4th INTERNATIONAL LOGISTICS AND SUPPLY CHAIN CONGRESS

"THE ERA OF COLLABORATION THROUGH SUPPLY CHAIN NETWORKS"

IZMIR. 2006
NOVEMBER 29-30, DECEMBER 01, 2006

PROCEEDINGS
4th International Logistics and Supply Chain Congress

November 29-30, and December 1, 2006
IZMIR TURKEY

“The Era of Collaboration Through Supply Chain Networks”

PROCEEDINGS

Izmir University of Economics Publication
EDITORS
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Izmir University of Economics Publication No: 009
Logistics Association Publication No: 5
Publishing Date: December 2006

ISBN 975-8789-08-2

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Printed in Izmir-Turkey.

Graphics and Website Design by Melike D. Kaplan

Publication of this proceedings book was financed by TÜBİTAK.
PREFACE

On behalf of İzmir University of Economics and as the chair of the 4th International Logistics and Supply Chain Congress, İzmir 2006, I would like to state that we are honored to host all the participants in İzmir, one of the most important logistics centers and port city of Turkey, during 4th International Logistics and Supply Chain Congress, which was held on November 29-30 and December 1, 2006.

4th International Logistics and Supply Chain Congress, 2006 was organized by the cooperation of İzmir University of Economics-Turkey, University of Miskolc-Hungary, Belgrade University-Serbia and LODER-Logistics Association of Turkey. The congress was titled as “The Era of Collaboration through Supply Chain Networks”, which has been unanimously decided upon during the first meetings of the organizing institutions. Today, collaboration is the basic foundation for successful, effective and efficient supply chains. Any activity within the supply chain that lacks collaboration, coordination and trust will inevitably fail in the long run. Therefore, collaboration should be the keyword in further practices, both in business life and scholarly endeavors. The aim of our congress, which was to bring scholars, professionals, decision-makers and practitioners working in the area of logistics and supply chain management together, was successfully accomplished.

The congress brings together more than 300 academicians, researchers and practitioners from different countries. A total of 100 papers were accepted and presented during the Congress, and published in the Proceedings. These papers cover a wide range of topics including Intermodal Transportation, E-Technological Solutions for SCM and LIS, Supply Chain Management Strategies, Inventory Management and Network Design, Regional Logistics, Reverse Logistics, Global Responsibility, Mathematical Aspects of Logistics Management, Sourcing, Service Supply Chains and Transportation Management. We are grateful to our authors and reviewers for all their efforts during this remarkable scientific event.

We would like to thank our partners in organization who have supported us in realizing this event, University of Miskolc, Belgrade University and LODER-Logistics Association of Turkey. We also would like to acknowledge the support of the sponsors of the Congress for their contributions.

I would like to thank the members of the organizing committee, Oznur Yurt, Melike D. Kaplan, I. Ozge Yumurtaci and Bengu Sevil, who have put great enthusiasm, effort and time into realization of the Congress.

Finally, we would like to thank everyone who has contributed for making this Congress a memorable and successful event.

Sincerely,

Prof. Dr. Tunçdan Baltacıoğlu
İzmir University of Economics
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Banu Atrek Yaşaroğlu¹, Güzin Özdağoğlu², Aşkın Özdağoğlu³

Abstract

Third party logistics (3PL) decisions involve the use of external companies to perform logistic functions that have traditionally been performed within the organization. Choosing the right logistics provider can create competitive advantages due to the visible service impact on customers. However, just selecting the right logistic firm is not adequate; tracking the performance of these firms regularly also contributes to the sustainability of this competitive advantage. In this study, a fuzzy-based multi-criteria decision making (MCDM) model is proposed for selection and performance evaluation of logistics firms supplied in an agricultural product industry. The selection and evaluation process is developed based on TOPSIS concept in which a closeness coefficient is defined to determine the performance rates of logistic firms by calculating the distances to fuzzy-positive ideal solution (FPIS) and fuzzy-negative ideal solution (FNIS).

Keywords: Logistics, Fuzzy Logic, Selection, Evaluation, TOPSIS

1. Introduction

Within supply chain management, the task of logistics is to move and position inventory to achieve desired time, place and possession benefits with the possible minimum cost. The customer satisfaction should be fulfilled through being responsive, having high capability while controlling operational variance and minimizing inventory commitment (Bowersox, Closs & Cooper, 2002). Logistics Management provides the strategies for the coordination among product flow from supplier to the end user and the information flow that has a high priority. Besides, an efficient logistics management requires the optimization of the activities regarding the movement of the goods due to the intense competitive conditions. In this respect, in order to sustain their competitiveness, the firms have to focus on their core competencies and outsource their logistics activities. Through outsourcing, the customers will be provided with the expertise and experience that otherwise would be difficult or costly to have within the firm (Razzaque, Sheng, 1998). Logistics outsourcing or third party logistics (3PL) are the specialized service providers that provide many advantages like the power acquired by the economies of scale, process expertise, access to capital, reduced financial risks, access to expensive technology for the firms (Aktaş and Ulengin, 2005). In this manner outsourcing decisions became a very critical fact for the firms.

