Expert Systems with Applications 38 (2011) 8251–8258

Contents lists available at ScienceDirect

Expert Systems with Applications

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

Joint selection of customs broker agencies and international road transportation firms by a fuzzy analytic network process approach

Arzum Özgen [a,*], Mehmet Tanyas [b,1]

[a] Department of Industrial Engineering, Faculty of Engineering and Architecture, Okan University, Akfirat 34959, Tuzla, Istanbul, Turkey
[b] Department of International Trade and Logistics Management, Economics & Administrative Sciences Faculty, Maltepe University, Maltepe 34857, Istanbul, Turkey

ARTICLE INFO

Keywords:
Logistic activities
Customs broker
International road transportation
Analytic network process
Fuzzy sets

ABSTRACT

This paper considers a special case for logistics activities in Turkey: a joint selection of customs broker agency and international road transportation firm. For this purpose a decision-making team has been constituted, including members of logistics and finance departments and an academic. They determined related quantitative and qualitative criteria for the selection process. To cover the vagueness of related qualitative data, a fuzzy analytic network process (FANP) based model was formulated and applied to the decision-making process. The FANP model encompasses and substantially resolves the ambiguity and imprecision of the pairwise comparison process. By using the proposed FANP structure, the joint selection problem could be solved in a much easier way by also considering the inter-dependencies related to criteria.

1. Introduction

The pressure that the challenges of globalization puts on the shoulders of firms means that supply chain management has become an issue that goes beyond national boundaries. Manufacturing firms typically set up foreign factories in order to benefit from tariff and trade concessions, low-cost direct labor, capital subsidies and in order to develop close relationships with suppliers (Amin & Razmi, 2009; Chou & Chang, 2008; Ferdows, 1997; Lee, 2009; Wu, Sukoco, Li, & Chen, 2009). In this global perspective, significant geographical distances simply cause an increase in logistics costs. Nowadays firms focus on those core activities which are critical to their survival, and they assign the remaining activities to specialized firms. Many researchers have addressed the increasing use of logistics outsourcing as a widespread source of competition (Huiskonen & Pirttilä, 2002; Isiklar, Alptekin, & Buyukozkan, 2007; Jharkharia & Shankar, 2007; Liu & Wang, 2009; Wong & Karia, 2010).

Recent benchmarking studies have found that organizations often make important insourcing/outsourcing decisions without fully understanding all the implications. A "quick and dirty" approach to such decisions can have devastating results, including the loss of a core competence, or the outsourcing of an activity to a supplier or customer that could not meet customer performance requirements.

Several methodologies have been applied to logistics outsourcing and third party logistics provider selection problem. Traditional methods, such as the categorical method (CM) and the cost ratio method (CRM), have been studied by Timmerman (1987). Data envelopment analysis (DEA) also with consideration of multiple inputs and multiple outputs offers an estimate of comparative efficiency (Celebi & Bayraktar, 2008; Saen, 2007). Mathematical programming methods such as goal programming (GP), compromise programming (CP), multi-objective programming (MOP) have also been applied (Lee, Kang, & Chang, 2009; Lin, 2009; Sanayei, Mousavi, & Yazdankhah, 2009; Tsai & Chou, 2009) to selection problems. Examples of methods based on artificial intelligence (AI) technology that have been applied to supplier selection include neural networks and expert systems (Choy, Lee, & Lo, 2003; Lee & Ou-Yang, 2009). These methods mostly considered solving selection problems with quantitative criteria. Alongside these methods, several different group decision-making methods which take into consideration various forms of vagueness have also been developed. This goal has also been approached by the use of multi-criteria decision-making (MCDM) techniques such as analytic hierarchy processes (AHP), analytic network processes (ANP), technique of order preference by similarity to ideal solution (TOPSIS), elimination and choice expressing reality (ELECTRE) and preference-ranking organization method for enrichment evaluations (PROMETHEE). Some of these techniques give better results for specific decision problems.

* Corresponding author. Tel.: +90 (216) 6771630 (1960); fax: +90 (212) 2110717.
E-mail addresses: arzum.eser@okan.edu.tr, arzumeser@hotmail.com (A. Özgen), mehmettanyas@maltepe.edu.tr (M. Tanyas).
[1] Tel.: +90 (216) 626 10 50 (2646); fax: +90 (216) 626 10 70.

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doi:10.1016/j.eswa.2011.01.005

Supplier selection decisions are generally based on a set of criteria which are evaluated by experts. These evaluation criteria are usually in conflict with each other, and this further complicates the decision-making process. Tradeoffs between the evaluation criteria must be analyzed (Montazer, Saremi, & Ramezani, 2009). As can be seen from the literature, most of the multiple-criteria decision-making techniques give this opportunity. However, it can be seen that in most of the recent studies, decision-makers have preferred to use linguistic expressions. Recognizing this fact, in recent studies hybrid methods have been developed by combining decision-making techniques with fuzzy set theory (Boran, Genç, Kurt, & Akay, 2009; Ho, Xu, & Dey, 2009).

