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An integrated supplier selection methodology incorporating QFD and DEA with imprecise data

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ABSTRACT

Supplier evaluation and selection is an important group decision making problem that involves not only quantitative criteria but also qualitative factors incorporating vagueness and imprecision. This paper proposes a novel fuzzy multi-criteria group decision making framework for supplier selection integrating quality function deployment (QFD) and data envelopment analysis (DEA). The proposed methodology allows for considering the impacts of inner dependence among supplier assessment criteria through constructing a house of quality (HOQ). The lower and upper bounds of the weights of supplier assessment criteria are identified by adopting fuzzy weighted average (FWA) method that enables the fusion of imprecise and subjective information expressed as linguistic variables. An imprecise DEA methodology is implemented for supplier selection, which employs the weights of supplier assessment criteria computed by FWA utilizing the data from the HOQ and the supplier ratings with respect to supplier assessment criteria. The application of the proposed framework is demonstrated through a case study in a private hospital in Istanbul.

1. Introduction

The role of suppliers' performance is crucial in achieving cost, quality, delivery and service objectives of a supply chain. The evaluation and selection of suppliers is regarded as one of the critical issues encountered by operations and purchasing managers in a supply chain to enhance corporate competitiveness (Ghodsypour & O'Brien, 2001). Having identified the need to better manage the supplier selection process, the companies recognize the necessity for a systematic and sound approach to avoid the consequences of poor decisions on the selection of suppliers. The key benefit of a well-functioning supplier selection procedure is its momentum for competitiveness. In order to sharpen the competitive edge in a supply chain, a higher level of integration with suppliers and customers is required (Goffin, Szwejczewski, & New, 1997).

Supplier selection is a popular area of research in purchasing with methodologies ranging from conceptual to empirical and modeling streams. Supplier selection decisions are complicated by the fact that various criteria must be considered in decision making process. Dickson (1966) conducted one of the earliest works on supplier selection and identified 23 supplier attributes that managers consider when choosing a supplier. Several studies emphasized the relative importance of various supplier criteria such as price, quality, on-time delivery, and performance (Kannan & Tan, 2002; Wilson, 1994).

There is a continuing need for robust evaluation models that effectively incorporate several supplier criteria. Involvement of diverse criteria in decision making process has further complicated supplier evaluation and selection decisions. The classical multi-criteria decision making (MCDM) methods that consider deterministic or random processes cannot effectively deal with supplier selection problems since fuzziness, imprecision and interaction coexist in real-world. This also sets forth that pertinent supplier selection methodologies should enable imprecise and/or qualitative data to be taken into consideration.

In this work, an integrated group decision making methodology is developed to rectify the problems encountered when employing classical decision making methods in supplier selection. In supplier selection process, the company's ultimate aim is to have access to suppliers that ensure a certain quality standard in terms of the characteristics of the purchased products or services (Bevilacqua, Ciarapica, & Giacchetta, 2006). Achieving these objectives depends mainly on considering the relationships between purchased product features and supplier assessment criteria as well as the relationships between supplier assessment criteria avoiding the unrealistic independence assumption. Consequently, constructing

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a house of quality (HOQ), which enables not only the relationships among the purchased product features and supplier assessment criteria but also inner dependence of supplier assessment criteria to be considered, is essential to determine how well each supplier characteristic succeeds in meeting the requirements established for the product being purchased.

First, the proposed framework identifies the features that the purchased product should possess to meet the company's needs, and then it intends to establish the relevant supplier assessment criteria. Quality function deployment (QFD) is a powerful tool to create better outputs that are highly focused and responsive to the customers' needs. QFD ensures that supplier assessment criteria are in line with characteristics required of products purchased. In this paper, we focus on the first of the four matrices in QFD, also known as the HOQ. Then, an imprecise data envelopment analysis (DEA) framework, which utilizes the weights of supplier assessment criteria computed by fuzzy weighted average (FWA) using the data obtained from the HOQ and the pertinent supplier ratings with respect to supplier assessment criteria, is employed to identify the best suppliers.

DEA has been previously used in supplier selection owing to its ability to preclude the selection of a suboptimal supplier. Although DEA is a powerful tool in identifying the efficient units, it has two interrelated problems as the unrealistic weight dispersion and the deficiency in discriminating power. In DEA formulations, the decision making units (DMUs) can freely choose the weights to be assigned to each input and output in a way to maximize its relative efficiency. Allowing a DMU to seek maximum efficiency by selecting a mix of weights is impractical because it either ignores pertinent criteria or is inconsistent with expert judgments. Unfortunately, it is acknowledged that complete weight flexibility in DEA may lead to unacceptable efficiency results (Jahanshahloo & Soleimani-Damaneh, 2005). To overcome these limitations, the proposed methodology computes the bounds on weights of supplier assessment criteria by using FWA. The FWA method enables the fusion of imprecise and subjective information expressed as linguistic variables or fuzzy numbers, and it produces less imprecise and more realistic overall desirability levels. FWA, which rectifies loss of information when integrating imprecise data, is a robust procedure for imposing bounds on supplier assessment criteria weights that enables considering the relationships between requirements of the product established by its users and supplier criteria as well as the inner dependencies among supplier criteria. The efficiency scores obtained using the restricted model will be less than or equal to those of the classical DEA formulation, and accordingly result in an improvement in the discriminating power of DEA as well.

