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Designing a decision support system to evaluate and select suppliers using fuzzy analytic network process

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ABSTRACT

Recent information and communication developments caused that global organizations spread out their markets throughout the world. In this environment, local exclusive markets have been replaced with global competitive ones. Therefore, organizations must concentrate on their main operations to survive in such an environment. To do so, managers have intended to cooperate with some financial partners in long-term relations. In this paper, the aim is to develop a fuzzy analytic network process (ANP) model to evaluate the potential suppliers and select the best one(s) with respect to the vendor important factors. Additionally, ANP is developed by fuzzy sets theory to cover the indeterminacy of decisions made in this field. The authors have augmented the model with a non-linear programming model to elicit eigenvectors from fuzzy comparison matrices. Hybridization of these two concepts can model supplier selection problem in all circumstances and reaches the optimal choice. Finally, a numerical sample is used to validate the proposed model.

1. Introduction

Nowadays, organizations have realized that it is necessary to consider some other issues, such as product quality and manufacturing procedures, rather than traditional factors like prices, production rate, etc. Overcoming these issues, the organizations can succeed and survive in the global competitive markets. To do so, they must concentrate on their main operations and organizational goals and managers have decided to outsource non-strategic operations. Outsourcing help organizations focus on the important factors affecting their main operations. However, some items like supplier selection procedure and criteria are considerably essential in outsourcing. Moreover, cost of parts and raw materials forms a major portion of enterprises' expenditures in most industries. As it is declared, purchasing cost can make 70% of the production cost (Ghobadian, Stainer, & Kiss, 1993), and even exceeds 80% in hi-tech production environment (Weber, Current, & Benton, 1991). Therefore, proper purchasing strategies, and especially proper suppliers, can play a key role in management of successful organizations and it is worthwhile to invest on making appropriate decision on supplier selection.

Supplier selection is a complex decision making process in nature due to different parameters and various aspects which must be regarded. However, in a research performed by Verma and Pullman (1998), it is concluded that managers consider quality as the most important factor to select suppliers, though they actually select them regarding their costs. In a comprehensive study (Dickson, 1966); the author presents 23 criteria to select suppliers (Table 1); while some other different criteria are considered in the recently developed models. Moreover, some distinct factors are taken into account by Chou and Chang (2008), Üstün and Demirtas (2008) and Lee (2008) which are generally based upon management concepts. The involved parameters have various statuses and can be either dependent or independent. In addition, it is not possible to assign exact values to these parameters in most cases. To tackle the problem, some of methods have been proposed among which analytic hierarchy process (AHP) (Saen, 2007a), Cluster Analysis (CA) (Bottani & Rizzi, 2007) and data envelopment analysis (DEA) (Braglia & Petroni, 2000) can be mentioned. Most of the proposed methods cannot completely model supplier selection problem in a suitable, practical manner. In this paper, a hybridization of analytic network process and fuzzy sets theory is proposed to model and solve the problem under uncertain nature of the decision making process which made the model more applicable for practical situations. The proposed model is enhanced with a non-linear programming model to elicit weights of comparisons from comparison matrices in the ANP structure.

The structure of this paper is as follows: Section 2 reviews the literature of the problem. Section 3 describes analytic network process in detail. The paper follows in Section 4 on the proposed algorithm. Section 5 illustrates a numerical example to validate

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Table 1
Dickson's criteria.

No.	Suppliers selection criteria
1	Supplier's suggested net price (including discounts and transportation costs)
2	Supplier's qualitative capabilities
3	After sales services
4	Supplier's delivery capabilities
5	Supplier's geographical situation
6	Supplier's financial status
7	Supplier's capacity and production facilities
8	Supplier's partnership antecedents
9	Supplier's technical capacity (including R&D capabilities)
10	Supplier's organization and management
11	Future potential purchases from supplier
12	Supplier's information system (with processing information)
13	Supplier's operational control (including reporting, quality control, and inventory control system)
14	Supplier's status in related industry (including credit and leadership)
15	Supplier's individuals antecedents
16	Supplier's organizational behavior
17	Supplier's eagerness to cooperate
18	Supplier's policy of guarantee and legal claims
19	Supplier's capability to meet the product requirements
20	Effects of supplier's contract on other contracts
21	Suppliers educational aids corresponding products
22	Supplier's adaptation with the purchaser's procedures and instruments
23	Supplier's performance antecedents

the proposed algorithm. Finally, Section 6 comprises some results and remarking conclusions.

2. The literature review toward the supplier selection problem

There have been several approaches to tackle the supplier selection problem. One of these approaches is utilization of purchasing planning models. In some attempts such as De Boer, Labro, and Morlacchi (2001), it is shown that these models are applicable to the supplier selection problem. Also, an important aspect of this problem is its dynamism which is considered in some works such as (Marshal, Lamming, Fynes, & Deburca, 2005). However, different methods with different approaches have been developed to help decision makers to decide more profitably. As follows, some developed ones are reviewed.

