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Fuzzy AHP Approach for Route Selection in Multimodal Transportation: The Case of Coal Industry in Thailand

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ABSTRACT

In recent years, Thailand has looked to reduce the costs of logistics and transportation to remain competitive. Currently, road transportation is still the main part of Thailand's logistics. The utilization of railway and waterway transportation has increased in recent years. The importance of multimodal transportation has increased significantly as it is a key solution to help reduce the cost of Thailand’s logistics system. By deciding the best route, several companies can save transport costs, time, and increase competitive advantage. However, this problem is complicated in terms of route selection, multiple conflicting criteria, and vague and inaccurate parameters. Moreover, the uncertainty and imprecision of experts’ opinions are a significant characteristic of the problem. Therefore, this paper contributes a Multi-Criteria Decision Making (MCDM) tool as a Fuzzy Analytic Hierarchy Process (FAHP) that embeds the fuzzy logic into a basic Analytic Hierarchy Process (AHP). This tool is used for route selection in multimodal transportation with a case study of a coal transportation company in Thailand. The main attributes considered are transportation cost, transportation time, and seven risks of transportation. The results showed that the approach can effectively provide guidance for determining the priority ranking of different multimodal routes.

Keywords: Route selection; Multimodal transportation; Fuzzy analytical hierarchy process (FAHP); Multi-criteria decision making (MCDM)

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1. Introduction

Freight transportation is a supply chain system with logistics component to ensure the efficient movement and timely availability of raw materials and finished products [1-2]. Multimodal Transportation has been considered as a key component of modern logistics systems, especially for long distance transportation and large volumes. Multimodal transportation, as defined by the Multimodal Transport Handbook published by UNCTAD, is the transport of products by several modes of transport from one point to a final point where one of the carriers organizes the whole transportation route.

Multimodal transportation is an important development to make local industry and international trade more efficient and competitive. Nowadays, several manufacturers have reduced the costs of logistics and transportation in order to remain competitive. Opportunity-wise, Thailand has many businesses that can promote the concept of multimodal transportation, for example in the import and export of containers from and to other countries. The coal industry is an important industry that is suitable for multimodal transportation because it has a nonperishable product, with a long lead time for high-volume transportation.

Coal is one of the world's most important natural resources. It is used in electricity-generating processes, as well as in other manufacturing industries such as the cement industry, paper industry and others that need high heat in production. It is stated that coal will be increasingly used in the future [3]. The Electricity Generating Authority of Thailand (EGAT) uses coal as a second alternative resource in generating electricity, as it is the cheapest heat generating resource. Coal is usually transported by waterway and road transport from Indonesia and transferred into an inland vessel to travel along a river.

In the past, most of the studies about multimodal transportation route selection emphasized minimum cost and time [4-6]. However, there are some researchres dealing with minimum risk [7-10]. Risk is an important factor in route selection. Risk can be associated with accidents, which cause changes in direct cost, time and quality of logistics systems, as shown by Kengpol et al. [9]. Additionally, in the case of transportation and logistics processes, Kaewfak and Ammarapala [10] stated that risks imply a direct cost and reduce the competitiveness of exports. Therefore, in the transportation route selection process, it is important to consider all three factors, i.e., cost, time, and risk, in the model.

The objective of this research is to determine a route priority ranking that considers cost, lead time, and risk in multimodal transportation systems by utilizing FAHP. The remainder of this paper is organized as follows. Section 2 provides the contributing multimodal transportation factors for route selection. Section 3 explains the materials and methods. Section 4 presents the application in a coal company in Thailand. Section 5 shows the result of a case study. Finally, Section 6 presents the conclusion and discussion.

