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Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company

Semih Önüt *, Selin Soner Kara, Elif Işik

Mechanical Faculty, Department of Industrial Engineering, Yildiz Technical University, 34349 Yildiz, İstanbul, Turkey

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ABSTRACT

With the globalization and the emergence of the extended enterprise of interdependent organizations, there has been a steady increase in the outsourcing of parts and services. This has led firms to give more importance to the purchasing function and its associated decisions. Since these decisions require a long term investment for the telecommunication industry especially and affect the strategic positioning of the companies in the sector, the selection of the proper supplier is one of the most important problems. Supplier selection is a multi-criteria problem which includes both tangible and intangible factors. This paper develops a supplier evaluation approach based on the analytic network process (ANP) and the technique for order performance by similarity to ideal solution (TOPSIS) methods to help a telecommunication company in the GSM sector in Turkey under the fuzzy environment where the vagueness and subjectivity are handled with linguistic terms parameterized by triangular fuzzy numbers. Contrary to conventional Fuzzy ANP (FANP) methodology in the literature, we use triangular fuzzy numbers in all pairwise comparison matrices in the FANP. Hence, criteria weights are calculated as the triangular fuzzy numbers and then these fuzzy criteria weights are inserted to the fuzzy TOPSIS methodology to rank the alternatives. This approach is demonstrated with a real world case study involving six main evaluation criteria that the company has determined to choose the most appropriate supplier. The study was followed by the sensitivity analyses of the results.

1. Introduction

Supplier selection process is one of the most important components of production and logistics management for many companies. Selection of a wrong supplier could be enough to upset the company's financial and operational position. Selecting the right suppliers significantly reduces purchasing costs, improves competitiveness in the market and enhances end user satisfaction. The selecting process mainly involves evaluation of different alternative suppliers based on different criteria. This process is essentially considered as a multiple criteria decision-making (MCDM) problem which is affected by different tangible and intangible criteria including price, quality, performance, technical capability, delivery, etc. A number of alternative approaches have been proposed to take these criteria into account, called mathematical programming models, multiple attribute decision aid methods, cost-based methods, statistical and probabilistic methods, combined methodologies and other methods. Hence considerable amount of studies have been developed for supplier evaluation and selection problem since 1960. Among the available multi-attribute decision-making methods, only the analytic network process (ANP) can be used to evaluate the most suitable suppliers systematically due to the dependencies and feedbacks caused by the mutual effects of the criteria. The ANP is a multi-attribute approach for decision-making that allows for the transformation of qualitative values into quantitative values and performing analysis on them. Essentially it is a more general form of the analytical hierarchy process (AHP). The AHP is a special case of the ANP and it does not contain feedback loops among the factors. Hence, we selected the ANP method to calculate relative weights of criteria in our study. There are many weight calculation procedures, but the ANP has some advantages. One of the most important advantages of the ANP is based on pair-wise comparison. Furthermore it considers the dependencies and feedbacks of the criteria.

However, in many problems the human assessment is uncertain, and it is relatively difficult for the decision-maker (DM) to provide exact numerical values for the criteria. Hence most of the selection parameters can not be given precisely and the evaluation data of the alternative suppliers' suitability for various subjective criteria and the weights of the criteria are usually expressed in linguistic terms by the DMs. Furthermore, it is also recognized that human judgment on qualitative attributes is always subjective and thus imprecise. In order to model this kind

* Corresponding author. Tel.: +90 212 259 70 70x2652; fax: +90 212 261 66 59.
E-mail address: onut@yildiz.edu.tr (S. Önüt).

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of uncertainty in human preference, fuzzy logic could be a more natural approach. The ANP method deals only with crisp comparison ratios. However, uncertain human judgments with internal inconsistency obstructing the direct application of the ANP are frequently found. To cope with this problem, the fuzzy ANP (FANP) method can be used (Yu & Tzeng, 2006). Contrary to conventional FANP methodology in the literature, in our proposed method, the linguistic assessment is converted to (triangular) fuzzy numbers firstly. These triangular fuzzy numbers are used to build pair-wise comparison matrices for the ANP. In the FANP, weights are more simple to calculate than for conventional ANP. However, sometimes large number of pairwise comparisons should be performed by DMs and this situation become impractical the usage of the FANP process in some cases. To cope with this problem, fuzzy TOPSIS technique is then used to reduce the number of pairwise comparisons and to rank the alternatives in our study.

The technique for order performance by similarity to ideal solution (TOPSIS) (Hwang & Yoon, 1981) is a widely accepted multi-attribute decision-making technique due to its sound logic, simultaneous consideration of the ideal and the anti-ideal solutions, and easily programmable computation procedure (Karsak, 2002). This technique is based on the concept that the ideal alternative has the best level for all attributes, whereas the negative ideal is the one with all the worst attribute values. In fuzzy TOPSIS, attribute values are represented by fuzzy numbers. Using this method, the DM's fuzzy assignments with different rating viewpoints and the trade-offs among different criteria are considered in the aggregation procedure to ensure more accurate decision-making.

