APPLICATION OF METHOD FUZZY LOGIC FOR CARRIER SELECTION

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Abstract: *The one of the key strategic considerations in transport process is carrier selection problem. This problem is a multi objective problem involving both qualitative and quantitative factors. These factors and their interdependencies make the problem highly complex one. From the managerial perspectives,it is always convenient to express the variables and weights through linguistic values. An analytic hierarchy process (AHP) like procedure based on Eigen value has been proposed to derive the weightages of decision makers. This paper uses a fuzzy approach to deal with the carrier selection problem in transport process. A numerical example presented illustrates the different selection criteria to select the best carrier.*

***KEYWORDS**:* FUZZY LOGIC, SUPPLIER, CARRIER SELECTION, MULTI CRITERIA DECISION MAKING, TRANSPORT

1. Introduction

There are various transport companies / carriers / offering shipping services at the appropriate tariff policy, delivery time of goods and quality of the service in practice. In this sense, the optimal choice of transport services in a competitive market environment, is essential for cost management in manufacturing enterprises, in the realization of their material flows with their respective mode of transport and vehicle fleet.

The need for proper choice of carrier comes from the fact that transport costs are subject to change in the direction of increasing or decreasing, so manufacturing enterprises must periodically select the best transportation options for optimum compatibility between the parameters, the objectives of the manufacturing process, physical characteristics and specificity of the production and technical performance of the transport processes. In this regard, the decision to select the carrier is a complex multifactor problem, the core of which are set out various quantitative and qualitative criteria the evaluation of choice. Often, however, some of the criteria may conflict with each other, which could lead to inconsistent decision-making expertise inappropriate choice of transport variant, and hence, affecting the final financial performance of the companies, using transport services. Therefore, when choosing a carrier, along with methods of the expertise, have to apply modern methods of artificial intelligence in an experimental setting.

In this study, feasibility of the application of *Analytich ierarchy process* (AHP) is considered, based on fuzzy sets theory to estimate the significance and relationship of the criteria for selecting a suitable carrier.

.The possible artificial intelligence methods [6], suitable for the problem under consideration, are *Artificial neural network* **(**ANN) and *Fuzzy logic* (FL).

Fuzzy logic – (FL) - Fuzzy systems emulate the inaccuracy of human knowledge. They resemble the approximate conclusions of the people, using fuzzy terms, but in a quantitative manner. This allows computers to use fuzzy logic, which is much closer to the real world, as opposed to crisp logic.

Artificial neural network (ANN) are one of the major learning methods in computational intelligence. Acquired knowledge in neural networks is presented with numerical weights in structural connections.

With respect to the problem, the use of the ANN is less effective alternative, because it is difficult to change the trained ANN model when the decision makers change their evaluation rules.

Fuzzy sets theory was developed by Lotfi Zadeh in 1965 [5]. Fuzzy sets are defined versus crisp sets. For crisp sets, the element (x) either belongs to or not belongs to a set (S) totally.

By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set. This is described with the aid of a membership function valued in the real unit interval [0, 1].

2. Theoretical formulation of the method

With AHP method performs the following basic steps:

- Define the problem and precise formulation of objectives and results;
- Decomposition of the problem in a hierarchical structure by conditional elements (criteria, sub-criteria and alternatives);
- Sequentially (for each level of the hierarchy) assessing the importance of the alternatives using pair-wise comparisons;
- Consistent evaluation of local priorities comparison items (for each level of the hierarchy);
- Check for consistency of local priorities ;
- Aggregate the relative weights of decision elements to obtain an overall rating for the alternatives.

Based on a literature review is given a combination of FL и AHP, *Fuzzy AHP* [1,2,3,4]. Characteristic feature is that it keeps the logic of AHP and its basic steps, and implementation of some of them, become using FL.

Algorithm analysis by triangular fuzzy numbers are listed below.

<u>*Triangular fuzzy numbers*</u>

The number $M \in F(R)$ is called a fuzzy number if there exist $x_0 \in R$, such that $\mu_M(x_0)=1$. For any $\alpha \in [0,1]$, $A_\alpha=(x,\mu_{A\alpha}(x)\geq a)$ is a closed interval. Here *F(R)* represents all fuzzy numbers, and *R* - the set of real numbers.