2. Contributing Multimodal Transportation Factors for Route Selection

There are many papers in the area of multimodal route selection. Most research studies have focused on minimizing cost and time objectives. However, there are only a few researchers dealing with minimizing risk [8-12, 14, 15]. Kengpol et al. [9] suggested five key risk factors in route selection, including freight damage risks, infrastructure and equipment risks, political risks, operational risks and environmental risks. Kaewfak and Ammarapala [10], in contrast, recommended six key factors that affect route selection: transportation cost and time, risk of freight damage, risk of infrastructure and equipment, operational risks and risk of other factors. Based on the previous research, and information from the Logistics Service

Provider (LSP) interviews, this research categorized cost, time and risk factors for route selection in multimodal transportation into nine criteria. Table 1 shows examples of these factors.

2.1 Transportation cost

The selection of transportation mode or combination of transport mode has a direct impact on transportation cost [9]. The cost parameters include transportation cost, transshipment cost, transit cost, loading cost, unloading cost, operating cost, and etc.

2.2 Transportation time

The travel time is a significant factor in determining the benefits of transportation infrastructure investment and rulemaking initiatives. It consists of loading time, unloading time, storage time, transit time and transshipment time.

Table 1. Transportation factors.

No.	Factors	Examples of factors	Reference
C1	Transport Cost	1.1 Transportation Cost 1.2 Transshipment Cost 1.3 Loading Cost 1.4 Operating Cost 1.5 Investment Cost	[4-12]
C2	Transport Time	2.1 Transportation Time 2.2 Loading Time 2.3 Unloading Time 2.4 Storage Time	[4-12]
C3	Freight Damage Risk	3.1 Damage during transfer mode 3.2 Damage from transportation 3.3 Damage from delivery at warehouse 3.4 Damage from delivery to customer	[9, 15]
C4	Infrastructure and Equipment Risk	4.1 Poorly developed transport infrastructure or lack of it 4.2 Poor quality of transport infrastructure	[9, 15, 16]
C5	Operational Risk	5.1 Lack of skilled workers 5.2 Strikes, lockouts, stoppage or restraint of labor from any cause 5.3 Delays due to improper documentation 5.4 Error in server systems	[9, 15-17]
C6	Security Risk	6.1 Theft from insider 6.2 Terrorism 6.3 Fire 6.4 Accident	[9, 15, 18] and Expert opinion
C7	Environment Risk	7.1 Natural Disasters 7.2 Climate Changes	[9, 15, 16] and Expert opinion
C8	Community Impact, and Law Risk	8.1 Protesting interference by nearby residents 8.2 Law	[9, 15, 16] and Expert opinion
C9	Financial Risk	9.1 Rising cost of fuel, machines and materials 9.2 Increases in payrolls and tax payments in the transportation sector in the region 9.3 Poor financial situation	

2.3 Freight damage risk

It is identified by using the percentage of damaged goods (value) and loss information. It refers to a situation of a loss of goods or damaged goods during transfer, damage from transportation, damage from delivery at a warehouse, or damage from delivery to a customer [9, 10, 15].

2.4 Infrastructure and equipment risk

It can be defined as the slope and the width of roads, capacity of roads, trains or ships, risk of shipment in the rainy season, accident rate, and traffic volume. It is the accident rate of each route, quality of road, rail, port, traffic facilities, and equipment material handling in each route [9, 10, 15].

