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RESEARCH ARTICLE

AN INTEGRATED FAHP-FGP APPROACH FOR ROUTE SELECTION IN A DISRUPTED TRANSPORT NETWORK

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ABSTRACT

An efficient, effective and sustainable freight transport network is a crucial determinant for economic growth and development. This network needs to be structured as resilient as practicable and also quickly adoptable and adaptable to meet the needs of transport users and provide alternative optimal routes, if it is affected by disruptive events. This paper presents a route selection model which supports transport planners to decide rapidly on an optimal transport route in case of disruption in a multimodal freight transport network. An integrated method based on Fuzzy Analytic Hierarchy Process and Fuzzy Goal Programming is developed to support the decision of route selection.

Keywords: *Multimodal Transport, FAHP, FGP, Disruption, Decision Support*

Yaşanur KAYIKÇI

KESİNTİYE UĞRAMIŞ KOMBİNE YÜK TAŞIMACILIĞI AĞI İÇİN BİR BÜTÜNLEŞİK FAHP-FGP ROTA SEÇİMİ YAKLAŞIMI

ÖZ

Ekonomik büyüme ve gelişme için verimli, etkin ve sürdürülebilir bir yük taşımacılığı ağı çok önemli bir belirleyicidir. Bu ağın, uygulanabilir olduğu kadar esnek olması ve yıkıcı olaylardan etkilenmesi halinde kombine yük taşımacılığı operatörleri ve nakliyeciler gibi ulaştırma kullanıcılarının ihtiyaçlarını karşılamak ve alternatif en uygun ulaşım hatlarını sağlamak için hızla benimsenmesi ve uyarlanabilmesi gerekmektedir. Bu çalışma, kombine yük taşımacılığı ağında meydana gelebilecek bir kesinti durumunda, en uygun taşımacılık güzergâhını hızlı bir şekilde seçmek için ulaşım planlayıcılarını destekleyen bir rota seçim modeli sunmaktadır. Bulanık Analitik Hiyerarşi Süreci ve Bulanık Hedef Programlamaya dayalı bütünleşmiş bir yöntem, rota seçim kararını desteklemek için geliştirilmiştir.

Anahtar Kelimeler: *Kombine Taşımacılık, FAHP, FGP, Kesintiye Uğrama, Karar Destek*

1. INTRODUCTION

A well-functioning transport system and infrastructure are important to the economic growth and development. A competitive and sustainable multimodal freight transport network is therefore necessary for companies to plan and execute both domestic and international transport operations. Multimodal transport offers an advanced platform for more efficient, effective and sustainable freight transport network [1] by enabling technical and economic advantages of long distance, high safety and speed of connection, large transport capacity and low costs/tariffs [2]. Multimodal transport is defined as a transport system which integrates at least two different transport modes in a transport chain [3]. A multimodal freight transport network includes different combinations of transport modes such as: rail-road, inland waterway- road, sea-road, sea-rail and so on. Any disruption within a transport network caused by natural disaster (hurricane, flood, tornado, earthquake), traffic condition (road constructions, accident, high traffic jams), weather condition (snow, ice, drifting, wind), technical problem (traffic signal control problem, system failure), wear and tear (road damage from trucks), political issues (changing policies, customs issues) or human factor (strike and lock-out) may affect the system reliability and efficiency and risk overheating [4,5]. These problems may occur at any level and affect all transport modes, furthermore, prevent the goods to be delivered to the final delivery point on-time. Therefore, it is an important goal for decision makers, mostly transport network planners or operators, to offer cost effective, swift, time efficient alternative freight routes for transport users in case of a disruption.

Based on this need, this study proposes an optimal route selection approach using an integrated Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Goal Programming (FGP) methods. FAHP is used to determine weights of each selection criteria, whereas FGP is used to calculate the optimal route in terms of weights of each goal. Finally, a real-world case is included in this study to present the practicality of the proposed approach. The numerical example is solved using LINGO 13.0 software package.

2. MULTIMODAL TRANSPORT NETWORK: RESEARCH FOCUS

Multimodal freight transport, also known in the literature as intermodal transport, combined transport or integrated transport chain, refers a multi-unit transport chain in which transport of goods are moved by the integration of at least two or more different transport modes among road, rail, sea, inland waterway, short-sea shipping and air based on a single multimodal freight transport contract. The goods are carried by using advanced and standardized transport units (mostly trailer, semi-trailer or container), which are received from a departure terminal (origin) in a country by right of Multimodal Transport Providers (MTPs) in transport means (e.g. vessel, train) to a delivery terminal (destination) for delivery in another country [6]. Until end of journey, transport goods are not handled and transport units do not change. Often an MTP or a consortium of MTPs (such as liner shipping provider and railway freight provider) is responsible for the performance of the complete haulage contract from Origin to Destination (O-D) [7].

