INTER MODEL ROUTINGS SOLUTION OF THAILAND –CHINA SHIPMENTS UNDER FTA USING FUZZY AHP

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Abstract

This paper deals with a method to solve transports problems. Actually, there are many routings possibilities between Thailand and China who are under Free Trade Agreement. For example, the goods can transit through Laos, through Myanmar or on the Mekong River by ship. All possibilities are available but we need to choose the best one according to fuzzy criteria. This study will try to use this method to find the best routing. Fuzzy AHP used linguistic variables to assess the ratings and the weights for quantitative or qualitative factors such as cost, time, risk and others performances. These linguistic ratings can be expressed in trapezoidal or triangular fuzzy numbers. Then a MCDM model is proposed to deal with the selection problem. To determine the ranking order of each possible solution, a closeness coefficient is defined by calculating the distances to the both fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) simultaneously.

1. Introduction

As the relations between Thailand and China improving, both countries decided an agreement called FTA (Free Trade Agreement) for making easier exchanges. For example, Tariffs for 188 types of fruits and vegetables have been cut to zero. The agreement took effect in October 2003. China and ASEAN intend to conclude a comprehensive trade and economic agreement by 2010. [12]

Moreover, recognizing the economic and social benefits that could result from the linking of the countries of Asia, roads and particularly highways are under construction. This Asian Highway project was launched under the auspices of ESCAP [11]. The aim of this project is to build :
- capital-to-capital links for international transport;
- connections to main industrial and agricultural centres as well as growth triangles and zones (links to important origin and destination points);
- connections to major sea and river ports (integration of land and water transport networks); and connections to major container terminals and depots (integration of road and rail networks).

Now, with such an agreement and with such a connections improvement, both countries need a new management policy for exchanging goods. So they also need new tools for decision making. The Analytical Hierarchy Process (AHP) method is one of the most widely used MCDM (multiple criteria decision making) tool [4]. Generally, it consists of a questionnary for comparison of each element and geometric mean to arrive at a final solution. The main advantage of this method is its flexibility because it can be integrated with different techniques like fuzzy logic in this case.

For determining a best routing we need criteria which are not only numeric values, furthermore, their importance is variable. The best representation for this kind of criteria is using linguistic variables. Actually, mathematical operations are available in fuzzy logic, so we can adapt mathematical methods with just linguistic variables.

The main advantages of fuzzy logic is that exact values are not needed. For example, a distance can be long, short, medium, medium long… It is possible to have as many categories we wish for the model precision. Moreover for a decision making some criteria are evaluated differently according the decision maker position and their importance may change depending on the point of view. Furthermore, it is possible to mix exact numerical values with fuzzy numbers scaling the values in different categories.

In this article, the Fuzzy Analytical Hierarchy Process will be described with a numerical example about a routing decision making problem. This explanation will be divided in several steps, from the criteria evaluation to the final result, the closeness coefficients for each alternative and their interpretations. And finally, others configurations will be computed to have a general vision of the whole decision making problem.

2. Model formulation:

[5], [6]

In a MCDM model we need three categories of inputs :

- The Candidates $\{A_1, A_2, \ldots, A_m\}$
- The Criteria $\{C_1, C_2, \ldots, C_n\}$
- The Decision-Makers $\{D_1, D_2, \ldots, D_k\}$

The decision makers use linguistic variables which can be represented as a positive trapezoidal fuzzy number, as shown in the figure 1 and 2 [1], [2] and [3], for evaluating the importance and the rating of the criteria.

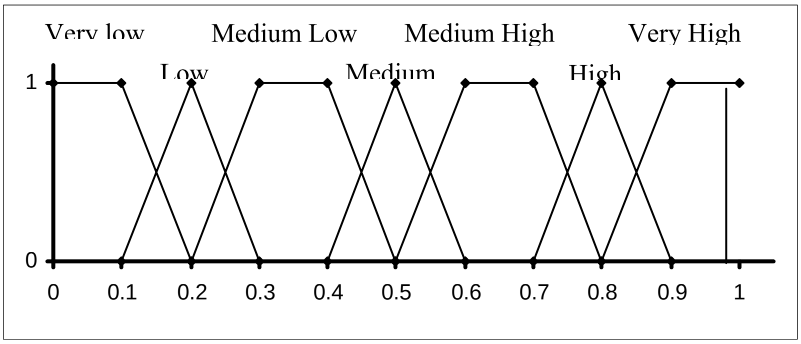

Fig. 1 - Linguistics variables for importance weight of each criterion.