The selection of a 3PL that matches with the needs of the firm is not an easy task. Many researchers have worked on the selection process and suggested some methods. For example in the study of Andersson and Norman (2002) eight points are suggested to select the right 3PL provider. Defining or specifying the service, understanding the volume bought, simplifying and standardizing, market survey, request for information, request for proposal, negotiations and contracting are the eight point plan of the authors. Besides, Jharkharia and Shankar (2005) in their study made a literature review on the selection criteria that can be seen in Table 1. Apart from the criteria illustrated in Table 1 different selection criteria have also been used by other researchers. Management stability (İsklar, Alptekin & Büyüközkancan, 2006), conflict resolution (Chen, Lin & Huang, 2005), innovation (willingness to engage in new logistics concepts) and operative logistical transactions like labels, documents (Schmitz and Platts, 2002), ability of carrier to customize its services to meet specific and unique needs (Aktaş and Ulengin, 2005) are some other criteria that are mentioned in literature. The ultimate aim of selection 3PL provider is to obtain the maximum value by meeting the firm’s needs with minimum cost as a matter of fact criteria should be applicable to all providers.

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Table 1. Criteria for the selection of a provider

<table>
<thead>
<tr>
<th>Selection Criterion</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance measurement</td>
<td>Bhatnagar et al. (1999), Lynch (2000), Langley et al. (2002)</td>
</tr>
<tr>
<td>Willingness to use logistics man power</td>
<td>Razzaque and Sheng (1998), Ackerman (1996)</td>
</tr>
<tr>
<td>Flexibility in billing and payment</td>
<td>Bradley (1994)</td>
</tr>
<tr>
<td>Operational performance</td>
<td>Langley et al. (2002), Tam and Tummala (2001)</td>
</tr>
<tr>
<td>Size and quality of fixed assets</td>
<td>Boyson et al. (1999), Hum (2000)</td>
</tr>
<tr>
<td>Experience in similar products</td>
<td>Razzaque and Sheng (1998), Ackerman (1996), Richardson (1993)</td>
</tr>
<tr>
<td>Delivery performance (speed &amp; reliability)</td>
<td>Stock et al. (1998),Gattorna and Walters (1996)</td>
</tr>
<tr>
<td>Employee satisfaction level</td>
<td>Lynch (2000), Boyson et al. (1999), Langley et al. (2002)</td>
</tr>
<tr>
<td>Financial performance</td>
<td>Andersson and Normran (2002), Boyson et al. (1999), Gattorna and Walters (1996)</td>
</tr>
<tr>
<td>Market share</td>
<td>Thompson (1996)</td>
</tr>
<tr>
<td>Geographical spread and range of services provided</td>
<td>Boyson et al. (1999), Maltz (1995), Bradley (1994)</td>
</tr>
<tr>
<td>Risk Management (insurance coverage)</td>
<td>Boyson et al. (1999), Aktas and Ulengin (2005)</td>
</tr>
<tr>
<td>Surge capacity of the provider</td>
<td>Anonymous (1999)</td>
</tr>
<tr>
<td>Clause for arbitration and escape</td>
<td>Richardson (1993)</td>
</tr>
<tr>
<td>Flexibility in operations and delivery</td>
<td>Stank and Daugherty (1997)</td>
</tr>
</tbody>
</table>

Source: Adapted from Jharkharia and Shankar (2005)

The selection of the most appropriate 3PL provider through the criteria mentioned above is another issue that must be focused on. Many studies on selection applications are available in the literature. Case based reasoning technique (Choy and Lee, 2002), rule based reasoning and a hybrid intelligent decision support model by integrating both case based reasoning rule based reasoning is proposed by İşkınlar, Alptekin and Büyüközkakan (2006). Fuzzy multicriterion decision making models are also applicable to selection problems many efficient methods have been used to solve these problems. Average weighted comprehensive method (Brans and Mareschal, 1990), fuzzy optimum seeking method (Belton and Hodgkin, 1999; Belacel, 2000), fuzzy neural networks comprehensive decision making method (5), fuzzy iteration method (3)AHP, ELECTRE, PROMETHEE, ORESTE and TOPSIS are the some of the evaluation methods that can be used (Kahraman, Ataş, Çevik, Gülbay & Erdoğan, 2004).

In this study, a fuzzy-based multi-criteria decision making (MCDM) model is used for selection and performance evaluation of logistics firms supplied in an agricultural product industry. In the following sections literature review on TOPSIS and Fuzzy-AHP, brief information about the methodology that is used in selecting and evaluating the 3PLs is discussed.

1.1. TOPSIS- Technique for Order Preference by Similarity to Ideal Solution

TOPSIS was first developed by Hwang and Yoon based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution when solving a multi-criteria decision making problem (Hwang & Yoon, 1981) in which the positive ideal solution is composed of all the best values of criteria whereas the negative ideal solution is composed of the worst values (Chen & Tzeng, 2004).