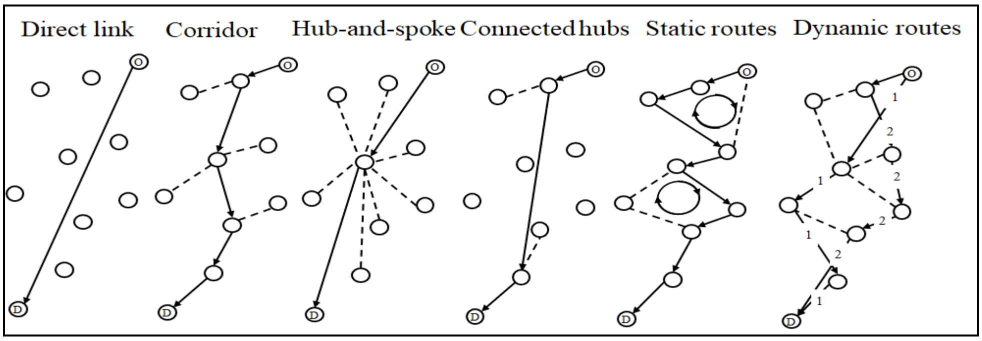

Figure 1. Six Transport Options from Origin to Destination in a Transport Network

There are different types of transport network seen in Figure 1. in order to define routing between O-D: direct link, corridor, hub-and-spoke, connected hubs, static routes, and dynamic routes [8], where the dotted lines refer operationally related routes in the freight transport network. In dynamic routes, two alternative routes are shown. In all other network configuration, the routing is predefined [8]. In the literature, freight consolidation systems are mostly designed as hub-and-spoke networks, with hub being a freight consolidation facility. Locations of hubs are determined and spoke nodes are allocated to these hubs [1]. The hub-and-spoke system is a process whereby the main legs (main-haulage) by carrier haulage between the ocean port and the hub are operated by rail or sea/inland waterways, meanwhile the initial leg (pre-haulage) and final legs (end-haulage) are usually operated by road [9] and these are often offered or arranged by an MTP or an MTP consortium. This concept is a typical illustration of the multimodal transport networks.

Because of its complex nature, multimodal transport networks are characterized by dynamically changing conditions and various modes of transport running on simultaneously. The objectives of relevant interest such as the minimization of cost, time, risk or maximization of service level, reliability, are conflicting goals. Thus, in general, there is no single optimal solution, but rather a set of optimal trade-off solutions, from which the decision maker must select either the most appropriate solution, or the best compromise solution. It is usually assumed that the route selection in multimodal transport network is a multi-goal multi-criteria decision problem which needs to consider both qualitative and quantitative factors evaluating potential routes. Many experts solve this problem based on the mathematical programming models [10] where often the quantitative factors are taken into considerations. In this study, an integrated FAHP and FGP is proposed as a solution methodology, as this method is suitable to process both qualitative and quantitative factors in route selection problem, using FAHP, decision makers can consistently integrate multi expert opinions and effectively determine appropriate weights. With the objective functions of FGP, decision makers can effectively set the upper and lower limits to find the optimal route for each condition.

3. RESEARCH METHODOLOGY

This study is integrated FAHP and FGP to find the optimal route for multimodal transport. A procedure is given in Figure 2. First, FAHP is used to obtain the relative weights of route selection criteria based on different freight conditions. It includes these steps: (1) determine the route selection problem, determine the possible routes (2) identify the selection criteria and construct the FAHP hierarchy, (3) perform the pairwise comparisons, decision makers are interviewed to obtain their opinions by using linguistic variables, (4) calculate weight for each criterion, (5) check consistency if it is not less than 0.10 then the expert is asked to revise his opinion until a consistency is met, (6) determine weights for main goals.