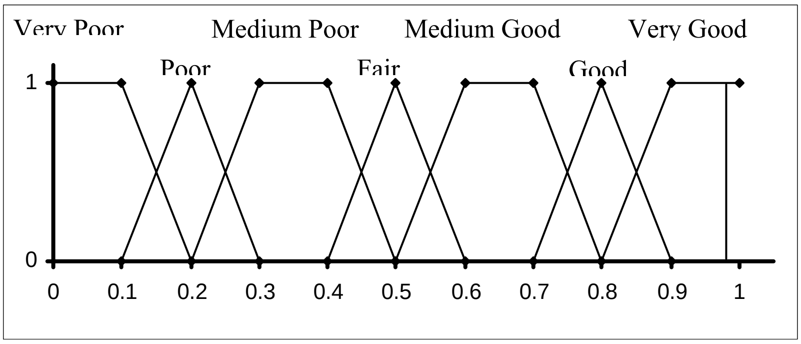

Fig. 2 – Linguistics variables for ratings each criterion.

Table 1 - Fuzzy numbers and linguistic variables [7]

Very High	(0.8; 0.9; 1.0; 1.0)	**Very Good**
High	(0.7; 0.8; 0.8; 0.9)	**Good**
Medium High	(0.5; 0.6; 0.7; 0.8)	**Medium Good**
Medium	(0.4; 0.5; 0.5; 0.6)	**Fair**
Medium Low	(0.2; 0.3; 0.4; 0.5)	**Medium Poor**
Low	(0.1; 0.2; 0.2; 0.3)	**Poor**
Very Low	(0.0; 0.0; 0.1; 0.2)	**Very Poor**

In this numerical example, the fuzzy AHP will be used to evaluate three candidates (Birmany, Mekong, Laos) with six criteria (Distance, Traveling Time, Cost/Unit, Borders, Problem Resolution, Reliability) for the shipment from Thailand to China in the future considering the connections improvement. Moreover three decision makers (D_1,D_2,D_3) participate in the method. In the method below, we will use these parameters :

C_1 : Distance
C_2 : Traveling Time
C_3 : Cost / Unit
C_4 : Borders
C_5 : Problem resolution
C_6 : Reliability

A_1 : Myanmar
A_2 : Laos
A_3 : Mekong river

Fig. 4 – Routing possibilities map

3. Method

<u>Step 1 :</u> Evaluation.

The three decision makers use the linguistic weighting variables from the figure 1 to assess the importance of the criteria and the linguistic rating variables from the figure 2 to evaluate the ratings of the candidates with respect of each criterion. These decisions are shown in table 2.

Table 2 – Importance and Ratings of the three candidates by the Decision-Makers

		Weight	A_1	A_2	A_3
D_1	C_1	M	MG	G	VG
	C_2	H	MG	G	P
	C_3	H	F	MG	VG
	C_4	M	F	MG	G
	C_5	H	F	G	G
	C_6	VH	F	VG	MG
D_2	C_1	M	G	MG	VG
	C_2	MH	MG	G	P
	C_3	H	F	MG	VG
	C_4	H	P	MG	VG
	C_5	VH	F	VG	MG
	C_6	VH	MG	VG	MP
D_3	C_1	M	MG	G	VG
	C_2	H	MG	G	P
	C_3	H	F	MG	VG
	C_4	H	P	F	G
	C_5	H	F	G	G
	C_6	VH	F	VG	MG

After converting linguistic variables into trapezoidal fuzzy numbers using the matching table 1, the average decision matrix can be calculated from the linguistic values defined by decision makers.

