Expert Systems with Applications 37 (2010) 1939–1945

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Development of a fuzzy decision support system for commodity acquisition using fuzzy analytic network process

Semra Boran [a], Kerim Goztepe [b,*]

[a] Department of Industrial Engineering, Sakarya University, Esentepe Campus, 54187 Sakarya, Turkey
[b] Institute of Science and Technology, Sakarya University, Esentepe Campus, 54187 Sakarya, Turkey

ARTICLE INFO

Keywords:
Commodity acquisition
Fuzzy analytic network process (FANP)
Supply chain management

ABSTRACT

Commodity acquisition is one of the most critical tasks in a firm especially for an accountancy department. Because of imprecise and uncertain product requirements, firm accountants have to make their best effort at this stage. Determining the most critical criteria for commodity acquisition process is a vital means for a firm to balance its limited budget. Therefore, firms have used different methods to cope with this time-consuming and mentally intensive process. This study develops a fuzzy analytic network process model which may help firm accountants in this process. Results derived from a data sample are presented to exemplify the established model. Briefly, this paper proposes an intelligent approach to vendor selection through a fuzzy ANP which takes into consideration quantitative and qualitative elements in evaluating vendor alternatives.

1. Introduction

Supply chain management (SCM) has gained influence and became very important for efficient management of industrial activities over the years. The effect of SCM has increased growingly with the developments in areas such as operations research, management and decision-making. If used, SCM provides a competitive advantage to organizations and firms. Commodity acquisition is a part of SCM and does not cover the whole process. Deciding on the correct supplier reduces commodity costs and improves competitiveness in the market.

The model presented in this paper helps to structure commodity acquisition by evaluating alternative suppliers through a systemic multi-attribute analytical technique, known as the fuzzy analytic network process (FANP) (Chang, 1996; Kahraman, Ertay, & Buyukozkan, 2006; Mikhailov, 2003a, 2004). An illustrative example providing additional insights for research and practical application is given in this study. Below, a review of some analytical models for strategy development and decision-making in supply chain management and commodity acquisition is presented.

2. Related research

The ANP is a comparatively simple and systematic mathematical model that can be used in decision-making process. In fact ANP is a more general form of the analytical hierarchy process which is introduced by Saaty (1996). Due to the mutual dependencies and feedback effect of the criteria, ANP is used to evaluate the many problems in different sectors, such as logistics (Jharkharia & Shankar, 2007; Meade & Sarkis, 1998), election and selection process (Boran, Goztepe, & Yavuz, 2008; Meade & Presley, 2002) and environmental studies (Promentilla, Furuichi, Ishii, & Tanikawa, 2006a). The ANP is a multi-attribute approach in decision-making process which helps transform qualitative values into quantitative ones.

Researchers have utilized the FANP method for various problem areas. Buyukozkan, Ertay, Kahraman, and Ruan (2004) applied a fuzzy ANP approach to quality function deployment problems. When establishing an ANP model, uncertain human judgments with internal inconsistencies very often prevent the direct application of the model. Yu and Tzeng (2006) tried to solve this problem by using FANP method in their studies. The method was used successfully in a transportation problem aiming to select the best mode of transportation between two countries, Turkey and Germany (Tuzkaya & Onut, 2008). Onut, Kara, and Isik (2009) worked on a supplier selection model for a telecommunication company using a combined fuzzy multiple criteria decision-making (MCDM) and included FANP in his study. In another study, Chan and Kumar (2007) demonstrated a fuzzy extended AHP-based methodology for global supplier selection. Some different procedures related to fuzzy AHP are used in studies of Csutora and Buckley (2001), Mikhailov (2003a) and Kahraman et al. (2004).

3. The ANP method

Although there are many multi-attribute decision-making methods, analytic network process is unique in evaluating the

* Corresponding author.
E-mail addresses: boran@sakarya.edu.tr (S. Boran), kerimgoztepe@yahoo.com (K. Goztepe).

0957-4174/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2009.07.017

most appropriate suppliers according to the feedbacks given by decision makers or experts. The ANP approach, as used in this study, not only leads to a logical result but also enables the commodity acquisition experts or company accountants to visualize the impact of various criteria in the final result. ANP integrates various criteria, alternatives and enablers in the decision model. The method also provides an appropriate approach for relationships and interdependencies between criteria across and along the hierarchies.

4. Background of fuzzy sets and fuzzy-ANP method

4.1. Triangular fuzzy numbers

The fuzzy set theory is introduced by Zadeh (1965, 1976) to deal with the uncertainty and imprecision related with information concerning several parameters. A fuzzy set can be described in different ways: either one can enumerate the elements that belong to the set, or describe the set analytically by stating conditions of membership, or depict the member elements by using a characteristic function or by the level sets. Namely there are two main steps for representing fuzzy sets: identifying a suitable universe of discourse and defining membership functions (Yager & Zadeh, 1992).