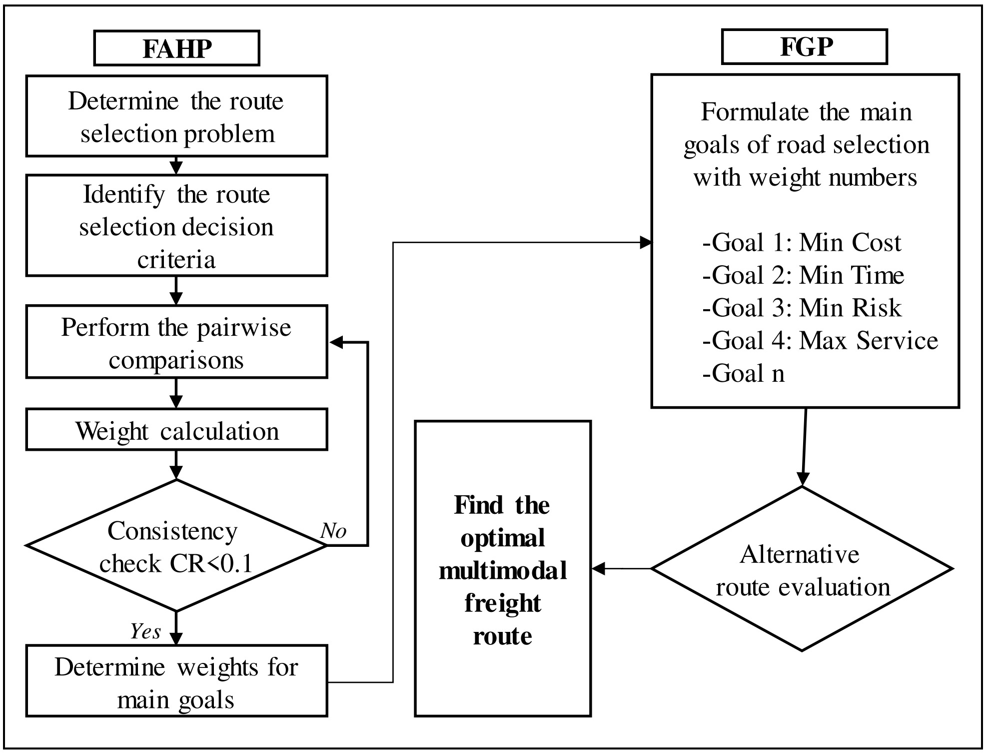

Figure 2. Proposed Route Selection Model by Integration of FAHP and FGP in a Multimodal Freight Transport Network

Second, FGP is utilized to process quantitative evaluation using weight numbers as coefficients of an objective function to determine the optimal route among given alternatives. It includes these steps: (1) Formulate the main goals of road selection with weight numbers that includes cost minimization, time minimization, risk minimization and service maximization. (2) solve FGP and evaluate the potential routes, (3) filter potential routes. Finally, one of these potential routes can be selected as optimal route.

3.1. The Fuzzy Analytic Hierarchy Process

The AHP model, firstly suggested by Saaty [11], is one of the commonly used Multi Criteria Decision Making (MCDM) methods. AHP can effectively address both qualitative and quantitative data to solve problem hierarchically. Therefore, the problem is completely broken down and the relevant sub-criteria are listed with respect to the hierarchical level in relation to the overall objective/goal to the sub-objectives. However, the conventional AHP method may not accurately reflect human judgment. For this reason, AHP with fuzzy extension, namely FAHP approach, using fuzzy set theory and hierarchical structure analysis has been proposed to solve MCDM problems. The basic concept of FAHP [12] is presented as follows:

Step 1: Development of hierarchical structure for the decision-making problem with an overall goal or objective at the top, criteria and sub-criteria at various levels and the decision alternatives at the bottom of the hierarchy.

Step 2: Construction of the fuzzy judgment matrix, $\tilde{M}(a_{ij})$, by using Triangular Fuzzy Numbers (TFNs) with pair-wise comparison as in Equation (1):

$$\tilde{M}(a_{ij}) = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \frac{1}{\tilde{a}_{12}} & (1,1,1) & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{\tilde{a}_{1n}} & \frac{1}{\tilde{a}_{2n}} & \cdots & (1,1,1) \end{bmatrix} \quad (1)$$

The judgment matrix $\tilde{M}$ is an $n \ x \ n$ fuzzy matrix containing fuzzy numbers $\tilde{a}_{ij}$ (2):

$$\tilde{a}_{ij} = \begin{cases} 1,2,3,4,5,6,7, \quad or \\ 1^{-1}, 2^{-1}, 3^{-1}, 4^{-1}, 5^{-1}, 6^{-1}, 7^{-1}, if \ i \neq j \\ 1, \quad if \ i = j \end{cases} \quad (2)$$

Where $\tilde{a}_{ij} = \tilde{a}_{ij}^{-1}$, and all $\tilde{a}_{ij}$ are TFNs $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$.