As mentioned before, supplier evaluation and selection has received considerable attention in the literature. Since we used the ANP and TOPSIS methods under fuzzy environment, we only focused on the supplier selection literature related to these methods and similar approaches. The AHP is used for supplier selection problems commonly, instead of the ANP. Some examples of the supplier selection literature related to the AHP are given as follows. Ghodsypour and O'Brien (1998) proposed an integration of an AHP and linear programming to consider both tangible and intangible factors in choosing the best suppliers. Tam and Tummala (2001) proposed an AHP-based model and applied to a telecommunications company to examine its feasibility in selecting a vendor for a telecommunications system. Haq and Kannan (2006) developed an integrated supplier selection and multi-echelon distribution inventory model for the original equipment manufacturing company in a built-to-order supply chain environment using fuzzy AHP and a genetic algorithm. Pi and Low (2006) suggested a method for supplier evaluation and selection based on quality, on-time delivery, price and service. The model quantifies these four multiple criteria in terms of Taguchi quality loss and then uses an AHP to combine them into one global variable for decision-making. Chan and Kumar (2007) presented a fuzzy extended AHP-based methodology for global supplier selection. Xia and Wu (2007) proposed an integrated approach of AHP improved by rough sets theory and multi-objective mixed integer programming to simultaneously determine the number of suppliers to employ and the order quantity allocated to these suppliers in the case of multiple sourcing, multiple products, with multiple criteria and with supplier's capacity constraints.

Although the AHP has been applied to many supplier selection problems summarized above, the ANP and TOPSIS has received much less attention in the supplier selection literature. Chen, Lin, and Huang (2006) developed a hierarchy multiple criteria decision-making model based on fuzzy sets theory to deal with the supplier selection problems. Their model uses the concept of TOPSIS to determine the ranking order of all suppliers. Shyur and Shih (2006) recently developed a combined ANP and TOPSIS model for strategic vendor selection. Furthermore the FANP has also received much less attention in the all literature than the classical ANP (Büyüközkan, Ertay, Kahraman, & Ruan, 2004; Ertay, Buyukozkan, Kahraman, & Ruan, 2005; Kahraman, Ertay, & Buyukozkan, 2006; Mikhailov & Singh, 2003; Mohanty, Agarwal, Choudhury, & Tiwari, 2005). Although there were a number of publications selecting the most suitable supplier alternatives in the literature and some of them have been prepared using the multi-attribute/multi-criteria decision-making methods considering human judgments, tangible, intangible and multiple criteria, there is no evidence in the literature that any of them were prepared with the aim of the selection of the suitable supplier using either the ANP or integrated ANP and TOPSIS methodology under a fuzzy environment. Our study proposes an integrated FANP and fuzzy TOPSIS methodology for evaluating and selecting the most suitable suppliers for a telecommunication company in the GSM sector as a real world application. Fuzzy TOPSIS is used to select a supplier alternative and the FANP is applied to calculate criteria weights. In conventional FANP methodology, DMs' linguistic evaluations in fuzzy forms are first converted to crisp numbers by using different algorithms and then these crisp evaluations are used in the ANP to performed pairwise comparisons. Contrary to conventional FANP methodology in the literature, we use triangular fuzzy numbers in all pairwise comparison matrices through the FANP. Hence, criteria weights are calculated as the triangular fuzzy numbers and then these fuzzy criteria weights are inserted to the fuzzy TOPSIS methodology to rank the alternatives.

The rest of the paper is organized as follows. Section 2 describes the contents of the ANP process. Fuzzy theory is briefly reviewed in Section 3. Sections 4 and 5 describe the basics of the FANP and fuzzy TOPSIS, respectively. Section 6 presents application of the integrated model to the supplier selection problem as a real world case study. The results of the application are discussed and some of the model parameters are evaluated with the sensitivity analysis in Section 7. In Section 8, the conclusions, main findings and contributions are drawn and future developments are suggested.

2. The ANP

The ANP is the most comprehensive framework for the analysis of corporate decisions. It allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in human society, especially when risk and uncertainty are involved. The elements in a cluster may influence other elements in the same cluster and those in other clusters with respect to each of several properties. The main object is to determine the overall influence of all the elements. In that case, first of all properties or criteria must be organized and they must be prioritized in the framework of a control hierarchy. Then the comparisons must be performed and synthesized to obtain the priorities of these properties. Additionally, the influence of elements in the feedback system with respect to each of these properties must be derived. Finally, the resulting influences must be weighted by the importance of the properties and added to obtain the overall influence of each element (Saaty, 2003; Saaty, 1999).

The modeling process can be divided into three steps for the ease of understanding which are described as follows:

2.1. Step I: the pairwise comparisons and relative weight estimation

Before performing the pairwise comparisons, all criteria and clusters compared are linked to each other. There are three types of connections, namely one-way, two-way and loop. If there is only one-way connection between two clusters, only one-way depen-