In this study a fuzzy analytic network process (F-ANP) approach has been proposed for the joint selection of Turkish customs broker agencies and international road transportation firms. The analytic network process (ANP) is a widely-used multiple-criteria decision-making tool which was first proposed by Saaty (1996). ANP can be applied to tackle more general structures, including interrelationships between different criteria in different clusters or within the same cluster, while AHP can only model strictly hierarchical structures. Hence, ANP can be considered a more general form of AHP, in which dependencies and feedbacks between elements of a decision can be modeled (Razmi, Rafiei, & Hashemi, 2009). Beside these advantages, ANP has a great drawback, which is the pairwise comparison section. This section consists of deterministic comparisons, while real world cases by their very nature contain vagueness. Therefore, we have combined fuzzy sets theory (Zadeh, 1965) with ANP to overcome this drawback.

The remainder of this paper is organized as follows: Section 2 provides detailed descriptions of the contents of the ANP process and fuzzy ANP. Section 3 explains the constitution of the decision-making team (DMT) and criteria determination. In Section 4 a FANP-based joint selection model is presented and the obtained results are commented. The paper concludes with Section 5.

2. Analytical network process (ANP) and fuzzy analytical network process (FANP)

2.1. Analytical network process (ANP)

The analytic network process (ANP) is the generalization of the analytic hierarchy process (AHP). By using the analytic network process (ANP) we could identify clusters of elements that influence each other and are influenced by elements in other clusters. In addition, ANP makes it possible to analyze influence separately according to many factors, and then combine them in a single outcome (Ayag & Özdemir, 2007; Chan, Kumar, Tiwari, Lau, & Choy, 2008; Cheng & Li, 2004).

2.1.1. Step I: problem definition and model construction

In this phase the decision-making problem must be clearly defined and decomposed to networks. This structure could be achieved by brainstorming sessions and other decomposing methods which must be considered by the decision making team (DMT). The important elements/components that affect the decision should be identified. After defining the decision goals, the clusters must be decomposed into sub-components such as criteria cluster (purposes), sub-criteria cluster (evaluation factors) and alternatives cluster. The analytic network process (ANP) enables dependencies within a single cluster (inner dependence) and between clusters (outer dependence) (Saaty, 1996). Thus, each element in each cluster can have relationships with other elements in the system. The conclusive aim of this framework will be the identification of alternatives which must be considered in determining the best outsourcing firm.

2.1.2. Step II: pairwise comparison matrices between components/attributes levels and related weighs

Pairwise comparison matrices are formed according to the decision-makers' answers by using the ratio scale given in Table 1. The linguistic scale is used to compare two components. All relations between elements in each network must be formulated and the following comparisons for eigenvector computations must be conducted:

Cluster comparisons: Paired comparisons of the clusters that influence a given cluster, with respect to the control criterion for that network. Values derived from this process will be used to weigh the elements in the corresponding column blocks of the supermatrix for that network.

Comparisons of elements: Paired comparisons of elements within the clusters. Compare the elements within a cluster according to their influence on an element in another cluster to which they are connected (or influence on elements within their own cluster).

Comparisons for alternatives: Compares the alternatives, with respect to all elements to which they are connected.

When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix. That is, if a_{ij} is a matrix value assigned to the relationship of component i to component j, then a_{ij} is equal to $1/a_{ij}$ or $a_{ij} = 1$. After completing the pairwise comparisons, eigenvector w is used to estimate the relative importance of the elements. For this, the equation given below is used. The $\lambda_{\max}$ is the largest eigenvalue of the pairwise comparison of matrix A

$$Aw = \lambda_{\max} w, \tag{1}$$

2.1.3. Step III: supermatrix formulation and analysis

The values obtained from pairwise comparisons (explained in the preceding step) are used in the formation of a supermatrix structure. This matrix shows a local priority vector derived from the paired comparisons which represent the impact of a given set of elements within a component on another element in the system (Saaty, 2004). These impacts could be direct or indirect. To identify the transfer of influence along all paths defined in the network, and to obtain the overall priorities of the elements, Saaty (1996) proposes the supermatrix approach. This partitioned matrix represents the influence of an element (on the left of the matrix) on another element at the top of the matrix. This matrix shows the interdependency and relative importance of each previously-defined element. The initial supermatrix must be transformed to a matrix in which each of its columns sums up to unity (Promentilla, Furuichi, Ishii, & Tanikawa, 2007). For this reason, this matrix must be normalized using the weigh of the cluster to achieve the unit columns. In this way we could achieve the stochastic or weighed supermatrix (Saaty & Vargas, 1998, 2006). The supermatrix representation model is as follows:

$$\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{pmatrix} w_{11} & 0 & 0 & w_{14} \\ w_{21} & w_{22} & 0 & w_{24} \\ w_{31} & 0 & w_{33} & w_{34} \\ w_{41} & w_{42} & w_{43} & 0 \end{pmatrix} \end{array} \tag{2}$$

Table 1
Linguistic scale for relative importance (Kahraman et al., 2006).

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important (WMI)	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important (SMI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important (VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important (AMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)