Let $X = \{\{x_1, x_2, \dots, x_n\}$ be a set of objectives, whereas $G = \{g_1, g_2, \dots, g_m\}$ be a set of goals. According to the model of fuzzy extent analysis, each object is taken and extent analysis for each goal, g_i, is carried out respectively. Resulting in m extent analysis values for each object can be obtained with $\tilde{M}_{gi}^1, \tilde{M}_{gi}^2, \dots, \tilde{M}_{gi}^m$, $i = 1,2, \dots, n$, where all the

$\widetilde{M}_{gi}^{j} (j = 1,2, \ldots, m)$ are TFNs representing the performance of the object x_i by reference to each goal g_i .

Step 3: The value of fuzzy synthetic extent of the i th object for m goals is determined as:

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

To obtain $\sum_{j=1}^{m} \widetilde{M}_{gi}^{j}$ the fuzzy addition operation m extent analysis values for a particular matrix is applied such as

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

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{gi}^{j} \right]^{-1}$, the fuzzy addition operation of $M_{gi}^{j} (j = 1,2, \ldots, m)$ values is applied such as

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \quad (5)$$

And then the inverse of the vector above is calculated, such as

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \quad (6)$$

The degree of possibility of $\widetilde{M}_1 \geq \widetilde{M}_2$ is defined as:

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

When a pair (x, y) exist such that $x \geq y$ and $\mu_{\widetilde{M}_1}(x) = \mu_{\widetilde{M}_2}(y)$, the equality equation $V(\widetilde{M}_1 \geq \widetilde{M}_2) = 1$. Since $\widetilde{M}_1 = (l_1, m_1, u_1)$ and $\widetilde{M}_2 = (l_2, m_2, u_2)$ are convex fuzzy numbers and can be presented like that:

$$V(\widetilde{M}_1 \geq \widetilde{M}_2) = 1 \; if \; m_1 \geq m_2 \tag{8}$$

$$V(\widetilde{M}_1 \geq \widetilde{M}_2) = \text{hgt}[\![(\widetilde{M}_1]\!] \cap \widetilde{M}_2) = \mu_{\widetilde{M}_1}(d) \tag{9}$$

Where, d is the ordinate of the highest intersection point D between $\mu_{\widetilde{M}_1}$ and $\mu_{\widetilde{M}_2}$, seen in Figure 3. When $\widetilde{M}_1$ and $\widetilde{M}_2$, the ordinate of D is given by the following equation:

$$V(\widetilde{M}_2 \geq \widetilde{M}_1) = \text{hgt}[\![(\widetilde{M}_1]\!] \cap \widetilde{M}_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \tag{10}$$

To compare $\widetilde{M}_1$ and $\widetilde{M}_2$ both values of $V(\widetilde{M}_1 \geq \widetilde{M}_2)$ and $V(\widetilde{M}_2 \geq \widetilde{M}_1)$ are required.

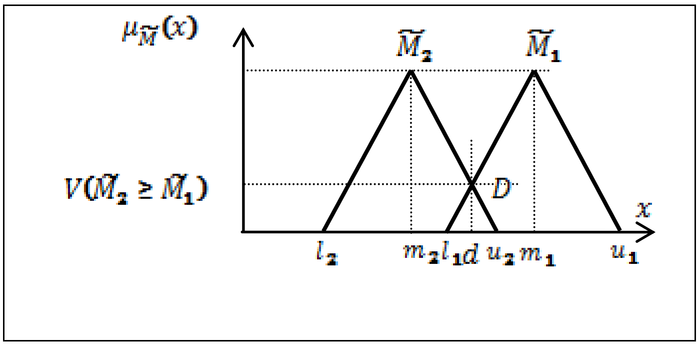

Figure 3. Intersection Point d between two TFNs, $\widetilde{M}_1$ and $\widetilde{M}_2$