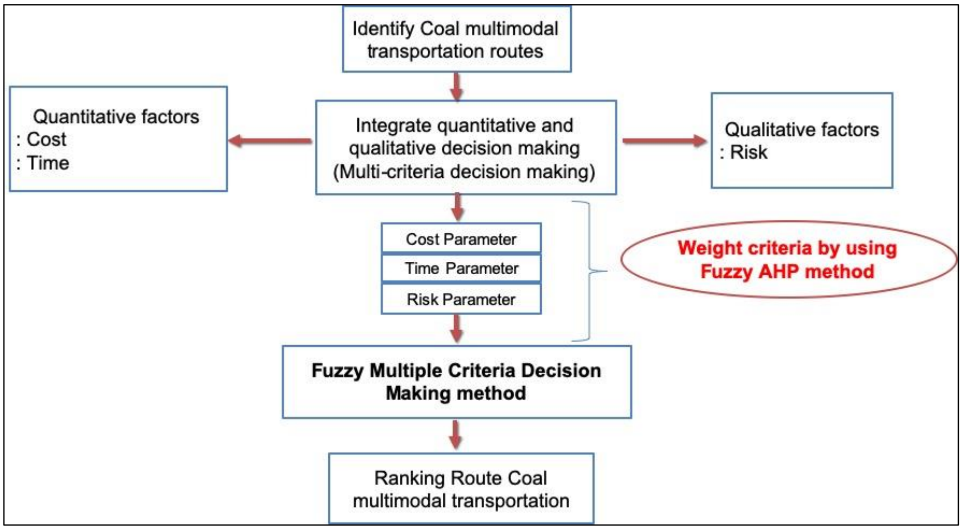

Fig. 1. Research framework.

2.5 Operational risk

It is defined as a lack of the skilled workers, lack of standardization of documents, and interpretation problems with documents or contracts [9, 10, 15].

2.6 Security risk

The transportation system is a significant consideration in overall transportation planning. Security risk refers to theft from an insider, terrorism, fire, and accidents.

2.7 Environment risk

It refers to natural disasters, climate changes, flood, tropical storm, and rainy season carbon released into the air along the multimodal route.

2.8 Law risk

It means laws, political risk, traffic rules, custom rules, and protesting interference of nearby residents [9, 10, 15].

2.9 Financial risk

It refers to financial crisis, fierce competition in the logistics sector and unattractive markets [9, 10, 15].

3. Materials and Methods

3.1 Scope of study, experts, and identification of all routes

This section describes a conceptual framework for route selection in multimodal transportation as shown in Fig 1. This paper considers a case study of the domestic freight route in multimodal transportation originating from Koh Sri-Chang, Chonburi Province in Thailand to a cement factory (destination) in Saraburi Province, Thailand.

The data were collected from interviews and the brainstorming of experts and LSPs, to identify areas of study and appropriate multimodal transportation routes. Seven experts were interviewed from three different areas of work associated with multimodal transportation in the coal industry (See Table 2). The following expert groups were requested to determine the significant weights of criteria: 1) Logistic Service Providers, 2) Experts from a coal company, and 3) Government officers. From the brainstorming and interviewing with the experts, there are 8 possible transportation routes. These routes are combinations of several different modes of transport (e.g. rail, sea and road). These 8 possible multimodal transportation routes are shown in Table 3.

Table 2. Interview experts in multimodal freight transportation.

Experts	Organization	Position	Role in the transportation sector
1	Large-size coal company	CEO, Transport manager	Multimodal transportation
2	Medium-size coal company	Logistics manager	Warehouse and distribution
3	Small-size coal company	Safety and risk manager	Risk management and control
4	LSP 1	Operation manager	Transportation
5	LSP 2	Logistics manager	Logistics and shipping
6	Department of Rural Roads, Ministry of Transport 1	Government officer 1	Transportation
7	Department of Rural Roads, Ministry of Transport 2	Government officer 2	Transportation

Table 3. Possible transportation routes.