Under many conditions, crisp data are inadequate to model the real situations. Furthermore, if human judgments include preferences, then these judgments are vague, and in many situations it is difficult to define them with an
1.2 Fuzzy AHP

One of the steps of TOPSIS model is to determine the weights of each criterion by using methods like analytical hierarchy process, linear programming, fuzzy logic etc. In this study, Fuzzy-AHP method is considered to obtain the weights of each criterion then the evaluation of alternatives is carried out with traditional TOPSIS steps.

The fuzzy-AHP technique can be viewed as an advanced analytical method improved from Saaty’s analytic hierarchy process (Saaty, 1994), which is a well-known decision-making analytical tool used for modeling unstructured problems in various areas, e.g., social, economic, and management sciences (Wabalickeis, 1988; Bard and Sousk, 1990; Triantaphyllou and Mann, 1995). Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision maker’s judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches (Bouyssou et al., 2000). Therefore, more and more researchers (Laarhoven and Pedrycz, 1983; Buckley, 1985a,b; Boender et al., 1989; Chang, 1996; Ribeiro, 1996; Lootsma, 1997; Yu, 2002) have engaged in the fuzzy extension of Saaty’s theory, referred to as fuzzy-AHP, which has been shown to provide relatively more accurate descriptions of the decision making process in comparison with conventional AHP techniques (Sheu, 2004, 45). As a result, though the purpose of AHP is to capture the expert’s knowledge, the conventional AHP still cannot reject the human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, is developed to solve the hierarchical fuzzy problems using Chang’s model which is also implemented in (Kahraman, Cebeci, and Ruan, 2004, 173).

2. Methodology

In this paper, a systematic and practical methodology is developed and presented for selection and assessment of logistics service providers among many alternatives based on fuzzy models using linguistic variables.

The sample study of the methodology has been carried out in a firm which exports agricultural foods to many countries like Germany, Japan, Canada etc. During the interviews made with the firm’s authorized people it’s determined that there is not an existing structured selection and evaluation process for the 3PL providers they work with. First of all a literature review done on the criteria for selection and evaluation of 3PL providers that are summarized in Table 1 is presented to the firm and they are required to eliminate the criteria that are not regarded in their existing selection process. The final list of criteria obtained are as follows: Cost, flexibility in billing and payment, quality of service, operational performance, delivery performance, long term relationship, information sharing & mutual trust and reputation.

In order to provide the consistency and completeness of the hierarchy of criteria set, authors and decision makers of the firm worked together and constructed the hierarchy seen in Figure 1.
Moreover, the list of 3PL providers that the company has been working with is gathered and a question form is prepared asking the pair wise comparison and evaluation of each criterion for each 3PL providers based on fuzzy AHP and TOPSIS, respectively.

The first phase of the methodology consists of weighting the hierarchical criteria set via fuzzy-AHP method so that the weights are calculated in a pair wise comparison manner which is the advantage of AHP method. In the second phase, the alternative logistics service providers are evaluated by considering each criterion in the bottom level of the criteria set. The evaluation process is carried out according to TOPSIS methodology which depends on linguistic variables and fuzzy logic. TOPSIS methodology concerns the distances of each alternative evaluation from negative ideal solution and positive ideal solution. Thus, the results of the solution show the closeness of each alternative that represents the importance among others. There exist two reasons to use TOPSIS model in the evaluation phase instead of any AHP method; when there are so many alternatives to be compared, AHP method may generate inconsistency problem which is approved by so many studies in literature. The second reason is the complexity of comparison process; because alternatives should be evaluated more often than criteria set, the higher the number of alternatives, the higher the complexity. Instead of that, it would be more practical to use TOPSIS which includes linguistic evaluations based on fuzzy logic.

The mathematical formulations for phase 1 and phase 2 are:

Phase 1: Criteria Importance Weighting: Fuzzy-AHP Methodology

To apply the process depending on the hierarchy, according to the method of Chang’s (1992) extent analysis, each criterion is taken and extent analysis for each criterion, \( g_i \), is performed, on respectively. Therefore, \( m \) extent analysis values for each criterion can be obtained by using following notation (Kahraman, et al, 2004, p.176):

\[
M_{g_1}^1, M_{g_2}^2, M_{g_3}^3, M_{g_4}^4, M_{g_5}^5, \ldots, M_{g_m}^m,
\]

where \( g_i \) is the goal set \( (i = 1, 2, 3, 4, 5, \ldots, n) \) and all the \( M_{g_j}^i \) \( (j = 1, 2, 3, 4, 5, \ldots, m) \) are Triangular Fuzzy Numbers (TFNs). The steps of Chang’s analysis can be given as in the following:

**Step 1:** The fuzzy synthetic extent value \( S_j \) with respect to the \( j^{th} \) criterion is defined as following equation 1.

\[
S_j = \left( \sum_{i=1}^{m} M_{g_i}^j \right) \odot \left( \sum_{i=1}^{m} M_{g_i}^j \right) \top
\]

