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A METHOD FOR SELECTING THIRD PARTY LOGISTIC SERVICE PROVIDER USING FUZZY AHP

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Abstract

Logistics service provider selection is a complex multi – criteria decision making process; in which, decision makers have to deals with the optimization of conflicting objectives such as quality, cost, and delivery time. Despite to the great variety of methods and models that have been designed to help decision maker for this process in literature, few efforts have been dedicated to develop systematic approaches for logistics service provider selection using these pre-designed methods and models. In this study, logistics service provider selection decision support system based on the fuzzy analytic hierarchy process (FAHP) method is proposed

ÜÇÜNCÜ PARTİ LOJİSTİK HİZMET SAĞLAYICININ (3PL) BULANIK AHP KULLANARAK SEÇİMİ İÇİN BİR METOT

Özetçe

Lojistik hizmet sağlayıcının seçimi, karar vericinin kalite, maliyet ve dağıtım zamanı gibi birbiri ile çelişen birçok amacı eşzamanlı eniyilemesini gerektiren karmaşık çok ölçütlü bir karar verme sürecidir. Literatürde karar vericilere bu süreçte yardımcı olmak amacı ile tasarlanan çok çeşitli metot ve modeller olmasına rağmen, tasarlanan bu metot ve modelleri kullanarak lojistik servis *sağlayıcı seçimine sistemsel bir yaklaşım getiren çalışma çok az bulunmaktadır. Bu çalışmada bulanık AHP'ye dayalı bir lojistik hizmet sağlayıcı seçimi karar destek sistemi önerilmiştir*

Keywords: Logistics Service Provider Selection, Fuzzy AHP, 3PL
Anahtar Kelimeler: Lojistik Servis Sağlayıcı Seçimi, Bulanık AHP, 3PL

1. INTRODUCTION

The logistics service provider selection is a complex multi-criteria problem that includes both quantitative and qualitative criteria some of which can conflict each other and is vital in enhancing the competitiveness of companies [1, 2]. It is an important function of the logistics departments as it brings significant savings for the organization. While choosing the appropriate provider, logistics managers might be uncertain whether the selection will satisfy completely the needs of the organization [3]. There are several supplier selection applications available in the literature. Verma and Pulman [4] examined the difference between managers' ratings of the perceived importance of different supplier attributes and their actual choice of suppliers in an experimental setting. They used two methods: a Likert scale set of questions and a discrete choice analysis (DCA) experiment. Ghodsypour *et al.* [5] proposed an integration of analytical hierarchy process (AHP) and linear programming to consider both tangible and intangible factors for choosing the best suppliers and placing the optimum order quantities among them such that the total value of purchasing becomes maximum.

AHP has a widespread application area in decision-making problems, involving multiple criteria in systems of many levels. The strength of the AHP lies in its ability of structuring complex, multi-person and multi-attribute problems hierarchically and investigating each level of the hierarchy separately combining the results.

In 2002, Bevilacqua and Petroni [2] developed a system for supplier selection using fuzzy logic (FL). FL; which was introduced by Zadeh in 1965 with his pioneer work "Fuzzy Sets", can simply be defined as "a form of mathematical logic in which truth can assume a continuum of values between 0 and 1" [6]. On the contrary to crisp (discrete) sets which divide the given universe of discourse in to basic two groups as members and nonmembers, FL has the capability of processing data using partial set membership functions which makes FL a strong device for impersonating the ambiguous and uncertain linguistic knowledge [7]. As fuzzy set theory became an important problem modeling and solution technique due to its ability of modeling problems quantitatively and qualitatively those involve vagueness and imprecision [7], it has been successfully applied many disciplines such as control systems, decision making, pattern recognition, system modeling and etc. in fields of scientific researches as well as industrial and military applications. Kahraman *et al.* [8] used fuzzy AHP (FAHP) to select the best supplier firm for a white good manufacturer established in Turkey providing the most satisfaction.