No.	Routes
A1	Koh Si-Chang + Pasak River + Nakornluang Port - Route 3008 - Route 3470 - Route 3041 - Route 362 - Mittraphap Road - Kaeng Khoi cement plant, Saraburi Province
A2	Koh Si-Chang + Pasak River + Nakornluang Port - Route 3008 - Ta Jao Sanook District - Jumpa District - Route 3048 - Route 362 - Mittraphap Road - Kaeng Khoi cement plant, Saraburi Province
A3	Koh Si-Chang + Pasak River + Nakornluang Port - Route 3008 - Samtai District - Don Yanang District - Route 3470 - Route 362 - KhokSwang - Mittraphap Road - Kaeng Khoi cement plant, Saraburi Province
A4	Koh Si-Chang + Laem Chabang = Sri Racha = Chonburi = Chachoengsao = Bang Nam Piew = NakornNayok = Kaeng Khoi cement plant, Saraburi Province
A5	Koh Si-Chang - Laem Chabang = Sri Racha = Chonburi = Chachoengsao = Bang Nam Piew = NakornNayok = Kaeng Khoi Train Station - Kaeng Khoi cement plant, Saraburi Province
A6	Koh Si-Chang + Bang Pa Kong - Route 314 - Suvinthawong Road - Bang Nam Piew - NakornNayok - Route 3051 - Suwannasorn Road - Route 3222 - Mittraphap Road - Kaeng Khoi cement plant, Saraburi Province
A7	Koh Si-Chang + Bang Pa Kong - Route 314 - Route 365 - Suvinthawong Road - Route 304 - Route 3076 - Suwannasorn Road - Rure 3222 - Mittraphap Road - Kaeng Khoi cement plant, Saraburi Province
A8	Koh Si-Chang + Bang Pa Kong - Route 314 - Route 365 - Suvinthawong Road - Route 305 - Sarakru District - NongRong District - Route 1 - Mittraphap Road - Kaeng Khoi cement plant, Saraburi Province

Note: + is ship transport, = is train transport, - is truck transport *

3.2 Fuzzy set

To cope with the vagueness of human decisions, the fuzzy set theory was introduced. It was oriented to the rationality of uncertainty due to imprecision or vagueness [19-20]. A significant contribution of the fuzzy set theory is its capability of representing vague data. A fuzzy set is a class of objects with a continuum of grades of membership [20]. The membership of an element into a fuzzy set is a single value between zero and one. The fuzzy set theory provides a wider framework than the classical set theory, contributing to the capability of reflecting the real world [21]. Various works now combine fuzzy concepts with other scientific disciplines as well as modern technologies. A triangular fuzzy number (TFN) is shown in Figure 2. A TFN is denoted as (l, m, u). The parameters l, m, and u, respectively, describe the smallest possible value, the most promising value, and the largest possible value. Each TFN has linear representations on its left and right side such that its membership function can be defined as:

$$u\left(x\middle|\tilde{M}\right)=\begin{cases}0 & ,x<l\\ \dfrac{x-l}{m-l} & ,l\le x\le m\\ \dfrac{u-x}{u-m} & ,m\le x\le u\\ 0 & ,x>u\end{cases} \tag{3.1}$$

A fuzzy number has corresponding left and right representations of each degree of membership:

$$\tilde{M} = \left(M^{l(y)} M^{r(y)}\right) = (l + (m-l)y, u + (m-u)y), y \in [0,1] \quad (3.2)$$

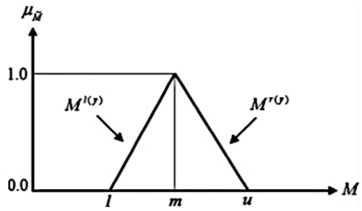

Fig. 2. Triangular fuzzy number [20] where *l(y)* and *r(y)* are the left-side representation and the right-side representation of a fuzzy number, respectively.

Several methods for TFNs have been developed in the literatures. These methods may give different ranking results. Most methods are tedious in that they require graphic manipulation with complex mathematical calculations. The algebraic operations with fuzzy numbers can be found in [20].

3.3 Analytic hierarchy process (AHP)

In 1990, Saaty [22] introduced the analytic hierarchy process (AHP) technique. The AHP has been widely applied in several studies to solve a Multi-Criteria Decision Problem (MCDM). The AHP method provides a structured framework for setting priorities on each level of the hierarchy using pairwise comparisons that are quantified using 1-9 scale [9, 22]. The traditional AHP requires exact judgments [22]. However, the uncertainty of the experts' opinions is the prominent characteristic of the problem. Moreover, the AHP has difficulty in assigning an exact numerical value in a pairwise comparison as the prioritization process is complex and subjective. Thus, instead of using an exact numerical number, the FAHP approach utilizes Triangular Fuzzy Numbers (TFNs) to express the pairwise comparison of decision elements [23].