Figure 1. Hierarchy Structure of Criteria Set and Alternatives
To obtain equation 2;
\[ \sum_{j=1}^{m} M'_{ij} \]  
(2)

perform the “fuzzy addition operation” of \( m \) extent analysis values for a particular matrix given in equation 3 below, at the end of calculation, new \((l,m,u)\) set is obtained and used for the next:
\[ \sum_{j=1}^{m} M'_{ij} = (\sum_{j=1}^{m} l, \sum_{j=1}^{m} m, \sum_{j=1}^{m} u) \]  
(3)

Where \( l \) is the lower limit value, \( m \) is the most promising value and \( u \) is the upper limit value.

and to obtain following equation 4;
\[ \sum_{i=1}^{n} \sum_{j=1}^{m} M''_{ij}^{-1} \]  
(4)

perform the “fuzzy addition operation” of \( M''_{ij} \) \((j = 1, 2, 3, 4, 5, \ldots, m)\) values give as equation 5:
\[ \sum_{i=1}^{n} \sum_{j=1}^{m} M''_{ij}^{-1} = \left( \frac{1}{\sum_{j=1}^{m} u}, \frac{1}{\sum_{j=1}^{m} m}, \frac{1}{\sum_{j=1}^{m} l} \right) \]  
(5)

and then compute the inverse of the vector in the equation 6 such that
\[ \begin{align*}
\sum_{j=1}^{m} l_M &= \frac{1}{\sum_{j=1}^{m} u} \\
\sum_{j=1}^{m} m_M &= \frac{1}{\sum_{j=1}^{m} m} \\
\sum_{j=1}^{m} u_M &= \frac{1}{\sum_{j=1}^{m} l}
\end{align*} \]  
(6)

Step 2: The degree of possibility of
\[ M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1) \] is defined as equation 7
\[ V(M_2 \geq M_1) = \sup_{x,y} \min(\mu_{M_1}(x), \mu_{M_2}(y)) \]  
(7)

and \( x \) and \( y \) are the values on the axis of membership function of each criterion. This expression can be equivalently written as given in equation 8 below:
\[ V(M_2 \geq M_1) = \begin{cases} 
1, & \text{if } m_2 \geq m_1, \\
0, & \text{if } l_2 \geq u_1, \\
\frac{l_2 - u_1}{(m_2 - u_1) - (m_1 - l)}, & \text{otherwise}
\end{cases} \]  
(8)

Figure 2. The Intersection between \( M_1 \) and \( M_2 \)

where \( d \) is the highest intersection point \( \mu_{M_1} \) and \( \mu_{M_2} \) (see Figure 2) (Zhu, et al, 1999, p. 451).

To compare \( M_1 \) and \( M_2 \), we need both the values of \( V(M_2 \geq M_1) \) and \( V(M_1 \geq M_2) \):

Step 3. The degree possibility for a convex fuzzy number to be greater than \( k \) convex fuzzy numbers
\[ M_i \ (i = 1, 2, 3, 4, 5, \ldots, k) \] can be defined by equation 9:
\[ V(M_i \geq M_j) = V(M_j \geq M_i) \]  
(9)

and \( (M_i \geq M_j) \) = \( \min V(M_i \geq M_j), i = 1, 2, 3, 4, 5, \ldots, k \) (9)

Assume the expression in equation 10 is:
\[ d(A_i) = \min V(S_i \geq S_k) \]  
(10)

For \( k = 1, 2, 3, 4, 5, \ldots, n; k \neq i \). Then the weight vector is given by equation 11:
\[ W = (d(A_1), d(A_2), d(A_3), d(A_4), d(A_5), \ldots, d(A_n))^T \]  
(11)

Where \( A_i \ (i = 1, 2, 3, 4, 5, 6, \ldots, n) \) are \( n \) elements.

Step 4. Via normalization, the normalized weight vectors are given in equation 12 below:
\[ W = (d(A_1), d(A_2), d(A_3), d(A_4), d(A_5), \ldots, d(A_n))^T \]  
(12)
Where \( W \) is nonfuzzy numbers.

To evaluate the questions, people only select the related linguistic variable, then for calculations they are converted to the following scale including triangular fuzzy numbers developed by (Chang, 1996) and generalized for such analysis as given in Table 2 below:

Table 2. TFN Values

<table>
<thead>
<tr>
<th>Statement</th>
<th>TFN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute</td>
<td>(7/2, 4, 9/2)</td>
</tr>
<tr>
<td>Very strong</td>
<td>(5/2, 3, 7/2)</td>
</tr>
<tr>
<td>Fairly strong</td>
<td>(3/2, 2, 5/2)</td>
</tr>
<tr>
<td>Weak</td>
<td>(2/3, 1, 3/2)</td>
</tr>
<tr>
<td>Equal</td>
<td>(1, 1, 1)</td>
</tr>
</tbody>
</table>


By using these linguistic statements and given in Table 2, criteria set is evaluated with the equations given in phase 1 (equation 1 through 12) weight of each criterion is obtained and so that the weights can be used in TOPSIS methodology, they are converted to trapezoidal fuzzy number such as \((a,a,a,a)\).

