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A fuzzy model for supplier selection in quantity discount environments

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ABSTRACT

Traditionally, supplier selection should simultaneously take into account numerous heterogeneous criteria, and then is a tedious task for the purchasing decision makers. It becomes especially complicated when quantity discounts are considered at the same time. Under such manner, most studies often formulate such a problem as a Multi-Objective Linear Programming (MOLP) problem, and then scale it down to a Mixed Integer Programming (MIP) problem to handle the inherited multi-objectives simultaneously. However, this approach often neglects to consider scaling and subjective weighting issues. In order to ease the problem mentioned above and to obtain a more reasonable compromise solution for allocating order quantities among suppliers with their quantity discount rate offered, the Analytical Hierarchy Process (AHP) and fuzzy compromise programming are introduced in this study. An illustrated example is presented to demonstrate the proposed model and to illuminate two kinds of attitudes for decision makers. The information from the experiments can be utilized further to explain the suppliers' possible improvement and to help create win–win policies.

1. Introduction

In a competitive environment, the selection and evaluation of suppliers are the most critical issues facing manufacturing firms because the costs of raw materials and components may, in fact, comprise the major portion of a product's final cost. Selecting an appropriate supplier can significantly reduce purchasing costs, decrease production lead time, increase customer satisfaction, and strengthen corporate competitiveness. As far as supplier relationship management (SRM) is concerned, firms should select the most appropriate suppliers according to the production capacity of all potential suppliers and build long-term and profitable relationships with them. In addition, manufacturing firms must make timely estimates of materials or components available from each selected supplier in order to minimize purchasing costs. Although the process of supplier selection and evaluation has been studied extensively, the problem of supplier selection under multi-supplier quantity discount has received little attention. An effective approach to solve this problem is necessary.

The supplier selection and evaluation process is multi-objective in nature; that is, more than one criterion may be considered and evaluated during the process. In addition, supplier selection decisions are complicated by the fact that various criteria must be taken into account simultaneously in the decision process. The analysis of such criteria and of supplier performance measurements has been the focus of many researchers and purchasing practitioners since the 1960s. Based on a survey of 170 purchasing managers, Dickson (1966) identified 23 different criteria evaluated in supplier selection. Among these criteria, price, delivery performance and the quality of the buyer are deemed particularly important in evaluating the suppliers. Weber, Current, and Benton (1991) reviewed 74 articles on supplier evaluation and concluded that quality was ranked highest in importance, followed in order by delivery performance and cost. Weber et al. also suggested that the supplier selection decision must not be based exclusively on the least cost criterion; other critical factors, such as quality and delivery performance should be incorporated into the evaluation and selection processes.

However, the evolution of the industrial environment has changed the relative importance of these criteria. Ellram (1990) proposed three principal criteria: (1) the financial statement of the supplier, (2) the organizational culture and strategy of the supplier, and (3) the technological state of the supplier. Barbarosoglu and Yazgac (1997) further distinguished three different primary criteria: (1) the performance of the supplier, (2) the technical capabilities and financial situation of the supplier, and (3) the quality system of the supplier. On the other hand, Wang, Huang, and Dismukes (2004) adopted 12 performance metrics as the standard criteria for evaluating a company's performance. The 12 performance metrics can be classified into four main categories: (1) delivery reliability, (2) flexibility and responsiveness, (3) cost, and (4) asset. Contained in the various evaluation methods proposed in the available literature, price, delivery performance, and quality are the most common criteria.

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To resolve the supplier selection problem, several evaluation techniques have been proposed in the literature. The vast majority of the quantitative methodologies can be classified into three categories: (1) multi-attribute decision-making, (2) mathematical programming models, and (3) intelligent approaches. The first category includes the linear weighting method (Timmerman, 1986; Turner, 1988; Wind & Robinson, 1968) and the analytical hierarchy process (AHP) (Akarte, Surendra, Ravi, & Rangaraj, 2001; Barbarosoglu & Yazgac, 1997; Chan, 2003; Narasimhan, 1983; Tam & Tummala, 2001). The mathematical programming models are the next most frequently used techniques. They include the linear goal programming model (Buffa & Jackson, 1983), linear programming models (Pan, 1989), mixed integer programming (MIP) (Chaudhry, Forst, & Zydiak, 1993; Kasilingam & Lee, 1996; Rosenthal, Zydiak, & Chaudhry, 1995), multi-objective programming (Weber & Current, 1993), and data envelopment analysis (DEA) (Liu, Ding, & Lall, 2000; Saen, 2007; Talluri, Narasimhan, & Nair, 2006; Weber, Current, & Desai, 1998; Weber & Desai, 1996). As for the third category, it explores some newly developed intelligent techniques, such as neural networks (Choy, Lee, & Lo, 2003; Siying, Jinlong, & Zhicheng, 1997), and expert system (Choy, Lee, & Lo, 2002), in order to process the activities of supplier selection. In addition, other methods have also been extensively used for the supplier selection problem, such as integrated AHP and linear programming (Ghodsypour & O'Briem, 1998), principal component analysis (Petroni & Braglia, 2000), fuzzy mixed integer goal programming (Kumar, Vrat, & Shankar, 2004), voting AHP (Liu & Hai, 2005), combined AHP and grey relational analysis (Yang & Chen, 2006), the fuzzy decision making approach (Amid, Ghodsypour, & O'Brien, 2006; Chang, Wang, & Wang, 2006; Chen, Lin, & Huang, 2006) and combined AHP, DEA and neural network (Ha & Krishnan, 2008).