Step 4: The degree possibility of a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1,2, \dots k)$ can be defined by

$$V(\widetilde{M} \geq \widetilde{M}_1, \widetilde{M}_2, \dots, \widetilde{M}_k) = V[(\widetilde{M} \geq \widetilde{M}_1) \text{ and } [\mathbf{V}(\widetilde{M} \geq \widetilde{M}_2) \textbf{and} (\widetilde{M} \geq \widetilde{M}_k)] = \min V(\widetilde{M} \geq \widetilde{M}_i) \; i = \mathbf{1, 2, \dots . }k. \tag{11}$$

Assuming that

$$d'(A_i) = \min V(S_i \geq S_k), k = 1,2, \ldots, n; k \neq i \tag{12}$$

Then, the weight vector is obtained as follows:

$$w' = \left(d'(A_1), d'(A_2), \ldots \ldots, d'(A_n)\right)^T \tag{13}$$

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

Step 5: After normalization, the normalized vectors are defined as:

$$w = \left(d(A_1), d(A_2), \ldots \ldots, d(A_n)\right)^T \tag{14}$$

Where w is a non-fuzzy number.

The normalized weight vector is calculated as $Nw_i = \frac{w_i}{\Sigma w_i}$.

3.2. Fuzzy Goal Programming

Route selection problem with varied preferences is a typical decision-making problem involving multi criteria and objectives. Therefore, it often has conflicting sourcing goal subjects like cost, time and service quality. To maximize the utility function and fulfil the decision maker's aspiration levels FGP [13,14] was implemented in solving this decision-making problem. Furthermore, the decision makers can define linguistic priorities with setting membership functions on goal values by considering the fuzzy logic.

A FGP can be formulated as follows [13]:

Max Subject to $X \in F$, (F is a feasible set), $X \geq \mathbf{0}$. (15)

Where is the extra continuous variable, $Z_k(X)$ is the linear function of the k th goal, X is $1 \times N$ vector of decision variables and $\mu_k(Z_k(X))$ is the fuzzy membership function of k th objective.

The preference-based membership functions are expressed as follows:

for $Z_k(X) \gtrsim g_k, k = 1,2,\ldots,k_1$ (16)

for $Z_k(X) \lesssim g_k, k = k_1 + 1,\ldots,K$ (17)

Where l_k and u_k are, respectively, the lower and upper tolerance limits for the k th fuzzy goal. $[(g]_k - l_k)$ as well as $(u_1k - g_1k)$ are the tolerances which are subjectively chosen. $\gtrsim$ and $\lesssim$ represent the fuzzified versions of $\geq$ and $\leq$. g_k is the aspiration level of the k th goal. $Z_k(X) \gtrsim g_k$ indicates the k th fuzzy goal approximately being essentially greater than or equal to the aspiration level g_k, whereas $Z_k(X) \lesssim g_k$ is to be understood as essentially less than or equal.

4. IMPLEMENTATION OF FAHP-FGP IN A REAL-WORLD CASE

Over the past decade freight transport volume between Turkey and the EU has grown rapidly and has generally been coupled with growth in gross domestic product. A white goods producer company based in Turkey that produces refrigerators and washing machines wants to transport the products from its factory in Bursa to a customer in Austria. The company works with different MTPs for each possible multimodal route. Transport units can be either semi-trailer or complete unit. The shipper wants to select an optimal multimodal route as the normal operation route by road route is disrupted at this moment because of cross-border road construction problem. The company established an expert group to decide on selection criteria and alternative routes with conducting a variety of rapid appraisals and surveys including brainstorming, semi-structured interviews. According to expert suggestions, the final hierarchy of selection criteria and routes are listed in Figure 4. The criteria which are considered during the selection of the optimal multimodal route include freight cost, transport time, risk of multimodal route and service level of MTP.

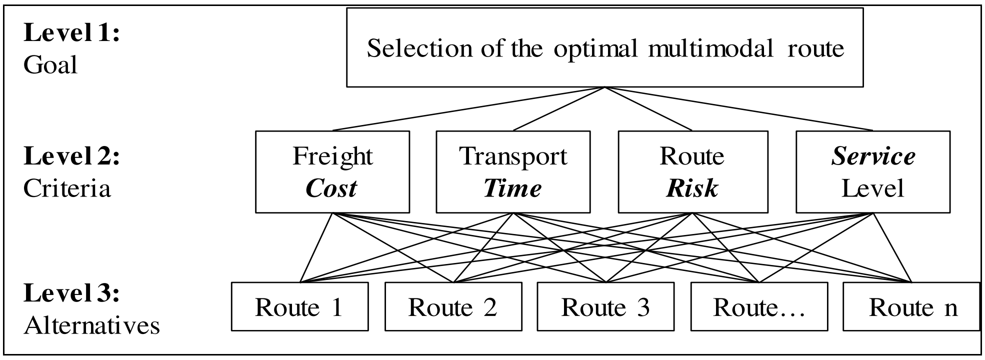

Figure 4. Hierarchy of Route Selection Problem

The expert group prioritized these criteria with three customers' freight conditions; respectively with slow (Case1), normal (Case2) and fast (Case3) transport by using FAHP method. By applying formulas from Equations (1) to (14).