3.4 Fuzzy analytic hierarchy process (FAHP)

The fuzzy AHP method is a systematic decision-making methodology that applies the concept of the fuzzy set theory and AHP. Recently, there have been many applications of FAHP in various fields including risk assessment [21], supplier selection [24], energy alternatives selection [25], and performance evaluation systems [26, 27]. Nevertheless, there are only some papers that focus on route selection. In fuzzy AHP, the pairwise comparisons of criteria and alternatives are performed through linguistic variables that are presented as triangular fuzzy numbers. One of the first fuzzy AHP applications was performed by Van Laarhoven and Pedrycz [28]. They defined the triangular membership functions for pairwise comparisons by using the Logarithmic least squares method (LLSM). Afterwards, Buckley [29] used the geometric mean for analysis and calculation of the resulting vector in the factor comparison. Chang [30] also introduced a new method that adapted the arithmetic mean that is used for determining the priority vector of factors. Furthermore, Chang used a fuzzy extent analysis for a comparison of matrices, deriving crisp weights for fuzzy comparison matrices. Wang [31] also proposed a modification of fuzzy LLSM. Currently, the best methods for route selection are the Buckley and Chang extent analysis methods. In this study, the extent FAHP is implemented that was originally proposed by Chang [31]. Let X $=\{x_1, x_2, \ldots, x_n\}$ be an object set, and G = $\{g_1, g_2, \ldots, g_n\}$ be a goal set. According to the method of Chang's extent analysis, each object is obtained and extent analysis for each goal is performed. Therefore, *m* extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m, i = 1, 2, \ldots, n \quad (3.3)$$

where M_{gi}^{1} $(j=1,2,...,m)$ are TFNs.

The steps of Chang's extent analysis [31] are given as follows:

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

$$S_i = \sum_{j=1}^{m} M_{gi}^{1} \otimes \left[\sum_{i=0}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \quad (3.4)$$

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

$$\sum_{j=1}^{m} M_{gi}^{1} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \quad (3.5)$$

To obtain $\left[\sum_{i=0}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, the fuzzy addition operation of M_{gi}^{1} ($j = 1, 2,..., m$) value is performed as:

$$\sum_{i=0}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \quad (3.6)$$

Then the inverse of the vector above can be computed as:

$$\left[\sum_{i=0}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{j=1}^{m} l_j}, \frac{1}{\sum_{j=1}^{m} m_j}, \frac{1}{\sum_{j=1}^{m} u_j} \right) \quad (3.7)$$

Step 2. The degree of possibility of $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ is defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left[\min(u_{m_1}(x), u_{m_2}(\mathrm{y}) \right] \quad (3.8)$$

And can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = u_{M_2}(d)$$

$$u_{M_2}(d) = \begin{cases} 1 & , M_2 \geq M_1 \\ 0 & , M_1 \geq M_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & , otherwise \end{cases} \quad (3.9)$$

where d is the ordinate of the highest intersection point D between u_{m_1} and u_{m_2} in Fig. 3.

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

Step 3. The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_1 = (i = 1,...,k)$ is defined by

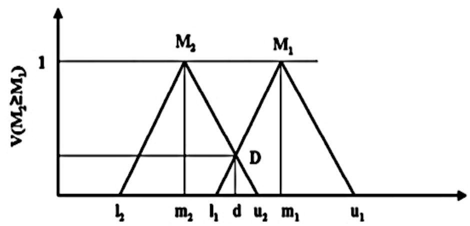

Fig. 3. Intersection between $M1$ and $M2$ [31].

$$V(M \geq M_1, M_2, ..., M_k) = V(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } (M \geq M_k) = \min V(M \geq M_i), i = 1,2,...,k. \quad (3.10)$$