Table 3 – Average fuzzy decision matrix

	Weight	A_1	A_2	A_3
C_1	(0.4; 0.5; 0.5; 0.6)	(0.6; 0.7; 0.7; 0.8)	(0.6; 0.7; 0.8; 0.9)	(0.8; 0.9; 1.0; 1.0)
C_2	(0.6; 0.7; 0.8; 0.9)	(0.5; 0.6; 0.7; 0.8)	(0.7; 0.8; 0.8; 0.9)	(0.1; 0.2; 0.2; 0.3)
C_3	(0.7; 0.8; 0.8; 0.9)	(0.4; 0.5; 0.5; 0.6)	(0.5; 0.6; 0.7; 0.8)	(0.8; 0.9; 1.0; 1.0)
C_4	(0.6; 0.7; 0.7; 0.8)	(0.2; 0.3; 0.3; 0.4)	(0.5; 0.6; 0.6; 0.7)	(0.7; 0.8; 0.9; 0.9)
C_5	(0.7; 0.8; 0.9; 0.9)	(0.4; 0.5; 0.5; 0.6)	(0.7; 0.8; 0.9; 0.9)	(0.6; 0.7; 0.8; 0.9)
C_6	(0.8; 0.9; 1.0; 1.0)	(0.4; 0.5; 0.6; 0.7)	(0.8; 0.9; 1.0; 1.0)	(0.4; 0.5; 0.6; 0.7)

Step 3 : Weighted fuzzy decision matrix.

The weighted fuzzy decision matrix is constructed multiplying the criteria fuzzy numbers by their own weight.

Table 4 – Weighted fuzzy decision matrix

	A_1	A_2	A_3
C_1	(0.23; 0.33; 0.37; 0.50)	(0.25; 0.37; 0.38; 0.52)	(0.32; 0.45; 0.50; 0.60)
C_2	(0.32; 0.44; 0.54; 0.69)	(0.44; 0.59; 0.61; 0.78)	(0.06; 0.15; 0.15; 0.26)
C_3	(0.28; 0.40; 0.40; 0.54)	(0.35; 0.48; 0.56; 0.72)	(0.56; 0.72; 0.80; 0.90)
C_4	(0.12; 0.21; 0.21; 0.32)	(0.28; 0.40; 0.44; 0.59)	(0.44; 0.58; 0.61; 0.75)
C_5	(0.29; 0.42; 0.43; 0.56)	(0.54; 0.69; 0.75; 0.87)	(0.46; 0.61; 0.66; 0.81)
C_6	(0.35; 0.48; 0.57; 0.67)	(0.64; 0.81; 1.00; 1.00)	(0.32; 0.45; 0.60; 0.70)

Step 4 : Determine FPIS and FNIS.

The fuzzy positive ideal solution (FPIS) , A^* and fuzzy negative ideal solution (FNIS), A^-, are easy to calculate [7]. For each criterion, each component is simply defined as the maximum (A^*) or minimum (A^-) of all the components among the candidates.

A^* = [(0.60; 0.60; 0.60;0.60) ; (0.78; 0.78; 0.78;0.78) ; (0.90; 0.90; 0.90;0.90) ; (0.75; 0.75; 0.75;0.75) ; (0.87; 0.87; 0.87;0.87) ; (1.00; 1.00; 1.00;1.00)]

A^- = [(0.23; 0.23; 0.23;0.23) ; (0.06; 0.06; 0.06;0.06) ; (0.28; 0.28; 0.28;0.28) ; (0.12; 0.12; 0.12;0.12) ; (0.29; 0.29; 0.29;0.29) ; (0.32; 0.32; 0.32;0.32)]

Step 5 : Distances.

To compute the distance between the fuzzy number from the weighted fuzzy decision matrix and both FPIS and FNIS, fuzzy mathematical proprieties can be used.

Assume that both $M_1=(m_1,m_2,m_3,m_4)$ and $N_1=(n_1,n_2,n_3,n_4)$ are two trapezoidal numbers. The distance between them can be calculated using the vertex method [9] as :

$$d(M_1, N_1)= \frac{1}{2}\sqrt{(m_1-n_1)^2+(m_2-n_2)^2+(m_3-n_3)^2+(m_4-n_4)^2} \qquad (1)$$

Table 5 – Distances between A_i ($i \in \{1,2,3\}$) and A^* and A^-

	$d(A_1, A^*)$	$d(A_2, A^*)$	$d(A_3, A^*)$	$d(A_1, A^-)$	$d(A_2, A^-)$	$d(A_3, A^-)$
C_1	0.26	0.24	0.17	0.16	0.18	0.26
C_2	0.32	0.21	0.63	0.45	0.56	0.12
C_3	0.50	0.40	0.20	0.16	0.28	0.48
C_4	0.54	0.34	0.19	0.12	0.33	0.49
C_5	0.46	0.20	0.26	0.16	0.44	0.37
C_6	0.50	0.20	0.50	0.23	0.56	0.24