S1=(0.2031,0.3008,0,4716), S2=(0.1525,0.2161,0.2720),

S3=(0.1623,0.2167,0.2957), S4=(0.1875,0.2665,0.3786),

$V(S1\geq S2)=1, V(S2\geq S1)=0.45, V(S3\geq S1)=0.52, V(S4\geq S1)=0.84,$

$V(S1\geq S3)=1, V(S2\geq S3)=0.99, (S3\geq S2)=1, V(S4\geq S2)=1,$

$V(S1\geq S4)=1, V(S2\geq S4)=0.63, V(S3\geq S4)=0.69, V(S4\geq S3)=1,$

$d'(\text{Cost})=1, d'(Time)=0.45, d'(Risk)=0.52, d'(Service)=0.84,$

$w'=(1,0.45,0.52,0.84)T$, $w=(0.36,0.16,0.19,0.30)$, $CR=0.095$.

In this calculation, a set of linguistic values is used

I=(*very low=VL,low=L,medium low=ML,medium=M,medium high=MH,high=H, very high=VH*

in order to denote the importance weight of each criterion. TFNs corresponding to these linguistic values are:

VL=(0.0,0.0,0.1), *L*=(0.0,0.1,0.3), *ML*=(0.1,0.3,0.5),

M=(0.3,0.5,0.7),*MH*=(0.5,0.7,0.9),*H*=(0.7,0.9,1.0).

Table 1. shows the fuzzy expert evaluation of selection criteria for slow transport.

Table 1. The Fuzzy Evaluation of Criteria for Case1

#	Cost	Time	Risk	Service	Weight
Cost	(1,1,1)	(1,1.11,1.43)	(1.43,2,3.34)	(0.7,0.9,1)	0.36
Time	(0.7,0.9,1)	(1,1,1)	(0.9,1,1)	(0.5,0.7,0.9)	0.16
Risk	(0.3,0.5,0.7)	(1,1,1.11)	(1,1,1)	(1,1.11,1.43)	0.19
Service	(1,1.11,1.43)	(1.11, 1.43,2)	(0.7,0.9,1)	(1,1,1)	0.30

The consistency ratio of expert judgments is checked. The ratio of consistency (CR) should not be greater than 0.10 . Else, expert should re-enter the judgments. First of all, the consistency index should be calculated with Equation (18), where $\lambda_{\max}$ is main value of comparison matrix, and n is number of columns.

$$CI = \frac{[\![(\lambda]\!]_{max} - n)}{(n-1)} \qquad (18)$$

Consistency ratio is calculated by using Equation (19), where RI is the random index.

$$CR = \frac{CI}{RI} \qquad (19)$$

After the consistency check the weight of criteria according to three cases are determined as seen in Table 2. For the Case 1, cost is ranked as prior criterion, as the freight can be transported slowly therefore the route can be mainly cost efficient whereas for the Case 2, the prior criterion is risk and for the Case 3, cost and time are ranked as prior criteria.

The expert group determined ten potential multimodal routes according to the existing rail route, road route and sea route within O-D shown in Figure 5. There are number of sea ports ($v_1 n$) and railway terminals ($t_1 n$) in this transport network.

