relevant costs of each supplier.

LW models (Barbarosoglu and Yazgac, 1997; Jarimo and Salo, 2009) place a weight on each criterion and provide a single score for each supplier by summing the supplier's weighted performance on each criterion. These models require all the criteria considered to be assigned a certain (subjective) weight.

FST deals with sets or categories with blurry boundaries. Models that use FST (Amindoust et al., 2012; Ordoobadi, 2009) address the supplier selection problem using linguistic values to assess the supplier performances instead of using numerical values. The main disadvantage of FST models are the difficulty of estimating membership function and the presence of various ways of determining fuzzy rules.

In addition to these methods, Cluster Analysis (CA) (Holt, 1998; Keskin et al., 2010), Case-Based Reasoning (CBR) (Choy et al., 2005), Genetic Algorithm (GA) (Ding et al., 2005), Simple Multi-Attribute Rating Technique (SMART) (Barla, 2003; Huang and Keska, 2007), and Multi-Attribute Utility Theory (MAUT) (Sanayei et al., 2008) are also used to address multi-criteria supplier selection problem.

Finally, some authors propose decision-making approaches integrating two or more methods. For example, Ertay et al. (2011)