We define a fuzzy number, *M* on *R* to be a triangular fuzzy number if its membership function $\mu_M(x)$:$R \rightarrow [0,1]$ is equal to

$$(1) \qquad \mu_{\tilde{M}}(x) = \begin{cases} \dfrac{x}{m-l} - \dfrac{l}{m-l}, & x \in [l,m] \\ \dfrac{x}{m-u} - \dfrac{u}{m-u}, & x \in [m,u] \\ 0, & otherwise \end{cases}$$

Here $l \leq m \leq u$, *l* and *u* stand for the lower and upper value of M respectively, and *m* for the model value. The triangular number is denoted by (*l*, *m*, *u*). If *l* = *m* = *u*, it is non-fuzzy number. The *M* is the set $\{x \in R / l < x < u\}$

<u>*Extent Analysis Method*</u>

The extent analysis method is the technique that is widely used in the literature for fuzzy AHP problems. In this method, the "extent" is quantified by using a fuzzy number. The value of fuzzy synthetic extent can be obtained:

Let $X = \{x_1,..,x_n\}$ be an object set, and $G = \{g_1,..,g_n\}$ be a goal set. According to the method of *extent analysis*, we now take each object and perform extent analysis for each goal respectively. Therefore, we can get m extent analysis values for each object, with the following signs:

$$(2) \qquad \hat{M}^1_{g_i}, \hat{M}^2_{g_i}, \dots, \hat{M}^m_{g_i}, \quad i = 1, \dots, n$$

where all the $\widehat{M}_{g_i}^{j}$ (j = 1,…,m) are triangular fuzzy numbers.

The concerned method by described below mathematical tools is being displayed.

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

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

where:

M_g – triangular fuzzy number;

We can obtain $\sum_{j=1}^{m} M_{gi}^{j}$ by the fuzzy addition of m -th extent analysis values for a particular matrix such that:

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

where l, m, u are real numbers for $M_{g,i} = (l_i, m_i, u_i)$.

To obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, perform the fuzzy addition operation on values of M_{gi}^{j} $(j = 1,..,m)$ such that:

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

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

(6) $$\left[\sum_{j=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n} u_j},\frac{1}{\sum_{i=1}^{n} m_j},\frac{1}{\sum_{i=1}^{n} l_j}\right)$$

As $\widetilde{M}_1 = (l_1, m_1, u_1)$ и $\widetilde{M}_2 = (l_2, m_2, u_2)$ 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:

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

and can be equivalently expressed as follows:

(8) $$V(\widetilde{M}_2 \geq \widetilde{M}_1) = hgt\left(\widetilde{M}_1 \cap \widetilde{M}_2\right) = \mu_{M_2}(d)$$

$$\mu_{M_2}(d)=\begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & otherwise \end{cases}$$

According to *fuzzy sets theory* [5], the representation of a fuzzy triangular number is given in figura 1.

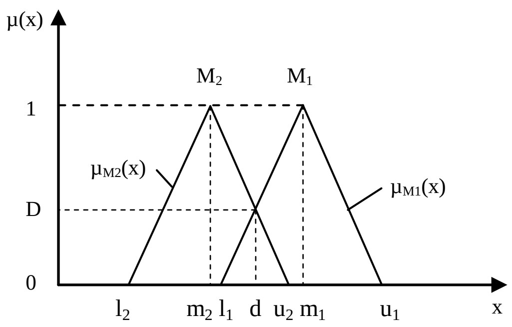


***Figure* 1.** *The intersection between M1 and M2*

According to Figure 1, D is the ordinate of the highest intersection point d between μ_{M_1} и μ_{M_2} .

To compare M_1 и M_2, both the values of $V(M_1 \geq M_2)$ и $V(M_2 \geq M_1)$.

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

(9) $V(M \geq M_1,...,M_k)$ = V[($M \geq M_1$) и ($M \geq M_2$) and...and ($M \geq M_k$)] = min V($M \geq M_i$), i = 1,2,3,…….k

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

(10) $$W' = (d'(A_1), d'(A_2),…., d'(A_n))^T$$

where A_i (i = 1,2,…n) are n elements.