Assume that,

$$d'(A_i) = \min V(S_i \geq S_k), \quad (3.11)$$

for k = 1, 2,…, n; $k \neq i$. The weight vector is given by the following:

$$W'(A_i) = \left(d'(A_1), d'(A_2), ..., d'(A_n) \right)^T, \quad (3.12)$$

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

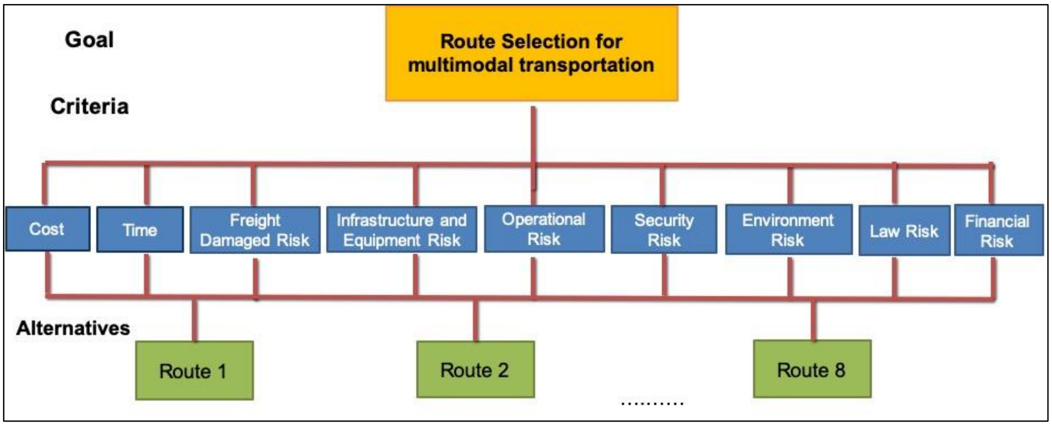

Fig. 4. The FAHP Model.

Step 4. Via normalization, the normalized weight vectors are:

$$W = \left(d(A_1), d(A_2), ..., d(A_n)\right)^T \qquad (3.13)$$

where W is a non-fuzzy number.

4. Application in a Coal Company in Thailand

To determine the multimodal route selection, the main attributes considered are transportation cost, transportation time, and 7 risks of transportation. Based on the literature study, we consider 8 possible coal multimodal routes, regarding 9 criteria.

These criteria and the alternative weights were then calculated. All alternatives and criteria are marked as alternative A = {A1,…, A8} and criteria C = {C1,…, C9}. Then, the following steps were performed to utilize the FAHP analysis. The FAHP model with significance weight of each criteria is as shown in Fig. 4.

4.1 Definition of the fuzzy judgment matrix

To complete the pair-wise comparison matrix a panel of experts was assembled. Decision makers or experts compared the criteria or alternatives through linguistic terms as shown in Table 4.

Table 4. Linguistic terms and the corresponding triangular fuzzy numbers.

Linguistic scale for relative importance	Saaty Scale	Triangular fuzzy scale	Reciprocal of triangular fuzzy scale
Equally important	1	(1,1,1)	(1,1,1)
Weakly important	3	(2,3,4)	(1/4,1/3,1/2)
Fairly important	5	(4,5,6)	(1/6,1/5,1/4)
Strongly important	7	(6,7,8)	(1/8,1/7,1/6)
Absolutely important	9	(9,9,9)	(1/9,1/9,1/9)
The intermittent values between two adjacent scales	2	(1,2,3)	(1/3,1/2,1)
	4	(3,4,5)	(1/5,1/4,1/3)
	6	(5,6,7)	(1/7,1/6,1/5)
	8	(7,8,9)	(1/9,1/8,1/7)

To determine the criteria and evaluate the alternatives for the route selection process, a pair-wise comparison was performed by 7 experts [13]. According to their preferences, the average pair- wise comparison of criteria is shown in Table 5.

