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A fuzzy-based decision-support model for rebuy procurement

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ABSTRACT

Under rapid innovations and technological changes due to fierce competition, purchasing managers are often faced with a high level of uncertainty in making procurement decisions. To maximize the buying firm' overall performance, managers also need to scrutinize suppliers' performance regarding multiple criteria. This paper proposes a practical decision-support model to deal with the rebuy procurement problem in this common scenario. Based on prior transaction data, the decision-support model enables the purchasing manager to obtain the most preferred solution through an interactive procedure. Thus the proposed model can facilitate self-improving learning effects, and tackle supplier selection problems for multiple items with vague information about the multi-dimensional performance of suppliers. The proposed model is applied to an example problem, in which we select suppliers by considering multi-criteria under the demand constraint of multiple items of varied importance to the buying firm.

1. Introduction

During the past decades, purchasing has evolved from a purely administrative activity to a function of strategic importance for firms in many industries (Ellram and Carr, 1994; Carr and Pearson, 1999). The fact behind this phenomenon is the growing recognition of the pivotal role played by purchasing in enhancing organizational performances and increase shareholder's values. Under intensified competition, a company's success will largely depend on the critical ability to integrate the company's complex network of business relationship (Lambert and Cooper, 2000). Establishing partnerships with other companies, however, is usually considered a high-level strategic decision that involves substantial investments. Increased competitive pressure has also induced rapid product introductions and shortened product lives, which render fuzziness a common trait in the supplier selection problem. To survive in the market, the buying firm needs to exploit all available information to select the most appropriate suppliers for the company's long-term benefits.

Despite the importance of sourcing decisions, supplier selection problems are complicated and are not easy to handle. First, buyers need to simultaneously consider multiple criteria in selecting suppliers; for example, price, quality, experience with the supplier, the supplier's reputation are the most commonly seen criteria, among others (Ghodsypour and O'Brien, 1998; Garg, 1999). Specifically, buyers need to consider quantifiable factors such as product quality, delivery performance and price offers, as well as qualitative factors such as single or multiple sourcing (Richardson, 1993; Swift, 1995; Dyer et al., 1998; Burke et al., 2007), the relationship with candidate suppliers, the importance of different purchase items, the level of uncertainty in the market, and the knowledge and experience of the purchasing manager see, e.g., De Boer et al. (2001). Anticipative actions and negotiations can also wield considerable influence on the supplier selection process and the supply-chain

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coordination (Dudek and Stadler, 2005; Farrington and Lysons, 2005).

In practice, however, the information required for solving supplier selection problems can often be incomplete or insufficient. Qualitative factors are usually intrinsically difficult to be properly incorporated into the analysis. Moreover, decision parameters in the supplier selection problem, such as prices and quotas, are often subject to negotiations between both parties. Therefore an ideal decision-support model should take these practical aspects of the problem into account, and at the same time enable managers to make the most of his professional knowledge and available information in the system to reach the most satisfactory solution. Models that provide solutions based on the mathematical rather than practical viewpoint will easily lead to oversimplified and biased decisions. In this regard, the proposed fuzzy-based model provides a realistic method to systematically deal with vagueness and uncertainty of the problem.

Numerous studies in the literature have utilized different multi-criteria approaches to tackle supplier selection problems. In the evaluation phase, data envelopment analysis (DEA) has been a popular method to evaluate suppliers by their multiple inputs and outputs in the production processes (Weber, 1996; Weber et al., 1998; Talluri and Narasimhan, 2003). Another popular selection approach is the analytic hierarchy process (AHP) (Ghodsypour and O'Brien, 1998; Masella and Rangone, 2000). AHP, however, can become unwieldy in practice when the number of criteria or suppliers increases. These methods can provide evaluation results of suppliers that are essential to the final choice phase, where the manager determines the exact purchase quantities from each supplier. Methods often used in the final choice phase are linear programming (Ghodsypour and O'Brien, 1998), goal programming (Buffa and Jackson, 1983; Karpak et al., 1999) and multiple criteria optimization (Dahel, 2003; Xia and Wu, 2007). De Boer et al. (2001) and Aissaoui et al. (2007) provide comprehensive literature reviews on different supplier selection methodologies. These studies, however, do not consider the fuzzyness in both decision phases—which is crucial to today's ever-changing business environment. Moreover, these extant approaches fail to construct a coherent decision-support structure to exploit prior transaction experiences with suppliers, which can greatly facilitate the learning effect in the decision-making process.

In this paper, I propose a systematic approach to incorporate multiple uncertain factors into the decision of rebuy purchases. The paper employs a fuzzy-based mathematical programming approach to account for multiple criteria and vagueness within the decision process. The proposed model uses fuzzy numbers to map out the performance variation based on all accessible information, and the fuzzy-based analysis enables the manager to interactively adjust the specifications of the fuzzy numbers, so as to draw on his prior problem solving experience or professional insight in the market.

Several salient features distinguish this paper from other similar studies in the literature (e.g., Kumar et al., 2004; Chen et al., 2005; Amid and O'Brien, 2006). First, the proposed model can reflect the manager's preference and internalized professional knowledge, such as insights on the market and partnerships with suppliers. This contribution responds to the criticism that previous studies utilizing optimization techniques often fail to incorporate qualitative factors into the analysis; see Ghodsypour and O'Brien (1998), De Boer et al. (2001) and Chen et al. (2005). Methodologically, the proposed decision-support model combines available information (i.e., accessible empirical data and optimization techniques) and the subjective assessment from the decision maker (i.e., buyer–supplier negotiation and expected suppliers performance) to obtain the most satisfactory solution. In addition, the proposed model is in line with the principle idea of the cased-based reasoning (CBR) approach (e.g., Choy et al., 2002), in the sense that both approaches emphasize the importance to integrate past problem solving experiences into current decision-making. The proposed model, however, focuses specifically on utilizing the data of historical performance of suppliers, and enable managers to learn and draw on their subject understanding of the fuzzy environment through the interactive decision process. The model aims at solving general supplier selection problems, in which we select suppliers by multi-criteria to satisfy the demand of multiple items, and the items may be of different importance to the purchasing firm.

Finally, previous research in this area did not provide a clear guideline about how to systematically specify the functional support of fuzzy numbers in the constraints of the model where they used the max–min (Zimmermann, 1978) approach to model vagueness of the objectives. This paper develops a pragmatic approach to incorporate the decision-support structure into the construction of fuzzy numbers.

The remainder of this paper is structured as follows. Section 2 briefly introduces the fuzzy set theory. In Sections 3 and 4, I present the fuzzy optimization problem and the decision-support structure, respectively. This is followed by a numerical example in Section 5, in which the proposed methodology is applied to a multi-item, multi-criteria supplier selection problem. Section 6 summarizes the paper and provides directions for future research.

2. Fuzzy set theory

Fuzzy set theory was first proposed by Zadeh (1965) to present data that cannot be precisely ascribed to a certain set. Contrary to traditional set theory, in which sets have "crisp" boundaries, fuzzy sets define the membership by a function mapping to the continuum from 0 to 1. Formally, a fuzzy set $\tilde{A}$ in X is characterized by an ordered pair, with $\mu_{\tilde{A}}$ being the corresponding membership function:

$$(\tilde{A}, \mu_{\tilde{A}}) \quad \text{where } \mu_{\tilde{A}} : X \to [0, 1]$$

A fuzzy number is a one-dimensional fuzzy set that has a membership function with a support included in $\Re$. The α-cut of the fuzzy number $\tilde{A}$ is defined as

$$\tilde{A}^{\alpha} := \{x | \mu_{\tilde{A}}(x) \geq \alpha\}$$