Via normalization, the normalized weight vectors W (a non-fuzzy number.) are:

(11) $$W = (d(A_1), d(A_2),…., d(A_n))^T$$

3. Application of the Fuzzy AHP model in carrier selection

In the following section, we suggest a solution to the above mentioned problem by considering a situation involving three carriers *П1,…П3*, evaluated on four main criteria's *К1,..,К4*. To simplify the presentation of the methodology does not consider the sub-criteria of the main criteria.

The proposed criteria in this report are as follows:

-The cost of transport-К1;
- Time delivery of consignments-К2;
- Reliability and quality of service-К3;
- Financial stability of carrier-К4.

The relative degree of importance of each criterion is systematized in Table 1.

Table 1: *The fuzzy scale*

Triangular Fuzzy Scale	alternatives	weight rating	Triangular Fuzzy Reciprocal Scale
(1,1,1)	poor(P)	Very Low (VL)	(1/3,1,1)
(1,3,5)	Medium poor(MP)	Low (L)	(1/5,1/3,1)
(3,5,7)	Medium good(MG)	Normal (N)	(1/7,1/5,1/3)
(5,7,9)	good(G)	High (H)	(1/9,1/7,1/5)
(7,9,9)	Very good(VG)	Very High (VH)	(1/9,1/9,1/7)

The hierarchical structure of the problem is given in Figure 2. The problem is selecting the best supplier among 3 alternative carriers which are П1, П2, and П3.

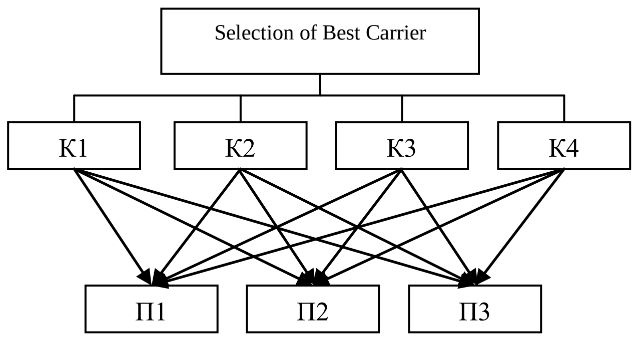


***Figure* 2.** *Proposed hierarchical structure of the problem*

We assume that we have expert judgments offered by experts. We do not consider the problem of assessing the experts and obtain the weights of their evaluations on different criteria for different carriers. And start from the moment we get the final scores for each one of the criteria for individual carriers in *Linguistic scale*, summarized in Table 1.

Now as the linguistic assessments simply approximate the subjective judgment of decision-makers, we consider the linear triangular membership functions to capture the vagueness of linguistic assessment. The linguistic variables are expressed as positive triangular fuzzy numbers. The decision makers are asked to use the linguistic variables as shown in Tables 2 and 3, to evaluate the importance of the criteria and the ratings of alternatives with respect to qualitative criteria.

Table 2: *Evaluation criteria of importance*

	criteria			
	K1	*K2*	*K3*	*K4*
rating	H	N	N	N

Table 3: *Rating of carriers by decision makers under various criteria*

carrier	criteria			
	K1	*K2*	*K3*	*K4*
П1	H	L	N	N
П2	N	N	H	H
П3	L	H	N	L

The Tables 1, 2 and 3 are used for rating the criteria by the decision-makers and the rating of carriers on various criteria. The ratings are represented using fuzzy values in Table 4.

Table 4: *The rating of carriers in fuzzy numbers*

carrier	criteria			
	K1	*K2*	*K3*	*K4*
П1	5,7,9	1,3,5	3,5,7	3,5,7
П2	3,5,7	3,5,7	5,7,9	5,7,9
П3	1,3,5	5,7,9	3,5,7	1,3,5

In order to find the priority characteristics of main criteria, the fuzzy synthetic extent values were calculated using equation (3). The different values of fuzzy synthetic extent with respect to the different criteria are denoted by *K1*, *K2*, *K3*, and *K4*, respectively.