4.2 Calculating the consistency index and consistency ratio of the fuzzy comparison matrix

Confirming the certain quality level of a decision, the consistency of evaluation was analyzed. Saaty [22] introduced a consistency index to measure consistency. The fuzzy comparison matrices need to be converted into crisp matrices. For testing the consistency, the maximum eigenvalue of the Consistency Index (CI) is calculated by

$$CI = \frac{\lambda_{\max} - n}{n-1}, \qquad (4.1)$$

where $\lambda_{\max}$ is the largest eigenvalue of the comparison matrix, and n is the dimension of the matrix.

The consistency ratio (CR) is defined as the ratio between the consistency of an evaluation matrix and the consistency of a random matrix

The judgment needs to be revised. All values do not exceed the allowed value; thus, result of the matrix of pairwise comparison may be correctly used in further calculations.

4.3 Calculating the weight and individual preferences aggregation

When the consistency in the comparison matrix is accepted, the pair-wise comparison matrix of weight vectors is formed using fuzzy AHP. The fuzzy values of the pair-wise comparison are converted to crisp values through Chang's extent analysis as mentioned above.

Table 5. Fuzzy pair-wise comparison matrix of criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	(1,1,1)	(2,3,4)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)	(6,7,8)	(6,7,8)	(4,5,6)
C2	(0.25,0.33,0.50)	(1,1,1)	(2,3,4)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)	(4,5,6)	(6,7,8)
C3	(0.17,0.20.0.25)	(0.25,0.33,0.50)	(1,1,1)	(4,5,6)	(0.25,0.33,0.50)	(2,3,4)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)
C4	(0.17,0.20.0.25)	(0.25,0.33,0.50)	(0.17,0.20.0.25)	(1,1,1)	(0.25,0.33,0.50)	(2,3,4)	(0.17,0.20.0.25)	(1,1,1)	(1,1,1)
C5	(0.17,0.20.0.25)	(0.25,0.33,0.50)	(2,3,4)	(2,3,4)	(1,1,1)	(2,3,4)	(0.17,0.20.0.25)	(1,1,1)	(1,1,1)
C6	(0.13,0.14,0.17)	(0.17,0.20.0.25)	0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(1,1,1)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)
C7	(0.13,0.14,0.17)	(0.17,0.20.0.25)	(2,3,4)	(4,5,6)	(0.25,0.33,0.50)	(2,3,4)	(1,1,1)	(1,1,1)	(4,5,6)
C8	(0.13,0.14,0.17)	(0.17,0.20.0.25)	(2,3,4)	(1,1,1)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(2,3,4)
C9	(0.17,0.20.0.25)	(0.13,0.14,0.17)	(2,3,4)	(1,1,1)	(1,1,1))	(2,3,4)	(0.17,0.20.0.25)	(0.25,0.33,0.50)	(1,1,1)

$$CR = \frac{CI}{RI(n)}, \qquad (4.2)$$

where $RI(n)$ is a random index that depend on n, RI as shown in Table 6.

Table 6. Random Index (RI) of random matrices.

N	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI(n)	0.58	0.90	1.12	1.24	1.32	1.41	1.45

If the consistency ratio (CR) of the comparison matrix is equal to or less than 0.1, it is acceptable while if it is not less than 0.1 it is not acceptable. First the fuzzy synthesis extent values were calculated using Eqs. (3.1)-(3.4). Eqs. (3.5) and (3.6) were applied to present the degree of synthetic extent values. The weight vector is provided by Eq. (3.8). The step to normalize weight vector (*Ni*) was defined to obtain the priority weight vector of criteria. After completing the normalized relative weights for criteria, the same methodology is applied to determine the respective values for alternatives. However, the alternatives should be compared with respect to all criteria. Then, the aggregated results for each alternative, with respect to each criterion, are presented in Table 7.

5. Result

In this research, there are 9 criteria being considered by the FAHP model. The first second criterion is the transportation time and the last set of criteria are 7 multimodal transportation risks transportation risks. The result shows that the best multimodal route for the coal industry is route A2, which obtains the maximum total score. Therefore, it was recommended to be the best route among 8 routes, with respect to 9 criteria and the fuzzy.