Dulmin and Mininno [9] proposed a multi-criteria decision aid method (promethee/gaia) to supplier selection problem. They applied the model to a mid-sized Italian firm operating in the field of public road and rail transportation. Chan F. and Chan H. [10] reported a case study to illustrate an innovative model which adopts AHP and quality management system principles in the development of the supplier selection model. Xia and Wu [11] proposed an integrated approach of AHP (improved by rough sets theory and multi-objective mixed integer programming) to simultaneously determine the number of suppliers for employing and the order quantity allocated to these suppliers in the case of multiple sourcing, multiple products with multiple criteria and supplier's capacity constraints.

In this paper a decision support system for logistics service provider selection based on a FAHP model is designed and implemented. The following sections of the paper are organized as follow. In section 2, AHP and Fuzzy AHP models are introduced. In section 3, application of fuzzy AHP methodology is demonstrated. Finally, research findings and discussions are provided in section in section 4 and 5 respectively.

2. AHP AND FAHP MODEL

2.1 AHP Model

The analytic hierarchy process (AHP) was first introduced by Saaty in 1971 to solve the scarce resources allocation and planning needs for the military [12]. Since its introduction, the AHP has become one of the most widely used multiple-criteria decision-making (MCDM) methods, and has been used to solve many problems in different areas of human needs and interests, such as political, economic, social and management sciences.

In AHP, the factors that affect the system are designed in hierarchically and the decision alternatives are evaluated with pair-wise comparisons of elements in all levels. The scores of alternatives are calculated according to obtained characteristics.

AHP facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision. Once the hierarchy has been constructed, the decision-maker begins the prioritization procedure to determine the relative importance of the elements in each level. Prioritization involves eliciting judgments in response to questions about the dominance of one element over another with respect to a property. The scale used for comparisons in AHP enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion [13]. The decision-maker can express his or her preference between each pair of elements verbally as equally important, moderately more important, strongly more important, very strongly more important, and extremely more important. These descriptive preferences would then be translated into numerical values 1,3,5,7,9 respectively with 2,4,6, and 8 as intermediate values for comparisons between two successive qualitative judgments. Reciprocals of these values are used for the corresponding transposed judgments. Table 1 shows the comparison scale used by AHP.

Finally, all the comparisons are synthesized to rank the alternatives. The output of AHP is a prioritized ranking of the decision alternatives based on the overall preferences expressed by the decision maker. Sensitivity analysis is used to investigate the impact of changing the priorities of the criteria on the final outcome.

The solution procedure of the AHP involve six essential steps as follow [1, 14, 15, 16, 17, 18, 19]:

- Define the unstructured problem and state clearly the objectives and outcomes.
- Decompose the complex problem into a hierarchical structure with decision elements (criteria, detailed criteria and alternatives).
- Employ pair-wise comparisons among decision elements and form comparison matrices.
- Use the eigen value method to estimate the relative weights of the decision elements.
- Check the consistency of matrices to ensure that the judgments of decision makers are consistent.
- Aggregate the relative weights of decision elements to obtain an overall rating for the alternatives.

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly favor one activity over another
7	Very Strong Importance	An activity is favored very strongly over another; its dominance demonstrated in practice.

9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it.

Table 1. The fundamental scale [14]

2.2 FAHP Model

There are many FAHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and justification problems using the concepts of fuzzy set theory and hierarchical structure analysis.

The earliest work in FAHP appeared in van Laarhoven and Pedrycz [20], which compared fuzzy ratios described by triangular membership functions. Buckley [21] determines fuzzy priorities of comparison ratios with trapezoidal membership functions. Stam *et al.* [22] explore how artificial intelligence techniques can be used to determine or approximate the preference ratings in AHP. They conclude that the feed-forward neural network formulation appears to be a powerful tool for analyzing discrete alternative multi-criteria decision problems with imprecise or fuzzy ratio-scale preference judgments. Later, Ngai and Chan [23] present a conventional AHP application to select the most appropriate tool for supporting knowledge management (KWM), Wang and Chang [24] construct an analytic hierarchy prediction model based on the consistent fuzzy preference relations to identify the essential success factors for an organization in KWM implementation, KWM project forecast, and identification of necessary actions before initiating KWM. Another impressive study is made by Bozbura, Beskese, and Kahraman [25] in which a FAHP methodology to improve the quality of prioritization of human capital measurement indicators under fuzziness is proposed.

