Information Sciences 178 (2008) 3133–3146

Contents lists available at ScienceDirect

Information Sciences

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

A fuzzy analytic network process based approach to transportation-mode selection between Turkey and Germany: A case study

Umut R. Tuzkaya *, Semih Önüt

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

ARTICLE INFO

Article history:
Received 5 August 2007
Received in revised form 24 March 2008
Accepted 27 March 2008

Keywords:
Analytic network process (ANP)
Fuzzy sets
Transportation-mode selection

ABSTRACT

A case study examining the different modes for transportation of freight by a Turkish logistics-service provider company is presented herein. A number of conflicting qualitative and quantitative criteria exist for evaluating alternative modes of transport. Qualitative criteria are often accompanied by ambiguity and vagueness. To cope with ambiguity and vagueness problem, the fuzzy analytic network process (ANP) method has been used. A large number of detailed criteria that interact with each other have been evaluated and synthesized to obtain the most suitable transportation mode. This evaluation has been carried out by a group of decision makers coming from different management levels and functional areas in the sector of logistics and from the service company with intent to provide a more accurate and mutually acceptable solution. Furthermore, the model used here has been validated by comparing the results obtained with the current preferences of the company.

1. Introduction

Increasing the volume of trade relative to the globalization of world trade promotes lower costs for logistics and increased customer satisfaction that maintain long-term strategical competitiveness. The prevalent market economy places significant importance on having the right item at the right time in inventory in addition to providing the item to the customer within the desired timeframe. This requires the simultaneous consideration of both the inventory and the transportation functions of the supply chain. Transportation, one of the main subjects in logistics, is considered a process that benefits from all the modes of transportation. Transportation decisions include transportation-mode selection, shipment size, vehicle routing, and scheduling; all of these are directly related to the location of warehouses, customers, and factories. The relocation of warehouses and factories causes considerable changes in the transportation decisions at the strategic, tactical, and operational levels. At the strategic level, selection of the appropriate transportation mode is the most important concept in shipment planning. The four main modes of transportation for freight and passenger traffic, which have their own advantages and disadvantages, are rail, road, water, and air. Each of these modes has different characteristics, and any of them can be considered the best under different circumstances, depending on the location, distance, type of freight, and value of freight, among other things.

In the selection of a particular mode, all the advantages and disadvantages related to the concerned mode of transport have to be considered. Under certain conditions, the choice of a transportation mode may seem obvious, but a comparison that depends on a variety of criteria may be nevertheless required. The main criteria for transportation are the type and volume of freight and the distance to be covered. Other criteria may include speed, availability, reliability, capacity, security, and frequency of delivery. Each type of criterion has its own character; in other words, a number of possibly conflicting criteria

* Corresponding author. Tel.: +90 212 2597070x2242.
E-mail address: tuzkaya@yildiz.edu.tr (U.R. Tuzkaya).

0020-0255/$ - see front matter
doi:10.1016/j.ins.2008.03.015

exists for evaluating different transportation modes. Identifying these qualitative and quantitative evaluation criteria, defining their inter-related effects, assessing their importance, and choosing a particular transportation mode requires a well designed multiple-criteria decision-making (MCDM) based evaluation. Many researchers have studied the determination of suitable transportation modes using different methods [1,2,11,15,17,23,34,36]. Due to the mutual dependencies and feedback effects of the criteria, the analytic network process (ANP) can be used to systematically evaluate the most suitable transportation modes. The ANP is a multiattribute approach to decision-making that facilitates the transformation of qualitative values into quantitative values, enabling their analysis. Many problems that require a systematic decision cannot be hierarchical because of the dependencies of the criteria (inner/outer) and the influences between and within clusters (criteria, alternatives).

The ANP is a relatively simple and systematic approach that can be used by decision makers. Essentially, it is a more general form of the analytical hierarchy process (AHP), first introduced by Saaty [26]. The AHP is a special case of the ANP and contains neither feedback between nor loops within the criteria clusters representing inner dependence. Furthermore the ANP, tolerates complex interrelationships between the criteria and decision levels, but the decision-making structure in the AHP model uses unidirectional hierarchical relationships among the decision levels [26,28,29]. The evaluation criteria for transportation-mode selection are generally not independent of each other but are often interactive. Due to the different levels of criteria interacting with each other simultaneously in the mode-selection process, an invalid and unexpected result can be obtained in the face of this complexity. Hence, the traditional AHP method that neglects the mutual effect of different conflicting levels in this kind of selection process is not suitable for the problem under consideration. To deal with this dynamic problem and to handle interdependence among the criteria at different levels within the model, the ANP approach is used. Furthermore, a large number of criteria interacting with each other, and located in different clusters, are considered in a real-world case study. Complex decision-making problems, such as transportation-mode selection, which consist of a large number of interdependent criteria, are effectively solved using the ANP whereas the AHP can be only used for hierarchical decision structures.

Many precision-based methods for transportation-mode selection have been investigated, and most of them have been developed on the basis of accurate measurements and crisp evaluation. However, most of the selection parameters cannot be given precisely, and the required data for the suitability of the alternative modes with respect to various subjective criteria and the weights of the criteria are usually expressed in linguistic terms by decision makers. This makes fuzzy logic a more natural approach to this kind of problem. Fuzzy logic has been commonly used in different studies associated with transportation decisions, such as shipment size [5,19], vehicle routing [31,32], and scheduling [3,33]. Because of certain usage limitations, such as nonnormalized fuzzy ratings and fuzzy weights, fuzzy-logic based MCDM methods may be efficiently applied to the problem of transportation-mode selection. Moreover, the fuzzy-ANP (FANP) method can be used to cope with uncertain human judgments [37].

Several researchers have attempted to use the FANP method for different problems. Although ANP has also been applied to a large variety of decision-making processes for different applications, FANP has received much less attention in research [4,10,14,21,22]. There are a few publications using the ANP method for solving transportation problems; however, there is no evidence that the FANP method has been specifically applied to transportation-mode selection. A fuzzy extension of ANP with fuzzy pair-wise comparisons and a feedback between the criteria has been proposed by Ramik [24].

The remainder of this paper is organized as follows: Section 2 describes the contents of the ANP process; triangular fuzzy numbers are briefly reviewed in Section 3; Section 4 describes the basics of the FANP; in Section 5, a FANP-based transportation-mode selection model has been proposed, an application of the model to a logistics-service provider company is presented, and comments on the results obtained are provided. The paper is concluded in Section 6.

2. The ANP method

ANP is the most comprehensive framework available for the analysis of corporate decisions. It allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). The feedback element 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 that are in the same cluster or in other clusters with respect to several properties. The main objective in the process is to determine the overall influence of all the elements in conjunction with each other [28,29]. The modeling process can be divided into three steps for ease of understanding as follows:

Step I: Pair-wise comparisons and relative weight estimation

All the relations within the clusters of elements and between clusters are evaluated as pair-wise comparisons. A reciprocal value is assigned to the inverse comparison. Once the pair-wise comparisons are completed, such as the AHP, a local priority vector (eigenvector), w, is computed as an estimate of the relative importance of the elements compared by solving the following equation:

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

where $\lambda_{\max}$ is the largest eigenvalue of the pair-wise comparison matrix, A.