Although several of the methodologies mentioned above have been used for evaluating supplier performance and have their own strengths under certain specific conditions, we have identified in the supplier selection under multi-supplier quantity discount is treated as MIP to minimize purchasing costs (Chaudhry et al., 1993; Rosenthal et al., 1995). In these models, only one criterion was used as an objective function, and other criteria were modeled as constraints. However, one criterion considered as a single objective function rarely occurs in practice. Recently, multi-objective linear programming (MOLP) was adopted in two distinct research projects to solve the supplier selection problem while taking into consideration quantity discount. The first study employed a preference-oriented approach to handle the problems caused by the different scales of different objectives, which was then reformulated as a single-objective optimization model (Dahel, 2003). However, the model lacks an appropriate set of weights to generate a more objective decision. The second study, although employing AHP to reduce the assessment bias, still had trouble finding the unique optimal compromise solution (Xia & Wu, 2007).

Under such manner, the solution procedures presented in available literature focus mainly on formulation of linear programming. However, there are two critical obstacles, scaling and subjective weighting, in the multi-suppliers under the conditions of quantity discount. Thus, the purpose of this study is to employ both AHP and fuzzy compromise programming in order to release the above-mentioned shortcomings and to help obtain a more reasonable compromise solution for allocating order quantities to each supplier offering a quantity discount rate.

The remainder of this paper is organized as follows. Mathematical formulations of the supplier selection model under multi-supplier quantity discount are presented in the next section. In Section 3, a fuzzy compromise programming approach is proposed and is formulated to suit MOLP. The solution procedure for the proposed model is demonstrated in the fourth section. In Section 5, a numerical example with solution is presented to illustrate our approach. Finally, a summary and conclusions are presented in Section 6.

2. Supplier selection model under multi-supplier quantity discount

In this section, we formulate a mathematical model of the supplier selection decision under the conditions of a multi-supplier quantity discount. The following notations are defined in order to describe the model:

b_{ij}	the jth price level from supplier i, $i = 1,\ldots,n$, $j = 1,\ldots,m(i)$
c_{ij}^{k}	the coefficients of the kth objective function from supplier i at price level j, $k = 1,\ldots,K$
D	the buyer's demand
d_i	the delivery lateness rate per unit from supplier i
q_i	the average defective rate per unit from supplier i
$m(i)$	the number of quantity ranges in supplier i's price level
n	the number of suppliers
p_{ij}	the unit price of supplier i at price level j
S_i	the maximum capacity of supplier i
$U(\cdot)$	a global satisfaction degree of MOLP
$U_k(\cdot)$	the marginal satisfaction degree of the kth criterion
w_k	the weight of the kth criterion
x_{ij}	the number of units purchased from supplier i at price level j
y_{ij}	$\begin{cases} = 1 & \text{if the } i\text{th supplier is selected at price level } j; \\ = 0, & \text{otherwise} \end{cases}$
Z_k	the objective function of the kth criterion
$Z_k^{\min}$	the minimum value for the kth objective function
$Z_k^{\max}$	the maximum value for the kth objective function

In this model, we consider the case in which one buyer purchases raw materials or semi-products from a number of suppliers, as depicted in Fig. 1. Moreover, since conflicting criteria exist while attempting to configure the best possible combination of purchasing quantities among different suppliers, the basic objective function is then formulated as a multi-objective function. The constraints of the problem are the supplier's capacity and the buyer's demand. The following MOLP measuring the performance of supplier selection is used to determine order quantity:

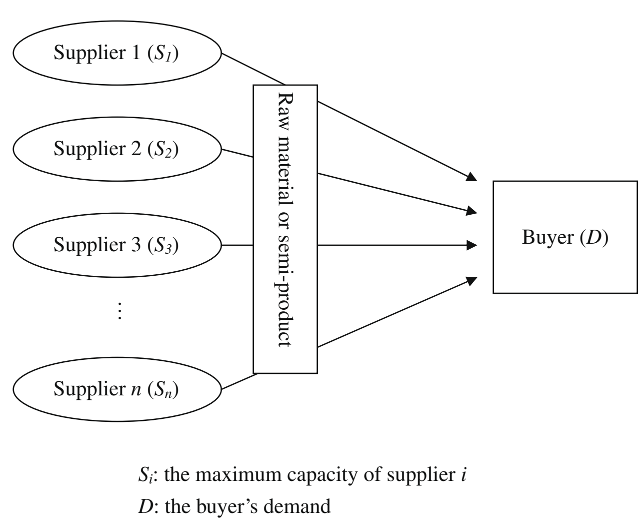

Fig. 1. Model of multiple suppliers.