6. Conclusion and Discussion

Nowadays, there exist various Fuzzy AHP methodologies developed by different authors. After having revised the methods, a decision to use the method of Chang extent analysis was used. The contribution of this research lies in the development of methodology that is flexible and applicable to the industrial sector to adopt multimodal transportation practices. In this perspective, the present work attempts to contribute in the preferences of decision makers. Furthermore, the research finding involved consulting with a group of coal industrial experts with an objective to have additional insights to reduce the consequence of the risks in multimodal transportation practices adoption, which will improve the multimodal transportation productively. The potential transportation factors by presenting the identification, understanding, and prioritization of factors involved with multimodal transportation its robustness and effectively on strategic level in a business.

Moreover, coal industry companies were examined in the research. As result, the optimal route is route A2 because of maximum score as compared to other factors.

Table 7. Aggregate result for transportation factors.

Criteria		Scores of alternatives, with respect to related criterion							
	Weight (*Ni*)	A1	A2	A3	A4	A5	A6	A7	A8
C1	0.40	0.24	0.31	0.10	0.06	0.08	0.14	0.03	0.06
C2	0.25	0.51	0.16	0.06	0.04	0.11	0.08	0.03	0.02
C3	0.06	0.37	0.18	0.10	0.09	0.10	0.08	0.05	0.04
C4	0.05	0.25	0.26	0.08	0.09	0.10	0.07	0.08	0.08
C5	0.08	0.34	0.28	0.08	0.05	0.09	0.06	0.05	0.05
C6	0.03	0.34	0.28	0.08	0.05	0.09	0.06	0.05	0.054
C7	0.13	0.24	0.33	0.12	0.08	0.07	0.08	0.03	0.06
C8	0.09	0.03	0.03	0.04	0.16	0.16	0.30	0.11	0.18
C9	0.06	0.02	0.03	0.07	0.17	0.15	0.25	0.15	0.15
	Total Score	0.33	**0.55**	0.16	0.06	0.09	0.13	0.09	0.06

Appendix

Example of Questionnaire

Pairwise comparison

Q#	A. Imp	S. Imp	F. Imp	W. Imp	CRITERIA	Eq. Imp	CRITERIA	W. Imp	F. Imp	S. Imp	A. Imp
	(9,9,9)	(6,7,8)	(4,5,6)	(2,3,4)		(1,1,1)		(2,3,4)	(4,5,6)	(6,7,8)	(9,9,9)
1					C1		C2				
2					C1		C3				
3					C1		C4				
4					C1		C5				
5					C1		C6				
6					C1		C7				
7					C1		C8				
8					C1		C9				
9					C2		C3				
10					C2		C4				
11					C2		C5				
12					C2		C6				
13					C2		C7				
14					C2		C8				
15					C2		C9				
16					C3		C4				
17					C3		C5				
18					C3		C6				
19					C3		C7				

Q#	A. Imp	S. Imp	F. Imp	W. Imp	CRITERIA	Eq. Imp	CRITERIA	W. Imp	F. Imp	S. Imp	A. Imp
	(9,9,9)	(6,7,8)	(4,5,6)	(2,3,4)		(1,1,1)		(2,3,4)	(4,5,6)	(6,7,8)	(9,9,9)
20					C3		C8				
21					C3		C9				
22					C4		C5				
23					C4		C6				
24					C4		C7				
25					C4		C8				
26					C4		C9				
27					C5		C6				
28					C5		C7				
29					C5		C8				
30					C5		C9				
31					C6		C7				
32					C6		C8				
33					C6		C9				
34					C7		C8				
35					C7		C9				
36					C8		C9				

CRI	Description
C1	Cost
C2	Time
C3	Freight Damaged Risk
C4	Infrastructure Risk
C6	Operational Risk
C6	Securiy Risk
C7	Environment Risk
C8	Law Risk
C9	Financial Risk

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