Phase 2: TOPSIS and Linguistic Variables for Ratings

By considering this main concept of TOPSIS model is implemented according to the following steps:

1) Normalize the evaluation matrix: \( x_{ij} \) is the evaluation matrix \( R \) of alternative \( i \) under the evaluation criterion \( j \). After normalization, the elements of matrix \( R \) convert into \( r_{ij} \). Normalization is carried out one of the methods which convert them into the numerical value, i.e. between 0-1, according to the characteristics of the problem (Chen, Lin & Huang, 2006).

2) Construct the weighted normalization matrix according to the values determined for each criterion. These weights \((w_{ij})\) can be obtained by any method such as eigenvector, AHP, fuzzy numbers, linear programming models, etc., then these weight vector is multiplied by normalized matrix \( R \) to obtain the weighted normalized matrix \( v_{ij} \).

3) Determine the negative and positive ideal solutions.

4) Calculate the separation measure. This measure is selected among the measures for calculating the distances. This can be an Euclidean distance (Chen & Tzeng, 2004) or vertex distance (Chen, Lin & Huang, 2006).

5) Calculate the negative closeness to the ideal solution. The relative closeness of the \( i^{th} \) alternative with respect to the ideal solution is calculated by negative distance over total distance.

6) Rank the priority: a set of alternatives sorted according to descending order of relative closeness.

Fuzzy triangular and trapezoidal numbers are used to evaluate each logistics service provider alternative. The linguistic variable for evaluation lies between “very poor” and “very good”, the membership function set is given in Figure 3, and as an example, the linguistic variable “Very Good (VG)” can be represented as \((8,9,9,10)\), the membership function of which is given in equation 13:

\[
\mu_{\text{Very Good}}(x) = \begin{cases} 
0, & x < 8 \\
\frac{x-8}{9-8}, & 8 \leq x \leq 9 \\
1, & 9 \leq x \leq 10
\end{cases}
\]

Figure 3. Linguistic variables for ratings
Source: Chen, Lin, Huang, 2006
In fact, Logistics service provider selection is a group multiple-criteria decision-making problem, which may be described by means of the following sets (Chen, Lin & Huang, 2006):

1. a set of \( K \) decision-makers called \( E = \{ D_1; D_2; \ldots; D_K \} \)
2. a set of \( m \) possible service providers called \( A = \{ A_1; A_2; \ldots; A_m \} \)
3. a set of \( n \) criteria, \( C = \{ C_1; C_2; \ldots; C_n \} \) with which logistics service provider performances are measured;
4. a set of performance ratings of \( A_i \) (\( i = 1; 2; \ldots; m \)) with respect to criteria \( C_j \) (\( j = 1; 2; \ldots; n \)), called \( X = \{ x_{ij}; i = 1; 2; \ldots; m; j = 1; 2; \ldots; n \} \)

Assume that a decision group has \( K \) decision makers, and the fuzzy rating of each decision-maker \( D_k \) (\( k = 1; 2; \ldots K \)) can be represented as a positive trapezoidal fuzzy number \( \tilde{R}_k \) (\( k = 1; 2; \ldots K \)) with membership function \( \mu_{\tilde{R}_k}(x) \). A good aggregation method should be considered the range of fuzzy rating of each decision-maker. It means that the range of aggregated fuzzy rating must include the ranges of all decision-makers’ fuzzy ratings. Let the fuzzy ratings of all decision makers be trapezoidal fuzzy numbers \( \tilde{R}_k = (a_k; b_k; c_k; d_k), k = 1; 2; \ldots K \). Then the aggregated fuzzy rating can be defined as \( \tilde{R} = (a; b; c; d) \).

As mentioned before, weight of each criterion is calculated using Fuzzy-AHP method which produces crisp weights through fuzzy numbers. Thus, in order to aggregate weights with ratings, weights are assumed trapezoidal fuzzy numbers \( \tilde{R}_k \) with membership function \( \mu_{\tilde{R}_k}(x) \). Then, the aggregated fuzzy rating can be defined as \( \tilde{R} = (a; b; c; d) \).

After the ratings are aggregated into one matrix then normalized weighted matrix is constructed by calculating equation 18:

\[
V_j = w_j \times r_{ij} \quad (18)
\]

As mentioned before, weight of each criterion is calculated using Fuzzy-AHP method which produces crisp weights through fuzzy numbers. Thus, in order to aggregate weights with ratings, weights are assumed trapezoidal fuzzy numbers which have equal values \( (a=b=c=d) \). Then rating matrix is multiplied by weight matrix and finally weighted normalized matrix is obtained.