Table 2. The Weight of Criteria According to Cases

Goals	Case1	Case2	Case3
Cost	0.36	0.25	0.31
Time	0.16	0.15	0.31
Risk	0.19	0.39	0.18
Service	0.30	0.21	0.21
CR	0.095	0.088	0.077

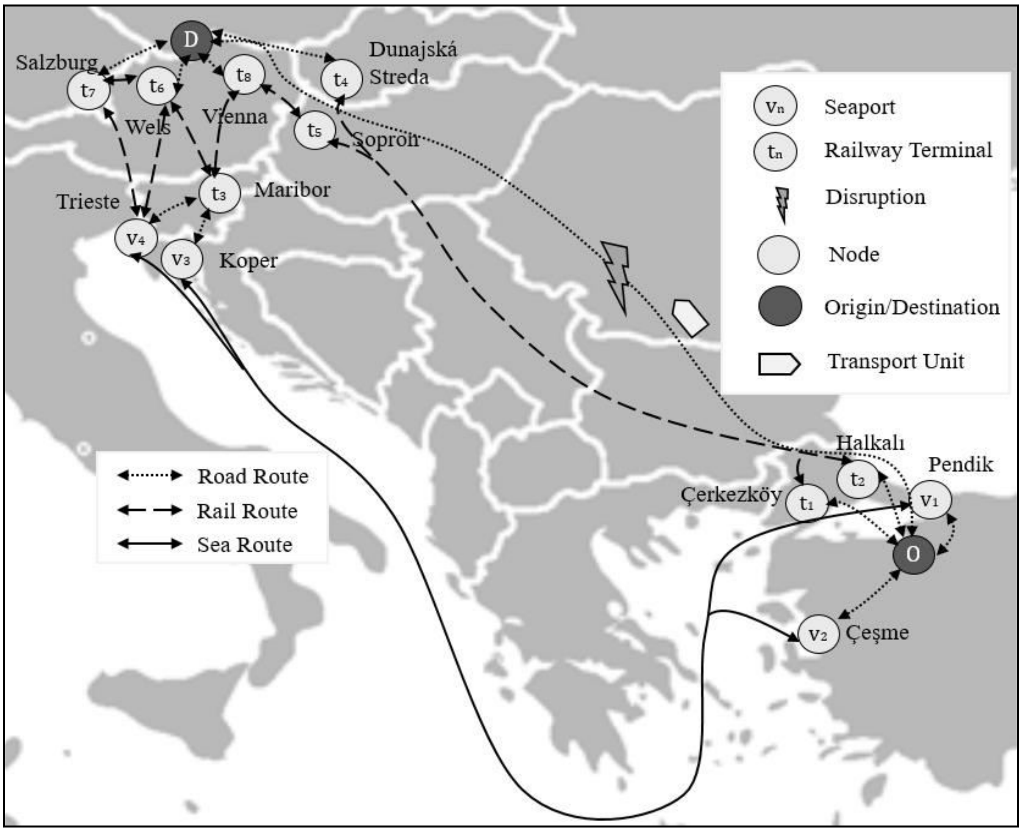

Figure 5. Multimodal Transport Routes between O-D in case of a Disruption

The main legs of transport network are operated via using sea and/or rail transport modes where all transport units are carried by using two types of transport: RoRo vessel and RoLa train. RoLa (rolling road) train services are specially designed wagons to carry wheeled cargo by rail route to/from the ports/terminals, whereas RoRo (roll-on/roll-off) vessels are specially types of ships designed to carry wheeled cargo by sea route to/from the ports. The initial (pre-haulage) and final legs (end-haulage) are operated by road route. The values of cost and time frame of each route are offered directly by MTPs that provide the transport services for those paths. The transport unit cost of semi-trailer is Euro and the time shows the total traveling time per day. Risk and service values are generated according the expert consensus. The higher score of risk means the higher average risk for route. The higher score of service means that MTP can provide a better average service for selected route. Table 3. denotes the route table according to each route and selection criteria.

Table 3. The Route Table for Multimodal Transport between O-D

#	Multimodal Route	Trans. Modes	Cost	Time	Risk	Service
1	$O - t_2 - t_4 - D$	rail	2800	6.5	10	6
2	$O - v_1 - v_4 - t_7 - D$	sea-rail	3800	7	6	8
3	$O - t_1 - t_5 - t_8 - D$	rail-rail	3500	8.5	8	8
4	$O - t_2 - t_8 - D$	rail	3200	10.5	6	6
5	$O - v_1 - v_4 - t_7 - t_6 - D$	sea-rail-rail	2900	7	10	8
6	$O - v_1 - v_3 - t_3 - t_6 - D$	sea-road-rail	3100	9	6	4
7	$O - v_1 - v_4 - t_3 - t_6 - D$	sea-road-rail	3050	6	8	6
8	$O - v_2 - v_4 - t_7 - D$	sea-rail	3000	8	4	6
9	$O - t_2 - t_6 - D$	rail	2900	9	6	8
10	$O - v_1 - v_4 - t_6 - D$	sea-rail	2950	8.5	6	4

There are four goals for the route selection, including cost, time, risk and service. Table 4. summarizes the lower and upper bound of the goals for the route selection. To determine the optimal multimodal route, the goals are formulated with FGP according to Equations (15) to (17) as detailed in the appendix. This problem is presented and solved by using LINGO 13.0 software package to obtain the solutions seen in Table 5.

