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Supplier selection in electronic marketplaces using satisficing and fuzzy AHP

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ABSTRACT

Supplier selection is a critical and demanding task for companies that participate in electronic marketplaces to find suppliers and to execute electronically their transactions. This paper is aimed to suggest a fresh approach for decision support enabling effective supplier selection processes in electronic marketplaces. We introduce an evaluation method with two stages: initial screening of the suppliers through the enforcement of hard constraints on the selection criteria and final supplier evaluation through the application of a modified variant of the Fuzzy Preference Programming (FPP) method. The proposed method alleviates the information overload effect that is inherent in the environment of electronic marketplaces, facilitates an easier elicitation of user preferences through the reduction of necessary user input (i.e. pairwise comparisons) and reduces computational complexity, in terms of the number of linear programs to be solved, in comparison with the original FPP method. The FPP method is adopted and modified accordingly in order to tackle the issue of inconsistency/uncertainty of human preference models. Our approach is demonstrated with the example of a hypothetical metal manufacturing company that finds and selects suppliers in the environment of an electronic marketplace.

1. Introduction

Business-to-Business commercial transactions are increasingly executed electronically. As indicated by the Economic Review of the Federal Reserve Bank of Kansas City, between 1999 and 2002, B2B e-commerce sales grew at an annual rate of 5.5 percent in the United States (Willis, 2004). Moreover, since the end of the nineties electronic marketplaces have played the role of an aggregator that merges potentially thousands of suppliers and customers as B2B electronic hubs. In the context of such environments, the critical task of supplier selection becomes an arduous procedure since the decision maker must make a choice between an abundance of alternatives. Furthermore, decision makers' interest about the supplier selection process has been continuously growing because reliable suppliers enable the reduction of inventory costs and the improvement of product quality (Braglia & Petroni, 2000). There is an agreement in relevant literature (Choy, Lee, & Lo, 2002) that selecting appropriate suppliers is a complicated issue because of the large number of criteria to be considered as well as because criteria are both quantitative (e.g. price, distance, delivery time) and qualitative (e.g. quality, design/technological capability, finances). Thus, there is an ongoing effort in the research community to develop appropriate techniques to grasp preferences and to define evaluation models and algorithms (Yang & Chen, 2006). Moreover, an electronic marketplace environment entails a potentially large number of candidate suppliers as well as the participation of buyer organizations with divergent needs and characteristics, which in their turn correspond to the identification of different decision criteria for the selection of suppliers (Pearson & Ellram, 1995). Therefore, electronic marketplaces make an effort to provide effective decision support services for supplier assessment and selection to their participants in order to enhance their satisfaction and loyalty (e.g. Ariba, Emptoris, Perfect Commerce, etc.) (Bartels, 2005).

The present paper, proposes a fresh approach for the provision of decision support to solve the supplier selection problem in an electronic marketplace environment. In particular, we propose a decision method that combines a special satisficing technique to prune the supplier selection search space with the application of a supplier ranking technique, a modified variant of the Fuzzy Preference Programming Method (Mikhailov, 2000), for the final supplier evaluation. A contribution of our work is that we modify Mikhailov's FPP method according to Liberatore's rating scale AHP method (Liberatore, 1987). This combination has both the advantages of the usual rating scale AHP approach and of the FPP method: it overcomes the explosion in the number of pairwise comparisons when the number of alternatives and/or the number of criteria is large (rating scale AHP) and at the same time solves the problem of inconsistency and of uncertain human preference models by using interval values for preference relations (FPP). The effectiveness of our approach is demonstrated through the provision of a numerical example of a metal manufacturing company that finds and selects suppliers in the environment of

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an electronic marketplace providing decision support services on this basis.

The remainder of this paper is organized as follows. Section 2 describes a background of the supplier selection process and related work. Section 3 introduces the proposed approach for supplier selection, consisting of supplier pre-qualification using Simon's satisficing model and supplier raking using a fuzzy AHP method. In Section 4 the proposed method is illustrated by a numerical example. Section 5 wraps up the paper with some concluding remarks.

2. Background

Modern industries have to adapt to a market environment that is characterized by openness to global competition. Therefore, companies are under pressure to rationalize their expenses, to reduce their production costs. Instrumental to this is the reduction of the purchasing costs through the selection of the appropriate suppliers (Dahel, 2003). Moreover, modern production systems such as Just-In-Time production and mass customization manufacturing presume the prompt supply of raw materials and outsourced parts in the expected quantity and with the expected quality (Yang & Chen, 2006). The importance of these requirements is further underlined by the fact that many businesses are outsourcing their operations in order to utilize more efficiently worldwide resources. Hence, it is understandable that decision makers are increasingly concerned about the effectiveness and rationality of the supplier selection process followed by their organizations.

Supplier selection is defined in (Sonmez, 2006) as the "*process of finding the suppliers being able to provide the buyer with the right quality products and/or services at the right price, at the right quantities and at the right time*". This process is generally described in the literature to consist of five stages: (1) Identification of the need for a new supplier; (2) Identification and elaboration of selection criteria; (3) Initial screening of potential suppliers from a large set; (4) Final supplier selection; and (5) Continuous evaluation and assessment of selected suppliers (de Boer, Labro, & Morlacchi, 2001; de Boer & van der Wegen, 2003).