S_{K1} = (10,16,22)⊗(47.2,33.41,20.94)$^{-1}$=(***0.21,0.48,1.05***)
S_{K2} = (4.34,6.53,9.33)⊗(47.2,33.41,20.94)$^{-1}$=(***0.09,0.19,0.45***)
S_{K3} = (4.34,6.53,9.33)⊗(47.2,33.41,20.94)$^{-1}$=(***0.09,0.19,0.45***)
S_{K4} = (2.25,6.34,6.53)⊗(47.2,33.41,20.94)$^{-1}$=(***0.04,0.19,0.31***)

With the help of equations (7) и (8), obtain:

$V(K1 \geq K2)=1$; $V(K1 \geq K3)=1$; $V(K1 \geq K4)=1$;
$V(K2=K3)=1$; $V(K2 \geq K4)=1$; $V(K3 \geq K4)=1$;

For given below degree of possibility, are calculated by equation (8):

$V(K2 \geq K1) = (k_{11}-k_{23}) / ((k_{22}-k_{23}) - (k_{12}-k_{11}))$ = (0,21-0,45)/((0,19-0,45)-(0,48-0,21)) = 0,45.
$V(K2 \geq K1)$ = ***0,45***.

Similarly calculations are made for the other degree of possibility.

$V(K3 \geq K1)$ = ***0,45***; $V(K4 \geq K1)$ = ***0,26***;
$V(K4 \geq K3,K2)$ = ***0,97***.

With the help of equation (9), the minimum degree of possibility of superiority of each criterion over another is obtained:

min(K1)= min(1,1,1); min(K2)= min(0.45,1,1)
min(K3)= min(0.45,1,1); min(K4)= min(0.26,0.97,0.97).

With the resulting values, the weight vector is given as:

W = (*1, 0.45, 0.45, 0.26*).

Via normalization on *W*, the normalized weight vectors (with respect to *K1*, *K2*, *K3* and *K4*) are::

W_K = (***0.464, 0.208, 0.208, 0.120***)^T.

Table 5: *The comparison matrix of criteria*

criteria	*K1*	*K2*	*K3*	*K4*	***Weight***
K1	1,1,1	1,3,5	3,5,7	5,7,9	**0,464**
K2	1/5,1/3,1/1	1,1,1	1/7,1/5.1/3	3,5,7	**0,208**
K3	1/7,1/5,1/3	3,5,7	1,1,1	1/5,1/3,1	**0,208**
K4	1/9,1/7,1/3	1/7,1/5,1/3	1,3,5	1,1,1	**0,120**

The comparison matrices of each alternative according to each criteria are given in Table 6,7,8 and 9 respectively. For the preparation of the weights, using that approach, and mathematical tools, applied to the Table 5.

Table 6: *The comparison of alternatives with respect to K1*

alternative	*П1*	*П2*	*П3*	***Weight***
П1	1,1,1	1,3,5	3,5,7	**0,574**
П2	1/5,1/3,1	1,1,1	1,3,5	**0,374**
П3	1/7,1/5,1/3	1/5,1/3,1	1,1,1	**0,052**

$S_{П1}$ = (0.224,0.605,1.523); $S_{П2}$ = (0.098,0.291,0.819)
$S_{П3}$ = (0.060,0.103,0.273)
W = (*1, 0.65, 0.09*)
$W_{П,K1}$ = (***0.574, 0.374, 0.052***)^T

Table 7: *The comparison of alternatives with respect to K2*

alternative	*П1*	*П2*	*П3*	***Weight***
П1	1,1,1	1/5,1/3,1	1/7,1/5,1/3	**0,052**
П2	1,3,5	1,1,1	1/5,1/3,1	**0,373**
П3	3,5,7	1,3,5	1,1,1	**0,575**

$S_{П1}$ = (0.060, 0.103, 0.273); $S_{П2}$ = (0.098, 0.291, 0.819)
$S_{П3}$ = (0.224, 0.605, 1.523)
W = (*0.09,0.65, 1*)
$W_{П,K1}$ = (***0.052, 0.373, 0.575***)^T