Table 4. The Goals for Route Selection

Constraints		Goals	Lower bound	Upper bound	Difference
G_1	*Minimize*	Cost	0	3000	3000
G_2	*Minimize*	Time	0	10	10
G_3	*Minimize*	Risk	0	8	8
G_4	*Maximize*	Service	6	10	4

Table 5. Result from Case1, Case2 and Case 3

	Route	Cost	Time	Risk	Service	Deviation
#	Target goal	3000	10	8	10	
Case1	**Weight**	**0.36**	**0.16**	**0.19**	**0.30**	
10	$O-v_1-v_4-t_6-D$	2950	8.5	6	4	8.83
6	$O-v_1-v_3-t_3-t_6-D$	3100	9	6	4	9.83
8	$O-v_2-v_4-t_7-D$	3000	8	4	6	11.50
4	$O-t_2-t_8-D$	3200	10.5	6	6	14.53
Case2	**Weight**	**0.36**	**0.16**	**0.19**	**0.30**	
8	$O-v_2-v_4-t_7-D$	3000	8	4	6	8.87
10	$O-v_1-v_4-t_6-D$	2950	8.5	6	4	13.25
6	$O-v_1-v_3-t_3-t_6-D$	3100	9	6	4	13.75
4	$O-t_2-t_8-D$	3200	10.5	6	6	16.53
Case3	**Weight**	**0.31**	**0.31**	**0.18**	**0.21**	
10	$O-v_1-v_4-t_6-D$	2950	8.5	6	4	10.58
6	$O-v_1-v_3-t_3-t_6-D$	3100	9	6	4	10.58
4	$O-t_2-t_8-D$	3200	10.5	6	6	11.06
8	$O-v_2-v_4-t_7-D$	3000	8	4	6	12.37

The result gives a list of possible routes. According to result of Case 1, slow transport, the prior route is the route 10 which uses sea and rail routes. Transport cost is 2950 Euro, time period is 8.5 days, risk scale is 6 and service level is 4. The result of Case 2 shows that the prior route is the route

8, which is composed of sea and rail routes. Transport cost is 3000, time period is 8 days, risk scale is 4 and service level is 6. The result of Case 3 denotes the route 10 as prior route which is the combination of sea and rail routes. Transport cost is 2950 Euro, time period is 8.5 days, risk scale is 6 and service level is 4.

5. EVALUATIONS AND CONCLUSION

The aim of this study is to develop and adapt a route selection methodology by integrating FAHP and FGP techniques that can evaluate criteria in decision-making and optimization on a multimodal transport route for transport users in case of any disruption. The main contribution of this research is to use pre-selected qualitative and quantitative criteria in order to solve a real-world case problem by applying FAHP-FGP techniques. The proposed method is accurate, flexible and efficient system, and support the transport network planner or operator to decide on an optimal route rapidly if any disruption occurs throughout transport network. According to needs of transport users or freight conditions, decision maker can evaluate other alternative routes and decide on an optimal one. This proposed approach can be applied in different transport scenarios with using other transport modes.

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APPENDIX

Max=0.36*C1+0.16*C2+0.19*C3+0.30*C4; (ForCase1)

C1≤(3000−(6.7*X1−26.7*X2−16.7*X3−6.7*X4+3.3*X5−3.3*X6−1.7*X7+3.3*X9+1.7*X10))/3000; (ForG1:MinimizeCost)

C2≤(10−(65*X1+70*X2+85*X3+105*X4+70*X5+90*X6+60*X7+80*X8+90*X9+85*X10))/10; (ForG2MinimizeTime)

C3≤(8−(−25*X1+25*X2+25*X4−25*X5+25*X6+50*X8+25*X9+25*X10))/8; (ForG3:MinimizeRisk)

C4≤((40*X1+20*X2+20*X3+40*X4+20*X5+60*X6+40*X7+40*X8+20*X9+60*X10)−10)/4; (ForG4:MaximizeService)

X1+X2+⋯+X10=1,Xj=0 or 1: j=1,2,…,10.

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