One of the basic aspects of human cognition is uncertainty (Zadeh, 2005). People do not express their impressions precisely in their daily life. Such vague notions as 'equally', 'moderately', 'strongly', etc. are used in order to describe a situation by the people. For instance rain is a mutual phenomenon which is difficult to describe. The word rain does not adequately describe variations in the intensity or amount. So rain can be regarded as a fuzzy phenomenon (Li & Yen, 1995).

A fuzzy number is a special fuzzy set denoted as $F = \{(x, \mu_F(x), x \in R\}$,where x takes values on the real line, $R: -\infty < x < +\infty$ and $\mu_F(x)$ is a continuous mapping from R to the closed interval $[0,1]$ (Zimmermann, 1994). Fuzzy set theory offers various methods to convert the qualitative judgment of the experts or decision makers to quantitative data. In the model for commodity acquisition triangular fuzzy numbers (TFN) are used in order to represent expert's opinion.

A TFN is announced simply as $(l/m, m/u)$ or (l,m,u). A tilde '$\sim$' will be placed above a symbol if the symbol represents fuzzy sets. The parameters l, m, and u denote the smallest possible value (lower bound), the modal value, and the largest possible value (upper bound) respectively and describe a fuzzy event. (l,m,u) is expressed in the following form (Ding & Liang, 2005):

$$\mu(x/\widetilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \leqslant x \leqslant m, \\ (u-x)/(u-m), & m \leqslant x \leqslant u, \\ 0, & x > u. \end{cases} \quad (1)$$

4.2. Fuzzy ANP method

Inconsistency of judgments in pairwise comparisons is measured by the consistency ratio (CR) proposed by Saaty (1980) as a test for the reliability of the decision results in both AHP and ANP method. Experts or decision makers are expected to revise and change their judgment to improve the consistency if the computed CR is more than 0.10. If CR values are high, there are some errors in the decision-making process and also in the judgment-making phase.

FANP method adapts the subjectivity of human judgment as being expressed in natural language. Reaching a conclusion is sometimes impractical and unclear to acquire exact judgments in pairwise comparisons. For instance in a comparison between an X and Y elements, it can be said that X is strongly preferred than Y. But if the question "*how strongly X dominates Y*" is asked, the answer will not be exact. There is always an uncertainty in a decision-making process. The words used in the science of decision-making are always unclear and fuzzy. Fuzzy based method, FANP, is able to meet required formation for uncertain and vague pairwise comparisons. In this study the aim of FANP is to capture the fuzziness in the commodity acquisition model and so in evaluation of factors and sub-factors.

FANP has some additional advantages according to the conventional ANP method. It gives more practical results in pairwise comparison process. Therefore the method uses a linguistic scale which helps the decision maker or the expert and provides a more flexible approach in reaching a conclusion. FANP method gives better elucidation and learning in decision-making process.

Below main advantages of the FANP against classical ANP are given (Mikhailov & Singh, 2003b)

- It better models the ambiguity and imprecision associated with the pairwise comparison process.
- It successfully derives priorities from both consistent and inconsistent judgments.
- It is cognitively less demanding for the decision makers.
- It is an adequate reflection of the decision-makers' attitude toward risk and their degree of confidence in the subjective assessments.

5. Commodity acquisition model

Commodity acquisition is a critical process for a company and can be evaluated in supply chain management. A wrong supplier selection for commodity acquisition can damage company's operational and financial situation. One of the critical challenges faced by company accountants is the selection of the vendors which provide required commodities at the exact time with best available price. Quality, delivery, flexibility etc. are important strategic and operational factors for the selection of a vendor.

5.1. Chang's extent analysis method

Chang's (1992, 1996) extent analysis method is used in commodity acquisition model. Steps of this method are especially easier than other known ones. Variables for the extent analysis method are provided below;

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set and $U = \{u_1, u_2, \ldots, u_m\}$ be a goal set. Each object is taken and extent analysis for each goal, g_i, is performed, respectively according to this method. Thus, m, extent analysis values for each object, can be obtained with the following signs:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, \quad i = 1, 2, \ldots, n, \quad (2)$$

where all the $M_{g_i}^j$ $(j = 1, 2, \ldots m)$ are TFN.

The steps of the method are presented below:

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \quad (3)$$

To obtain $\sum_{j=1}^{m} M_{g_i}^j$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \quad (4)$$