Table 8: *The comparison of alternatives with respect to K3*

alternative	*П1*	*П2*	*П3*	***Weight***
П1	1,1,1	1/5,1/3,1	1,3,5	**0,364**
П2	1,3,5	1,1,1	1,3,5	**0,445**
П3	1/5,1/3,1	1/5,1/3,1	1,1,1	**0,191**

$S_{П1}$ = (0.105, 0.333, 1.061); $S_{П2}$ = (0.143, 0.534, 1.667)
$S_{П3}$ = (0.067, 0.128, 0.455)

W = (*0.82,1, 0.43*)

$W_{П,K1}$ = (***0.364, 0.445, 0.191***)^T

Table 9: *The comparison of alternatives with respect to K4*

alternative	*П1*	*П2*	*П3*	***Weight***
П1	1,1,1	1/5,1/3,1	3,5,7	**0,440**
П2	1,3,5	1,1,1	1,3,5	**0,463**
П3	1/7,1/5,1/3	1/5,1/3,1	1,1,1	**0,097**

$S_{П1}$ = (0.188, 0.426, 1.054); $S_{П2}$ = (0.134, 0.471, 1.288)
$S_{П3}$ = (0.060, 0.103, 0.273)
W = (*0.95,1, 0.21*)
$W_{П,K1}$ = (***0.440, 0.463, 0.097***)^T

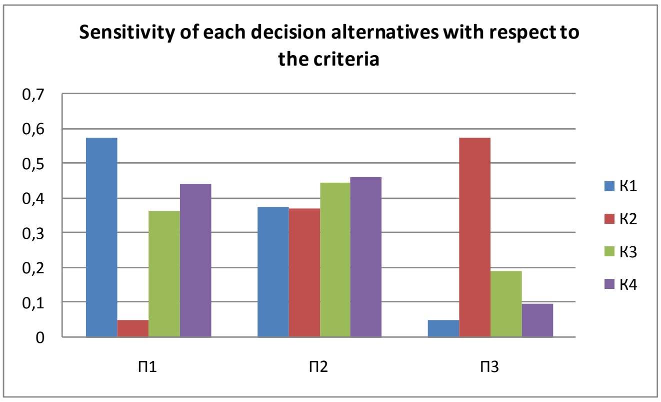
4. Results

Based on the methodology applied and the calculations are given weights considered carriers indicated in Table 10. Figure 4 illustrated their distribution.

Table 10: *Final weights of alternatives*

criteria	K1	K2	K3	K4	*Weight*
П1	0,574	0,052	0,364	0,440	0,406
П2	0,374	0,373	0,445	0,463	0,399
П3	0,052	0,575	0,191	0,097	0,195
weight	*0,464*	*0,208*	*0,208*	*0,120*	1

Figure 3 shows the sensitivity of each decision alternatives with respect to the criteria.



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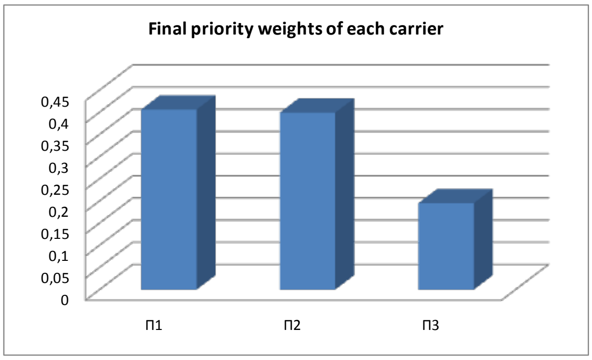

Figure 4. *Final priority weights of each carrier*

5. Conclusions

The choice of criteria and their hierarchical structure should as far as possible to reflect the strategic business goals of the company, using transport services.

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 the calculations made, it was seen that Carrier ***П2*** ranked first as carrier.

Input data are averages for the implementation of the key indicators of the activity of companies, using transport services in the past few years.

This approach can lead to useful results to other sectors or in other areas of application. Appropriate comparison of results, obtained with that discussed methods, with those obtained from the model of expertise, which is subject to further development.

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