In this study the Chang's extent FAHP is utilized [26]. Let $X = \{x_1, x_2, x_3, ..., x_n\}$ an object set, and $G = \{g_1, g_2, g_3, ..., g_n\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal is performed respectively. Therefore, m extent analysis values for each object; $M^1{}_{gi}, M^2{}_{gi}, ...M^m{}_{gi,}$ $i = 1,2,....,n$, can be obtained where M $_{jgi}$ (j = 1, 2, ...,m) all are triangular fuzzy numbers (TFN).

The steps of Chang's extent analysis can be given as in the following [26]:

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

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{1}$$

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

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{2}$$

and to obtain $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, perform the fuzzy addition operation of M jgi (j = 1, 2, ...,m) values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{3}$$

and then compute the inverse of the vector above, such that:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{4}$$

Step 2: As $\widetilde{M}_1 = (l_1, m_1, u_1)$ and $\widetilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as:

$$V\left(\widetilde{M}_2 \geq \widetilde{M}_1\right) = \sup_{y \geq x} \left[\min\left(\mu_{\widetilde{M}_1}(x), \mu_{\widetilde{M}_2}(y)\right)\right] \tag{5}$$

and can be equivalently expressed as follows:

$$V\left(\widetilde{M}_2 \geq \widetilde{M}_1\right) = hgt(\widetilde{M}_1 \cap \widetilde{M}_2) = \mu_{M_2}(d)$$
$$= \begin{cases} 1, & if \quad m_2 \geq m_1 \\ 0, & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \tag{6}$$

The following figure illustrates equation 6 where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} to compare M1 and M2, we need both values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ [14, 1].

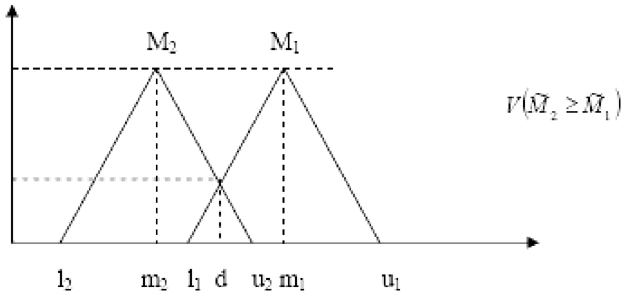

Figure 1. The intersection between M_1 and M_2 [14, 1].

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy Mi (i=1, 2, k) numbers can be defined by

$$V(M \geq M_1, M_2, \ldots. M_k) = V[(M \geq M_1) \;\; and \;\; (M \geq M_2) \;\; and \ldots. and \;\; (M \geq M_k)]$$
$$= \min \;\; V(M \geq M_i), \;\; i = 1,2,3,\ldots., k \qquad (7)$$

Assume that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1,2,\ldots., n; k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots\ldots, d'(A_n))^T \qquad (8)$$

where $A_i = (i = 1,2,\ldots n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \ldots\ldots, d(A_n))^T \qquad (9)$$

where W is a non-fuzzy number.

3. THE APPLICATION OF FAHP METHODOLOGY

The application of the fuzzy AHP approach is demonstrated for a medium-sized and growth-oriented fast-moving-consumer-goods (FMCG) company, which is steadily moving towards IT enablement of its supply chain. It has partially outsourced its outbound logistics to carrying and forwarding agents. The company is willing to outsource its entire logistics activities. The goal is to choose the best logistics service provider for a case company. So, this goal is placed at the top of the hierarchy. The hierarchy descends from the more general criteria in the second level to sub-criteria in the third level to the alternatives at the bottom or fourth level. General criteria level involved five major criteria: Cost of service, operational performance, financial performance, reputation of the 3PL, and long-term relationships. Three logistics service providers are considered for the decision alternatives, and located them on the bottom level of the hierarchy. These are alternative A, B, and C. Figure 2 illustrates a hierarchical representation of selecting best logistics service provider decision-making model [1].