According to the weighted normalized fuzzy-decision matrix, normalized positive trapezoidal fuzzy numbers can also approximate the elements \( \tilde{V}_{ij} \), \( \forall i, j \). Then, the fuzzy positive-ideal solution (FPS, \( A^+ \)) and fuzzy negative-ideal solution (FNIS, \( A^- \)) can be defined as

\[
A^+ = (\tilde{V}_1^+, \tilde{V}_2^+, \ldots, \tilde{V}_n^+), \quad A^- = (\tilde{V}_1^-, \tilde{V}_2^-, \ldots, \tilde{V}_n^-),
\]

where \( \tilde{V}_j^+ = \max_i \{ v_{ij} \} \) (19) and \( \tilde{V}_j^- = \min_i \{ v_{ij} \} \) (20), \( i = 1; 2; \ldots; m; j = 1; 2; \ldots; n \).

The distance of each alternative (3PL providers) from \( A^+ \) and \( A^- \) can be currently calculated with equation 21-22:

\[
d_i^+ = \sum j d_i(\tilde{V}_i, \tilde{V}_j^+) \quad (21), \quad d_i^- = \sum j d_i(\tilde{V}_i, \tilde{V}_j^-) \quad (22)
\]

Where \( d_i(\tilde{V}_i, \tilde{V}_j) \) is the vertex distance measurement between two trapezoidal fuzzy numbers that is calculated by equation 23:

\[
d_i(\tilde{V}_i, \tilde{V}_j) = \sqrt{\frac{(m_i - m_j)^2 + (n_i - n_j)^2 + (m_i - n_j)^2 + (m_i - n_j)^2}{4}} \quad (23)
\]

A closeness coefficient is defined to determine the ranking order of all possible \( s \) once \( d_i^+ \) and \( d_i^- \) of each 3PL providers \( A_i \) (\( i = 1; 2; \ldots; m \)) has been calculated. The closeness coefficient represents the distances to the fuzzy positive-ideal solution (\( A^+ \)) and the fuzzy negative-ideal solution (\( A^- \)) simultaneously by taking the relative closeness to the fuzzy positive-ideal solution. The closeness coefficient (\( CC_i \)) of each alternative (3PL providers) is calculated in equation 24:

\[
CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (24)
\]

It is clear that \( CC_i = 1 \) if \( A_i = A^+ \) and \( CC_i = 0 \) if \( A_i = A^- \). In other words, 3PL providers \( A_i \) is closer to the FPS (\( A^+ \)) and farther from FNIS (\( A^- \)) as \( CC_i \) approaches to 1. According to the descending order of \( CC_i \), the ranking order of all 3PL providers is determined and the best one among a set of feasible 3PL providers are selected. For evaluation process, approval status for each alternative is defined in Table 3 which can also be used for further evaluation when a decision is required for any 3PL provider.
Table 3. Approval status

<table>
<thead>
<tr>
<th>Closeness coefficient (CCi)</th>
<th>Evaluation status</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCi ∈ [0;0,2)</td>
<td>Do not recommend</td>
</tr>
<tr>
<td>CCi ∈ [0,2;0,4)</td>
<td>Recommend with high risk</td>
</tr>
<tr>
<td>CCi ∈ [0,4;0,6)</td>
<td>Recommend with low risk</td>
</tr>
<tr>
<td>CCi ∈ [0,6;0,8)</td>
<td>Approved</td>
</tr>
<tr>
<td>CCi ∈ (0,8;1,0)</td>
<td>Approved and preferred</td>
</tr>
</tbody>
</table>

Source: Chen, Lin & Huang, 2006, 8

3. Computational Results

According to the criteria set, hierarchy structure the pair wise comparisons within Fuzzy-AHP local and global importance weights are obtained as given in the Table 4:

Table 4. Fuzzy – AHP Results for Each Criterion

<table>
<thead>
<tr>
<th>Main criterion</th>
<th>Sub criterion name</th>
<th>Local importance</th>
<th>Global importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price &amp; payment</td>
<td>Cost</td>
<td>0,56667</td>
<td>0,358368</td>
</tr>
<tr>
<td>Quality characteristics</td>
<td>Flexibility in billing &amp; payment</td>
<td>0,433333</td>
<td>0,274046</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Long-term relationship</td>
<td>0,221711</td>
<td>0,031471</td>
</tr>
<tr>
<td>Information sharing &amp; mutual trust</td>
<td>0,778289</td>
<td>0,110475</td>
<td></td>
</tr>
<tr>
<td>Price &amp; payment</td>
<td>Cost</td>
<td>0,32253</td>
<td>0,14335</td>
</tr>
<tr>
<td>Quality characteristics</td>
<td>Delivery performance</td>
<td>0,19433</td>
<td>0,031471</td>
</tr>
<tr>
<td>Operational performance</td>
<td>0,00000</td>
<td>0,00000</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>0,00000</td>
<td>0,00000</td>
<td>0,00000</td>
</tr>
<tr>
<td>Operational performance</td>
<td>0,00000</td>
<td>0,00000</td>
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</tr>
<tr>
<td>Delivery performance</td>
<td>0,00000</td>
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</tr>
<tr>
<td>Quality of service</td>
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<tr>
<td>Flexibility in billing &amp; payment</td>
<td>0,00000</td>
<td>0,00000</td>
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</tbody>
</table>

