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A fuzzy inference and categorization approach for supplier selection using compensatory and non-compensatory decision rules

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ABSTRACT

Fuzzy set theory has been used as an approach to deal with uncertainty in the supplier selection decision process. However, most studies limit applications of fuzzy set theory to outranking potential suppliers, not including a qualification stage in the decision process, in which non-compensatory types of decision rules can be used to reduce the set of potential suppliers. This paper presents a supplier selection decision method based on fuzzy inference that integrates both types of approaches: a non-compensatory rule for sorting in qualification stages and a compensatory rule for ranking in the final selection. Fuzzy inference rules model human reasoning and are embedded in the system, which is an advantage when compared to approaches that combine fuzzy set theory with multicriteria decision making methods. Fuzzy inference combined with a fuzzy rule-based classification method is used to categorize suppliers in qualification stages. Classes of supplier performance can be represented by linguistic terms, which allow decision makers to deal with subjectivity and to express qualification requirements in linguistic formats. Implementation of the proposed method and techniques were analyzed and discussed using an illustrative case. Three defuzzification operators were used in the final selection, yielding the same ranking. Factorial design was applied to test consistency and sensitivity of the inference rules. The findings reinforce the argument that including stages of qualification based on fuzzy inference and categorization makes this method especially useful for selecting from a large set of potential suppliers and also for first time purchase.

1. Introduction

Purchasing decisions affect important activities such as inventory management, production planning and control, cash flow requirements and product and service quality [1–5]. The ISO quality management system [6] also includes requirements for supplier selection and assessment. Thus, purchasing and supplier relationship management have become very critical activities for performance management of organizations and supply chains [7].

A key step in purchasing and supplier relationship management is that of supplier selection. Basically, supplier selection is a decision process with the purpose of reducing the initial set of potential suppliers to the final choices. De Boer et al. [8] proposed a well-known cited framework that divides the supplier selection decision process into four interrelated phases: problem definition, formulation of criteria, qualification and final choice. In general, decisions in the qualification and final selection phases are based on the performance of suppliers concerning multiple criteria and relative weights of such criteria. Several multicriteria decision making techniques are proposed in the literature to tackle the problem of supplier selection [8–10].

Another characteristic of supplier selection is that decision making is affected by uncertainty mainly due to the vagueness intrinsic to evaluation of qualitative criteria, as well as imprecise weighing of different criteria by different decision makers. Fuzzy set theory has been the most important approach used to deal with uncertainty in the supplier selection decision process [11]. It provides proper language by which imprecise criterion can be handled and it is able to integrate the analysis of qualitative and quantitative factors in the selection process. The use of fuzzy inference in supplier selection is proposed by Carrera and Mayorga [12] and Amindoust et al. [13]. One advantage of using fuzzy inference in decision making is the assumption of the concept of approximate reasoning in the inference process that models human reasoning. Another advantage is capturing the specialist's judgements in the knowledge base [14]. Different techniques for supplier selection based on fuzzy theory are proposed by Ordoobadi [15], Shen and Yu [16], Shu and Wu

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[17], Hsu et al. [18] and Lam et al. [19]. Other integrating techniques combining fuzzy theory with multicriteria methods are reviewed by Ho et al. [9], Wu and Barnes [10] and Chai et al. [11].

Apart from these characteristics, De Boer et al. [20] call attention to the point that two types of decision rules can be used in supplier selection: compensatory and non-compensatory ones. In the first case, decisions are based on the assumption that a bad performance of a supplier in a particular criterion can be compensated by high scores in other criteria and therefore its overall evaluation of performance and its rank will reflect this. On the contrary, decisions can be based on a non-compensatory rule. In the qualification phase of supplier selection, the main objective is to sort suppliers that meet minimum requirements for some performance criteria so they can be qualified as a potential supplier. In this phase, there should be no compensation for a supplier not meeting the minimum requirement in a particular criterion. Therefore, in the qualification stage, a non-compensatory decision rule is more appropriate than a compensatory one. On the other hand, when it comes to final selection, all qualified suppliers meet minimum requirements and thus outranking can be based on compensatory decision rules.