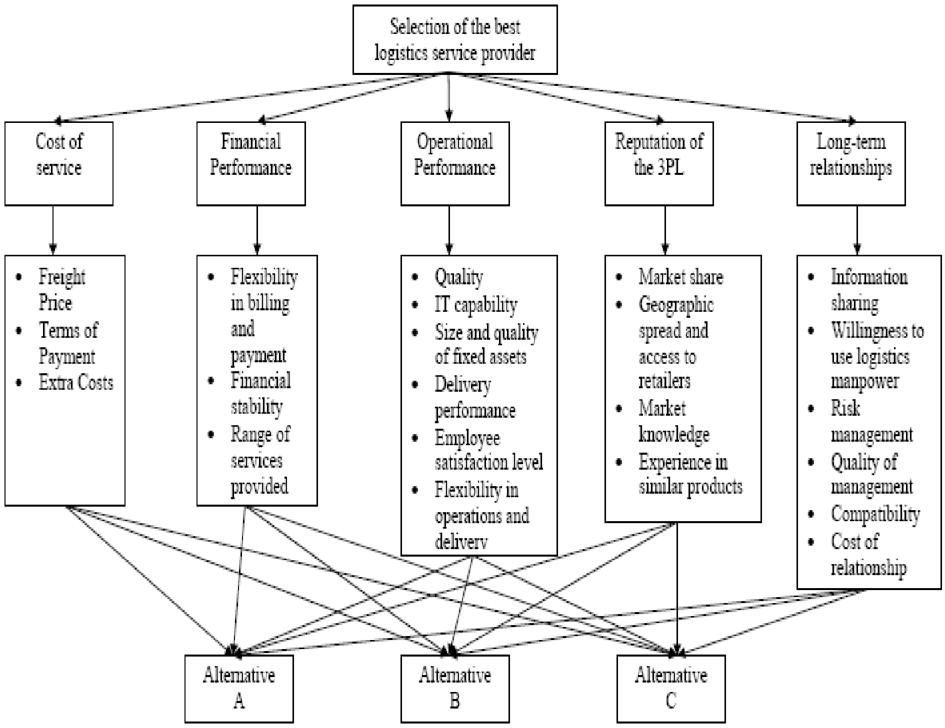

Figure 2. The decision hierarch [1].

Provider A is asset-based and has its own means of transportation, distribution, and warehousing. B is similar to a 4PL company with advanced IT, supply chain, and change management capabilities. However, the provider C is a non-asset-based company and, instead of having its own physical assets, it relies on contracting the logistics assets as per the requirement of the users. Qualifications of potential providers are illustrated in Table 2. For each of sub-criteria, potential providers (alternative A, B, and C) have a level such as very low, low, normal, high, and very high. This classification of alternatives according to their capabilities, helps making pair-wise comparison matrices.

Main Criteria	**Sub-Criteria**	**Alternative A**	**Alternative B**	**Alternative C**
Cost of Service	Freight Price	Low	Normal	High
	Terms of Payment	Very Low	High	Normal
	Extra Costs	High	Normal	Low
Financial Performance	Flexibility in billing and payment	Low	Normal	High
	Financial stability	Normal	High	High
	Range of services provided	Low	High	Very High
Operational Performance	Quality	Normal	High	High
	IT capability	Normal	Very High	High
	Size and quality of fixed assets	High	Normal	Low
	Delivery performance	Low	High	Normal
	Employee satisfaction level	Low	High	Normal
	Flexibility in operations and delivery	Low	Very High	High
Reputation of the 3PL	Market share	Normal	High	Low
	Geographic spread and access to retailers	Normal	High	Normal
	Market knowledge	High	High	Normal
	Experience in similar products	Normal	Normal	Very High
Long-term Relationships	Information sharing	High	Normal	High
	Willingness to use logistics manpower	Normal	Normal	High
	Risk management	Low	Normal	High
	Quality of management	Low	Normal	High
	Compatibility	Low	High	High
	Cost of relationship	Very High	Normal	High

Table 2: Qualifications of potential providers

After constructing the selection model hierarchy, pair-wise comparisons must be performed systematically to include all the combinations of criteria/sub-criteria/secondary sub-criteria/alternatives relationships. The criteria and sub-criteria are compared according to their relative importance with respect to the parent element in the adjacent upper level.