One class of the major methods in this field is comparing methods. Two conventional comparing methods are DEA and CA, in which potential suppliers' qualification is assessed upon comparisons with each other. DEA is a multi-attribute decision making tool for productivity analysis. This method is adopted by Weber and Desai (1996) to determine inefficient suppliers. Also in a research conducted by Braglia and Petroni (2000), a DEA method is proposed to handle different conflicting criteria in supplier selection problem. The authors validated the model via a real-world case in a medium-sized manufacturer of bottling machinery and packaging lines. In another attempt, Saen (2007b) has proposed a model based on Imprecise DEA (IDEA) to consider both quantitative and qualitative data without any weighting process by decision makers. However, a drawback of DEA is that it cannot find the best alternative among potential ones, while the supplier selection problem involves in selecting the best supplier. Another method can be categorized in this class is AHP. In a research in which AHP is accompanied with Mixed Integer Programming (MIP), Ghodsypour and O'Brien (1997a) developed a decision support system (DSS) to reduce the number of suppliers and manage partnership with them. In a similar attempt, Ghodsypour and O'Brien (1997b) utilized AHP with linear programming (LP) model which consider both qualitative and quantitative factors in a systematic approach. Another AHP-based model is proposed by Saen (2007a); he developed a model based upon non-homogenous Decision Making Units (DMUs), which was incorporated with AHP. The author respected each supplier as a DMU and the AHP is utilized to determine the weights of units in each input and output vector. In a recent research (Levary, 2008); a new AHP model is developed with respect to the risk of production interruption in cooperation with each potential supplier.

Another approach to solve this problem is mathematical programming which can be classified in several categories. One category which is adopted in many kinds of problems in literature is multi-objective optimization models. For instance, Weber and Current (1993) utilized a multi-objective linear programming in supplier selection to tradeoff among different conflicting criteria. Some other models are LP whereby several criteria, such as total cost of production and outsourcing are to be minimized. Liu, Wang, Luo, and Wang (2005) proposed a linear programming model which optimizes lot sizes in consequential production periods. In a hybrid fuzzy linear programming, Zimmermann (1987) adopted fuzzy sets theory to interpret linguistic judgments about suppliers. Also, Ng (2008) developed a weighted linear programming in which a transformation procedure is utilized. This transformation converts the linear model into a new model which does not need to be solved using an optimizer. Inspired from the Ng (2008), Amin and Razmi (2008) integrated a quantitative model with Quality Function Deployment (QFD) concept toward Internet Service Provider (ISP) selection. Among other researches utilized LP, readers are referred to Moore and Fearon (1973), Anthony and Buffa (1977), Buffa and Jackson (1983), Kingsman (1986), Turner (1988), Sevkli, Koh, Zaim, Demirbag, and Tatoglu (2008) and Razmi, Songhori, and Khakbaz (2008). As the supplier selection problem involves in selection, it can be well modeled by Integer Programming (IP). Gaballa (1974), the first researcher who utilized mathematical programming, formulated a Mixed Integer Programming (MIP) in Australian Post Office, by which an objective of suppliers' discounted prices is minimized. In another research based upon a real-world case, Narasimhan and Stoynoff (1986) proposed a single objective MIP model in a large-scale production company in Midwest to select optimally a group of suppliers. Similarly, MIP models can be found in Sharma, Benton, and Srivastava (1989), Chaudhry, Forst, and Zidyak (1993) and Wu, Sukoco, Li, and Chen (2008).

Recently, Artificial Intelligence (AI) has been applied to cope with the different problems. Some methods, such as Expert Systems (ES), case-based reasoning (CBR) and neural networks (NN), are used to select intelligently the desired supplies. In a research using CBR, Choy, Lee, Lau, and Choy (2005) propounded a knowledge-based model to select suppliers. In a related research (Valluri & Croson, 2005), an agent-based model was developed to (1) filter capable suppliers to produce high-quality goods, and (2) provide incentives for these suppliers to enhance the quality of their products to the highest level possible. In another attempt (Jiménez, Mateos, Ríos-Insua, & Rodríguez, 2007); a DSS, namely Generic Multi-Attribute Analysis, is designed and developed to select a suppler for cleaning services in a real-world case. This system can operate with incomplete information about decision-maker preferences and taken into account the uncertainty of offers' performances.

The great drawback of all mentioned methods is ignorance of interrelations and feedbacks among criteria. Thus, a fuzzy ANP model is developed in this research to consider these interdependencies, because ANP is able to model the interactions among factors and criteria as well as possible (Saaty & Vergas, 2006). Additionally, indeterminacy involved in decision making process is overcome using fuzzy sets theory. The proposed fuzzy ANP model is augmented with a non-linear programming model to improve the quality of comparison results.

3. The analytic network process

In the middle of the nineties, Saaty (1996) proposed ANP to decompose a multi-criteria decision making problem into components.