However, the majority of supplier selection models apply only compensatory types of decision rules for outranking suppliers [9–11], not considering the advantage of combining both types of decision rules. Therefore, this paper presents a supplier selection decision method based on fuzzy inference that integrates both types of approaches: a non-compensatory rule for sorting in qualification stages and a compensatory rule for ranking in the final selection. The qualification process is structured in subsequent stages of performance evaluation based on criteria identified by the literature review. Decisions in each qualification stage are the result of a fuzzy inference system (FIS) combined with the simple fuzzy grid method [21]. The resulting contribution of combining these methods is a procedure for pattern classification so as to sort suppliers into qualified and not qualified. After qualification, the performance of the qualified suppliers in the criteria evaluated in the previous stage are the input variables for another FIS to predict a global supplier performance index used for ranking suppliers in the final step.

A descriptive quantitative approach was adopted as a research method [22]. The fuzzy inference systems were implemented in MATLAB®. In an illustrative application case in the white goods manufacturing industry, qualification is carried out in four stages. In each stage, suppliers are evaluated by three performance subcriteria. A 3^K factorial design was used to test the consistency and sensitivity of the inference systems.

This paper is organized as follows: Section 2 briefly revises the subject of supplier selection, presenting the contributions from the literature in the process, criteria and methods for supplier selection. Section 3 aims to clarify some fundamental concepts regarding fuzzy set theory used in the proposition. Section 4 presents the proposed SS method, as well as details of implementation of the fuzzy inference systems. Section 5 presents and discusses the results of the illustrative case of application. Final considerations and conclusion concerning this research work are made in Section 6.

2. Supplier selection

Selecting suppliers involves determining the decision-making process, including the decision criteria as well as determining the multi-criteria decision methods to be used. Although most of the publications on SS focus on decision methods for the final choice phase [23], the supplier selection process comprises several steps previous to the final choice. De Boer et al. [8] propose a framework for supplier selection that consists of four steps: problem definition, formulation of criteria, qualification and choice. For each of these steps, variations from different purchasing situations are also considered such as: new task, modified or straight rebuy and routine or strategic/bottleneck items [24,25]. The first step aims at clearly defining the problem at hand which may mean searching for new suppliers for a completely new product, replacing current suppliers or choosing suppliers for new products from the same set of suppliers. In the next step, the buyer should translate their requirements into either quantitative or qualitative decision criteria so as to guide the choices. The main objective of the qualification step is to sort the potential suppliers from the initial set of suppliers based on qualifying criteria. Implicit in this qualification step is the non-compensatory rule of the decision making process [8]. The last step aims at ranking the potential suppliers so as to make the final choice. Here, unlike qualification, the compensatory decision rule applies so decision makers can select suppliers based on the resulting compensation between performance criteria. Sorting and ranking are especially important in decision making for new purchases, modified or straight rebuy of routine items in which there is usually a large set of potential suppliers. Wu and Barnes [10], based on this framework, proposed an additional step aiming at given feedback to potential suppliers in their performance in the selection process.

2.1. Supplier selection criteria

Formulating selection criteria is an extremely important step in the selection process. There are a number of descriptive studies that have attempted to identify criteria used by buyers to select suppliers. A seminal study conducted by Dickson [26] concluded that quality, delivery and performance history are the three most important criteria. Following this, Weber et al. [27] published a study based on the analysis of 74 papers on supplier selection criteria. They identified price as the most cited criterion, followed by delivery and quality. In a survey conducted with 139 manufacturing companies in the USA, Verma and Pullman [28] concluded that despite quality being perceived as the most important attribute, cost and on-time delivery are assigned more weight when actually choosing a supplier.

Kannan and Tan [29] also developed an empirical study on the importance of supplier selection and assessment criteria and their impact on business performance of the manufacturing companies surveyed. Out of 30 selection criteria, on-time delivery and quality were ranked as the most important. However, in another study [30] involving 12 purchasing professionals in the construction industry, the author reports that cost is placed as the most important criterion, followed by key competencies and the ability to collaborate, indicating the importance given to partnership and collaboration in supply networks.

Another study, by Katsikeas et al. [1], presents the results of a survey into British distributor firms of IT products. In their research, they confirmed a positive relationship among the four supplier selection criteria considered (reliability, price, service and technological capability) and distributors' performance. Ku et al. [31], based on a literature review, identified criteria for global supplier selection grouped as: cost or price, quality, service, supplier's profile, risk, buyer–supplier partnership, cultural and communication barriers and trade restrictions. Kahraman et al. [32] propose four groups of supplier performance criteria: supplier's profile, product performance, service performance and cost performance. Awasthi et al. [33] propose criteria for evaluating environmental performance of suppliers. Büyüközkan and Çifçi [34] present a summarized list of criteria for evaluating sustainability of suppliers including: organization; financial performance; service quality; technology; social responsibility and environmental competencies.