Step 6 : Computing of d^*_i, d^-_i and CC_i

The distance of each candidate from A^* and A^- can be currently computed as [7]:

$$d^*_i (A_p) = \sum_{k=1}^{n} d(A_p , A^*)_{Ck} \qquad (2)$$

$$d^-_i (A_p) = \sum_{k=1}^{n} d(A_p , A^-)_{Ck} \qquad (3)$$

The closeness coefficient of each candidate, CC_i, is defined with d^*_i and d^-_i as [7]:

$$CC_i = \frac{d^-_i}{d^*_i + d^-_i} \qquad (4)$$

Table 6 – Computing of d^*_i, d^-_i and CC_i

	A_1	A_2	A_3
d^*_i	2.57	1.59	1.95
d^-_i	1.28	2.34	1.95
$d^*_i + d^-_i$	3.85	3.93	3.90
CC_i	0.33	0.60	0.50

4. Solution and results

The final results of this example are :
CC (Myanmar) = 0.33 ; CC (Laos) = 0.60 ; CC (Mekong River) = 0.50

According to the table 7, the routing through Myanmar, with the smallest closeness coefficient, is recommended with high risk. The shipment on Mekong River is recommended with low risk. Then the routing through Laos with the highest closeness coefficient is approved.

Table 7 - Approval status

Closeness Coefficient (CC_i)	Assessment status
$CC_i \in [0, 0.2[$	Do not recommend
$CC_i \in [0.2, 0.4[$	Recommended with high risk
$CC_i \in [0.4, 0.6[$	Recommended with low risk
$CC_i \in [0.6, 0.8[$	Approved
$CC_i \in [0.8, 1]$	Approved and preferred

This numerical example was computing for a shipment from Thailand to China in the future. But it could be interesting to try this method for a shipment from China to Thailand, now and in the future.

Table 8 – Results with other alternatives

	Thailand - China		China - Thailand	
	Now	**Future**	**Now**	**Future**
Myanmar	0.36	0.33	0.33	0.28
Laos	0.49	0.60	0.46	0.56
Mekong River	0.54	0.50	0.64	0.59

According the Table 8, now, from Thailand to China, both shipment by ship on the Mekong River and routing through Laos are recommended with low risk. The Mekong River, with the highest closeness coefficient, should be the best solution. For a routing from China to Thailand, nowadays, the shipment on the Mekong River is approved and should be the best solution one more time.

As a decision making tool is made to help decision makers finding a good compromise. So the most interesting results are the ones which concern the future. For a shipment from China to Thailand, the Mekong River solution keeps being recommended with low risk like the Laos solution. Their closeness coefficients are very close so it is difficult to determine the best solution. On the other hand, for a Thailand to China shipment, the routing through Laos is approved and shipment on the Mekong River is still recommended with low risk.

5. Conclusion

As the traveling time increasing because of the Mekong stream for a shipment on the river from China to Thailand, the solution through Laos should be the optimal compromise. Actually, nowadays, the Mekong River solution is the most appropriated, but with the connections improvement between Laos and Thailand, in the future, the Laos should be the best choice.

The Fuzzy Analytical Hierarchy Process definitely and properly fits to this kind of decision making problem. To have more precise results, some criteria could be added and it is possible to have more decision makers. Computing this method in a mathematical software permit to have the results immediately after changing the inputs (weight and ratings of the criteria).

For summarizing the method, it is possible to divide it in various steps. The first one is the evaluation of the criteria and their importance by the decision makers. The second is the linguistic values converting into fuzzy numbers and the averages computing. The third step is the weighted fuzzy decision matrix computing. The fourth is the fuzzy positive ideal solution (FPIS), A^* and fuzzy negative ideal solution (FNIS), A^- calculating. Then, the fifth step is the distance from fuzzy numbers to both fuzzy ideal positions. And finally the sixth step is the closeness coefficients computing with the distances of d^*_i and d^-_i. After the sixth step, decision maker are able to discuss about the candidates and can make a decision to reach their common aim.

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