Therefore, supplier selection initially requires the identification and elaboration of decision criteria that will guide the decision making process (stage 2). *Different organizations may choose different decision criteria for supplier selection according to several factors, the most important one being the size of the buyer organization* (Pearson & Ellram, 1995). Several studies have identified a number of qualitative and quantitative factors. Talluri and Baker (1996) propose a model that considers cost, time and distance, Wang, Ip, and Yung (2001) distinguish the factors of cost and due date, while Muralidharan, Anatharaman, and Deshmukh (2002) identify quality, delivery, price, technical capability, financial position, past performance, attitude, flexibility and service. Choi and Hartley (1996) identified eight predominant factors guiding supplier selection in the auto industry of the United States – finances, consistency, relationship, flexibility, technological capability, customer service, reliability and price. More recently, Yang and Chen (2006) performed a literature review and an interview with three business executives that concluded to six qualitative criteria including quality, finances, service, production capacity, design, technological capability and IT infrastructure and to four quantitative criteria including turnover, cost, delivery and distance. From this account, it becomes evident that there is no common identification of factors guiding the supplier selection process in the literature. This stems from the fact that decision criteria vary in relation with various characteristics of the buyer organization such as its size, the sector it belongs, etc.

The stages of the initial screening and of the final selection of suppliers involve the application of decision methods and algorithms. According to the literature review conducted in the framework of this study (Bottani & Rizzi, 2005; Chan, Kumar, Tiwari, Lau, & Choy, 2008; Ding, Benyoucef, & Xie, 2004; Fischer, Jahn, & Teich, 2004; Fuqing, Yi, & Dongmei, 2006; Ip, Huang, Yung, & Wang, 2003; Karpak, Kumcu, & Kasuganti, 1999; Sha & Che, 2005, 2006; Talluri, Baker, & Sarkis, 1999; Yang & Chen, 2006) we found that decision methods and tools can be divided into two broad categories: Linear Optimization and Non-Linear Optimization. The first category includes AHP (Bottani & Rizzi, 2005), Integer Programming (Ko, Kim, & Hwang, 2001) and Goal Programming approaches (Karpak et al., 1999; Talluri et al., 1999) while the second includes a variety of approaches with main emphasis on Genetic Algorithms (Ding et al., 2004; Ip et al., 2003). Nevertheless, in the course of our research we found that in some cases hybrid approaches that combine both linear and non-linear methods are followed (Sha & Che, 2005). The results of our study are compatible with Sonmez's survey. Sonmez (2006) classifies decision making methods in two groups: linear weighted and non-linear and reports the use of mathematical programming methods such as goal programming, integer programming, total cost approach and data envelopment analysis, as well as the use of artificial intelligence methods such as case based reasoning. Also, Analytical Hierarchy Process (AHP), Multiple Attribute Utility Theory (MAUT), Outranking Methods and multivariate statistical analysis are reported in his study as typical multiple criteria decision making methods. Finally, Yang and Chen (2006) classify supplier selection decision methods in three categories: linear-weighting, total-cost and mathematical programming.

The Analytic Hierarchy Process has been identified in a significant number of studies as a useful, practical and systematic method for supplier selection (Chan et al., 2008; Narasimhan, 1983; Saaty, 1980). However, the AHP method has been criticized for not taking into account risk and uncertainty in supplier assessment (Chan et al., 2008; Dyer, Fishburn, Steuer, Wallenius, & Zionts, 1992). Thus, many researchers have proposed fuzzified versions of the AHP in order to tackle the issues of risk and uncertainty (Bottani & Rizzi, 2005; Chan et al., 2008; Mikhailov, 2002).

On the other hand, as suggested by Herbert Simon in his groundbreaking work (Simon, 1955, 1979) limitations in information gathering, computing abilities and a limited memory do not allow decision makers to take into account all possible alternatives in a decision environment characterized by uncertainty. Therefore, decision makers are forced to use simplifying decision strategies or heuristics, alternatives may be disregarded and "satisficing" alternatives may be accepted (Carter, Kaufmann, & Michel, 2007; Tversky & Kahneman, 1974, 1986). It must be underlined that Simon's breakthrough with regard to normative theories of decision making was the introduction of the notion of "bounded rationality". As we mentioned above, this notion was introduced because of the inherent weaknesses of the assumption of "perfect rationality" made by classical theory: all alternatives are rarely known, consequences of the alternatives are imperfectly known because of both limited computational power and uncertainty about exogenous events, in many cases no general and consistent utility function for comparing heterogeneous alternatives exists. To face these difficulties the theory of "bounded rationality" proposes the following measures: replacing optimal choices with satisfactory ones according to minimum standards that may change according to the environment, replacing abstract goals with tangible sub-goals, whose achievement can be observed and measured, and grasping decision making as an organization process so that choice is not only determined by the objective characteristics of the problem situation, but also depends on the particular heuristic process used by the organization to reach the decision (Simon, 1979).

The method presented in this paper is a synthesis of a satisficing approach with fuzzy AHP. Satisficing is used in the first stage of the