The rest of the paper is organized as follows: The following section presents a concise literature review on supplier selection. In Sections 3 and 4, the basic concepts of QFD and DEA are presented, respectively. Section 5 delineates the proposed decision making approach and provides its stepwise representation. The implementation of the proposed framework for evaluating medical suppliers of a private hospital in Istanbul is provided in Section 6. Concluding remarks and directions for future research are given in the final section.

2. Literature review

Most of the research on supplier selection focuses on the quantifiable aspects of the supplier selection decision such as cost, quality, and delivery reliability. However, as firms become involved in strategic partnerships with their suppliers, a new set of supplier selection criteria, which are difficult to quantify, needs to be considered. Fuzzy set theory is an effective tool to model uncertainty in supplier selection. In the literature, there are a number of studies that use different fuzzy decision making techniques to evaluate suppliers. Our focus will be limited to the research conducted in the recent past; in particular, from 2006 onwards where there has been a notable increase in the number of publications employing fuzzy set theory in supplier selection.

Several authors have used fuzzy mathematical programming approaches. Kumar, Vrat, and Shankar (2006) treated supplier selection problem as a fuzzy multi-objective integer programming formulation that incorporates cost minimization, quality maximization, and on time delivery maximization. Amid, Ghodsypour, and O'Brien (2009) developed a fuzzy multi-objective model for supplier selection. Chen (2009) employed a fuzzy mixed integer programming approach to account for multiple criteria and vagueness within the supplier selection decisions in the rebuy purchasing situation. Díaz-Madroñero, Peidro, and Vasant (2010) considered the supplier selection problem with fuzzy goals. A multi-objective model, which attempts to minimize the total order costs, the number of rejected items and the number of late delivered items simultaneously, was developed. Wu, Zhang, Wu, and Olson (2010) presented a fuzzy multi-objective programming supplier selection model for supply chain outsourcing risk management. Yücel and Güneri (2011) proposed a fuzzy multi-objective linear model to tackle supplier selection problem. More recently, the use of fuzzy multi-objective programming in supplier selection has further increased. Arikan (2013) employed fuzzy multi-objective programming for multiple sourcing supplier selection problem. Nazari-Shirkouhi, Shakouri, Javadi, and Keramati (2013) developed an interactive fuzzy multi-objective linear programming model to solve the multi-objective supplier selection problem under multi-price level and multi-product in the fuzzy environment.

A number of studies have focused on the use of fuzzy multi-attribute decision making (MADM) techniques for supplier selection process such as fuzzy analytic hierarchy process (AHP), fuzzy analytic network process (ANP), fuzzy technique for order preference by similarity to ideal solution (TOPSIS), and fuzzy VIKOR. Chen, Lin, and Huang (2006) extended TOPSIS to develop a methodology for solving supplier selection problems in fuzzy environment. Chan and Kumar (2007) identified the decision criteria including risk factors for the development of an efficient system for global supplier selection. Fuzzy extended AHP based methodology was used in the selection procedure. Chan, Kumar, Tiwari, Lau, and Choy (2008) used a fuzzy modified AHP approach to select the best global supplier. Boran, Genc, Kurt, and Akay (2009) proposed intuitionistic fuzzy TOPSIS to select appropriate supplier in group decision making environment. Awasthi, Chauhan, and Goyal (2010) used fuzzy TOPSIS for evaluating environmental performance of suppliers. Sanayei, Mousavi, and Yazdankhah (2010) proposed fuzzy VIKOR method to select the suitable supplier in a supply chain system. More recently, Shemshadi, Shirazi, Toreihi, and Tarokh (2011) tackled supplier selection as a multiple criteria group decision making problem and developed a fuzzy VIKOR method to solve this problem. Kilincci and Onal (2011) investigated supplier selection problem of a well-known washing machine manufacturer in Turkey, and employed a fuzzy AHP based methodology to select the best supplier firm. Vinodh, Ramiya, and Gautham (2011) used fuzzy ANP for the supplier selection process, and presented a case study in an electronics switches manufacturing company.

Lately, several researchers have employed the quality function deployment (QFD) in supplier selection. In most of these studies, QFD was implemented in combination with AHP. Bevilacqua et al. (2006) constructed a HOQ to identify the features that the purchased product should possess in order to satisfy the customers' requirements. Then, the potential suppliers were evaluated against