Geometric average is applied to combine the fuzzy weights of decision makers as;

$$\overline{\tilde{W}_i} = \left(\prod_{k=1}^{K} \tilde{W}_i^k \right)^{\frac{1}{K}}, \quad \forall k = 1, 2, \dots, K \qquad (10)$$

where $\overline{\tilde{W}_i}$ is the combined fuzzy weight of decision element i of K decision makers, $\tilde{W}_i^k$ is the fuzzy weight of decision element i of decision maker k and K illustrates the number of decision makers.

The pair-wise comparison matrix for the main attributes is built and illustrated in the following table and other matrices are constructed in the same manner.

	CST	FP	OP	RPT	LTR
CST	(1, 1, 1)	(1/2, 1, 3/2)	(1, 1, 1)	(1, 3/2, 2)	(1/2, 1, 3/2)
FP	(2/3, 1, 2)	(1, 1, 1)	(2/3, 1, 2)	(1, 3/2, 2)	(1, 3/2, 2)
OP	(1, 1, 1)	(1/2, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(3/2, 2, 5/2)
RPT	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1/2, 1, 3/2)
LTR	(2/3, 1, 2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(1, 1, 1)

Table 3: Pair – wise comparison matrix for main attributes

4. RESEARCH FINDINGS

The comparison of total weight of alternatives is showed that alternative B which has the highest priority weight is selected as a best logistics service provider. The logistics service provider B can fulfill the required demands of the FMCG case company. The sequence of alternatives according to their importance weight is as follows: Alternative B, Alternative C, and Alternative A. The priority weights collected from each of pair-wise comparison matrices of main criteria and alternatives are summarized in the Table 4. The results calculated shows that the main criteria *operational performance* is the most important factor for logistics service provider selection.

Main Criteria	**Main Criteria Point**	**Sub-Criteria**	**Weight A**	**Weight B**	**Weight C**
Cost of Service CST	**0.21**		0.05670	0.03308	0.00473
			0.00000	0.05424	0.03186
			0.00147	0.01029	0.01764
Financial Performance FP	**0.24**		0.00396	0.02772	0.04752
			0.01306	0.03427	0.03427
			0.00000	0.02930	0.04990
Operational Performance OP	**0.27**		0.00734	0.01928	0.01928
			0.00257	0.03078	0.01796
			0.02592	0.01512	0.00216
			0.00230	0.02754	0.01607
			0.00216	0.02592	0.01512
			0.00000	0.02552	0.01499
Reputation of the 3PL RPT	**0.12**		0.01050	0.01800	0.00150
			0.00660	0.01680	0.00660
			0.01260	0.01260	0.00480
			0.00000	0.00000	0.03000
Long-term Relationships LTR	**0.16**		0.01142	0.00435	0.01142
			0.00941	0.00941	0.00358
			0.00136	0.00952	0.01632
			0.00136	0.00952	0.01632
			0.00000	0.01440	0.01440

Main Criteria	**Main Criteria Point**		**Weight A**	**Weight B**	**Weight C**
			0.00136	0.01632	0.00952
		TOTAL WEIGHT	**0.17008**	**0.44398**	**0.38594**

Table 4. Priority weights of main and sub-attributes, and alternatives.

5. CONCLUSION

Logistics service provider selection process becomes increasingly important in today's complex environment. The selection process involves the determination of quantitative and qualitative factors to select the best possible provider. In this study logistics service provider selection via extent fuzzy AHP has been proposed. The decision criteria are cost of service, financial performance, operational performance, reputation of the 3PL, and long-tern relationships. These criteria were evaluated to obtain the preference degree associated with each logistics service provider alternative for selecting the most appropriate one for the company. By the help of the extent fuzzy approach, the ambiguities involved in the data could be effectively represented and processed to make a more effective decision. As a result of this study, alternative B is determined as the best logistics service provider which has the highest priority weight. The company management found the application and results satisfactory and decided to work with alternative B.

For further research, other fuzzy multi-criteria evaluation methods that have been recently proposed in a fuzzy environment like fuzzy TOPSIS or fuzzy outranking methods can be used and the obtained results can be compared with the ones found in this paper.

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