It is seen from Table 4 that the most important main criterion is “price and payment” with the weight 0.6324 whereas the second and third criterion is “quality characteristics” (0.2256) and “collaboration” (0.14195), respectively. When the bottom level of the hierarchy is examined in terms of global importance, the first three sub criteria can be sequenced as “cost (0.3584)”, “flexibility in billing & payment (0.2740)”, and “delivery performance (0.1943)”. An interesting result is obtained that “reputation” and “operational performance” has no importance or any effect on selection and/or evaluation of 3PL provider, although these criteria are selected from the candidate list for evaluation. Therefore, these two criteria can not affect the further steps. In the TOPSIS methodology, after the criterion weights are obtained, these weights are distributed to the evaluation matrix consisting of alternative ratings in terms of each criterion. For this purpose simple matrix multiplication is applied as given in the equation 18 to obtain \( V_i \) matrix. The next step in this methodology is to define the FPIS and FNIS from \( V_i \) so that the distances from these solutions can be calculated. Table 5 represents the FPIS and FNIS values for each criterion with trapezoidal fuzzy numbers \((a,b,c,d)\), elements of which is placed in each cell:

Table 5. FPIS & FNIS Values for Each Criterion

<table>
<thead>
<tr>
<th>Criterion</th>
<th>FPIS</th>
<th>FNIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term relationship</td>
<td>0,03147</td>
<td>0,03147</td>
</tr>
<tr>
<td>Reputation</td>
<td>0,00000</td>
<td>0,00000</td>
</tr>
<tr>
<td>Information sharing &amp; mutual trust</td>
<td>0,00000</td>
<td>0,00000</td>
</tr>
<tr>
<td>Cost</td>
<td>0,11048</td>
<td>0,11048</td>
</tr>
<tr>
<td>Operational performance</td>
<td>0,19433</td>
<td>0,19433</td>
</tr>
<tr>
<td>Delivery performance</td>
<td>0,00000</td>
<td>0,00000</td>
</tr>
<tr>
<td>Quality of service</td>
<td>0,00000</td>
<td>0,00000</td>
</tr>
<tr>
<td>Flexibility in billing &amp; payment</td>
<td>0,00000</td>
<td>0,00000</td>
</tr>
</tbody>
</table>

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For each value of \(V_{ij}\), both distances from FNIS and FPIS is calculated by using vertex distance (equation 23). The distance values are given in Table 6 and Table 7 for FPIS and FNIS, respectively. When this stem has been finished the trapezoidal fuzzy numbers are defuzzificated to single values. For the next step, all distance values through each raw is summed to reach the overall distance of alternative representing evaluations in terms of all criteria for both FPIS and FNIS. Then \(CC_i\) ratio is calculated to see the evaluation result of each alternative 3PL provider (see equation 24) and the results are given in Table 8.

Table 6. Distances between Logistics Firms and FPIS With Respect To Each Criterion

<table>
<thead>
<tr>
<th>Positive Distance</th>
<th>Long-term relationship</th>
<th>Reputation</th>
<th>Information sharing &amp; mutual trust</th>
<th>Cost</th>
<th>Operational performance</th>
<th>Delivery performance</th>
<th>Quality of service</th>
<th>Flexibility in billing &amp; payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>d(L_A, A*)</td>
<td>0.006676</td>
<td>0</td>
<td>0.020337</td>
<td>0.119157</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.09112</td>
<td></td>
</tr>
<tr>
<td>d(L_B, A*)</td>
<td>0.005271</td>
<td>0</td>
<td>0.031838</td>
<td>0.088187</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.067437</td>
<td></td>
</tr>
<tr>
<td>d(L_C, A*)</td>
<td>0.005271</td>
<td>0</td>
<td>0.031838</td>
<td>0.119157</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.067437</td>
<td></td>
</tr>
<tr>
<td>d(L_D, A*)</td>
<td>0.003519</td>
<td>0</td>
<td>0.018504</td>
<td>0.088187</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.067437</td>
<td></td>
</tr>
<tr>
<td>d(L_E, A*)</td>
<td>0.003519</td>
<td>0</td>
<td>0.018504</td>
<td>0.088187</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.067437</td>
<td></td>
</tr>
<tr>
<td>d(L_F, A*)</td>
<td>0.003519</td>
<td>0</td>
<td>0.050088</td>
<td>0.088187</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.067437</td>
<td></td>
</tr>
<tr>
<td>d(L_G, A*)</td>
<td>0.02221</td>
<td>0</td>
<td>0.05767</td>
<td>0.119157</td>
<td>0.03255</td>
<td>0.005244</td>
<td>0.09112</td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Distances between Logistics Firms and FNIS with Respect To Each Criterion

<table>
<thead>
<tr>
<th>Negative distance</th>
<th>Long-term relationship</th>
<th>Reputation</th>
<th>Information sharing &amp; mutual trust</th>
<th>Cost</th>
<th>Operational performance</th>
<th>Delivery performance</th>
<th>Quality of service</th>
<th>Flexibility in billing &amp; payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>d(L_A, A)</td>
<td>0.025275</td>
<td>0</td>
<td>0.07277</td>
<td>0.088187</td>
<td>0.076027</td>
<td>0.012249</td>
<td>0.067437</td>
<td></td>
</tr>
<tr>
<td>d(L_B, A)</td>
<td>0.02776</td>
<td>0</td>
<td>0.066566</td>
<td>0.119157</td>
<td>0.076027</td>
<td>0.012249</td>
<td>0.09112</td>
<td></td>
</tr>
<tr>
<td>d(L_C, A)</td>
<td>0.025275</td>
<td>0</td>
<td>0.066566</td>
<td>0.088187</td>
<td>0.076027</td>
<td>0.012249</td>
<td>0.09112</td>
<td></td>
</tr>
<tr>
<td>d(L_D, A)</td>
<td>0.029227</td>
<td>0</td>
<td>0.075581</td>
<td>0.119157</td>
<td>0.076027</td>
<td>0.012249</td>
<td>0.09112</td>
<td></td>
</tr>
<tr>
<td>d(L_E, A)</td>
<td>0.029227</td>
<td>0</td>
<td>0.075581</td>
<td>0.119157</td>
<td>0.076027</td>
<td>0.012249</td>
<td>0.09112</td>
<td></td>
</tr>
<tr>
<td>d(L_F, A)</td>
<td>0.029227</td>
<td>0</td>
<td>0.059035</td>
<td>0.119157</td>
<td>0.076027</td>
<td>0.012249</td>
<td>0.09112</td>
<td></td>
</tr>
<tr>
<td>d(L_G, A)</td>
<td>0.015674</td>
<td>0</td>
<td>0.043142</td>
<td>0.088187</td>
<td>0.036356</td>
<td>0.007705</td>
<td>0.067437</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Computations of \(d_i^*, d_i^-\) and \(CC_i\)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Total (d^*)</th>
<th>Total (d^-)</th>
<th>(d^* + d^-)</th>
<th>(CC_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_A</td>
<td>0.275084</td>
<td>0.341946</td>
<td>0.61703</td>
<td>0.55418</td>
</tr>
<tr>
<td>L_B</td>
<td>0.230528</td>
<td>0.392878</td>
<td>0.623407</td>
<td>0.63021</td>
</tr>
<tr>
<td>L_C</td>
<td>0.262903</td>
<td>0.359424</td>
<td>0.622327</td>
<td>0.577549</td>
</tr>
<tr>
<td>L_D</td>
<td>0.215442</td>
<td>0.405361</td>
<td>0.618803</td>
<td>0.651841</td>
</tr>
<tr>
<td>L_E</td>
<td>0.215442</td>
<td>0.405361</td>
<td>0.618803</td>
<td>0.651841</td>
</tr>
<tr>
<td>L_F</td>
<td>0.247025</td>
<td>0.386815</td>
<td>0.63384</td>
<td>0.610272</td>
</tr>
<tr>
<td>L_G</td>
<td>0.371969</td>
<td>0.258501</td>
<td>0.63047</td>
<td>0.410014</td>
</tr>
</tbody>
</table>

According to the approval status scale given in Table 3 and the \(CC_i\) results in Table 8, none of the alternatives are in “approved and preferred status”. However, none of them also are not in neither “Do not recommend” nor “Recommend with high risk”. The highest performance belongs to the alternative L_D and L_E with same ratio 0.6518, and L_F and L_G come after them and also in the “approved” status. The firm should consider this evaluation results when selecting a 3PL provider and should also use this decision process to evaluate them periodically to track the change in status.

4. Conclusion

In this paper, a systematic and practical methodology is developed and presented for selection and evaluation of 3PL providers among many alternatives based on fuzzy models using linguistic variables integrating Fuzzy AHP and TOPSIS model. The first phase of the methodology consists of weighting the hierarchical criteria set via fuzzy-AHP method so that the weights are calculated in a pair wise comparison manner which is the advantage of AHP method. In the second phase, the alternative 3PL providers are evaluated by and ranked via TOPSIS model. The sample study of the methodology has been carried out in a firm which exports agricultural foods to many countries. In addition to the selection process, an evaluation status scale is given for further evaluations of alternative service provider. An interesting result is obtained that “reputation” and “operational performance” has no importance or any effect on selection and/or evaluation of 3PL provider. If classical AHP were applied on the same hierarchy structure,
these “zero importance values” would not be same but would be too close to zero. This is one of important difference between classical AHP and fuzzy AHP.

Computations show that, the firm should revise its alternative list to find out new alternatives which can have the upper approval status. As a result, a systematic and practical process for selection and evaluation has been developed and approved by the executers. The methodology can be applied for the other sectors which have a problem for deciding how to select the 3PL providers.

References


Saaty, Thomas L., Vargas, Luis G. 1994. Decision Making With The AHP, University Of Pittsburgh, USA.


