Route prioritisation in a multi-agent transportation environment via multi-attribute decision making

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Abstract: Effective management of the vehicles plays an important role in transportation sector. There are some novel approaches in software engineering which can be used to dynamically control the trucks. One of the example technologies is multi-agent systems. Multi-agent-based technologies could be used for truck dispatching in real time. The trucks in such systems have their own transportation plan and they can decide about their routes throughout their operations. Any truck agent must select a route to pickup or deliver a transportation order while doing its transportation operation. However, truck driver route preference is also crucial for the transportation performances because of morale, motivation and psychological conditions of drivers have a considerable effect on transportation operation success. In this paper, driver route preference model is incorporated into a multi-agent-based vehicle dispatching system which uses fuzzy graph theoretical-matrix permanent approach which is a novel method in multi-attribute decision making (MADM). The model is also compared with fuzzy TOPSIS method. Spearman rank correlation test is used to assess the correlation between the ranks.

Keywords: transportation; multi-agent systems; multi-attribute decision making; MADM; matrix permanent; fuzzy TOPSIS.

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1 Introduction

Driving is a demanding task which requires constant concentration and appropriate manoeuvres of a vehicle on the road (Pang et al., 2002). The success of truck driver has a direct effect on any transportation operation. Therefore, transportation companies should consider the morale, motivation and psychological conditions of their drivers for a successful transportation operation. Vehicle drivers generally prefer the routes which are taking less time to complete transportation operations. However, it was found that there are some other dominant factors (Pang et al., 2002). For example, density of traffic signals, road safety, roadside assistance, visiting places on the road etc. could be some example factors. When the driver selects a route where he/she feels comfortable during transportation then it affects the success of transportation operation.

There may be some slack times in third-party logistics (3PL) company transportation operations that may give opportunity to truck drivers for selecting a route in a set of given routes. They can spend their leisure time whether on origin, destination or on a point between origin and destination. In this study, the transportation operations that fall into this category are analysed. When the truck driver completes a transportation operation then he receives the next operation information from the multi-agent-based truck control unit. Multi-agent-based truck control unit tries to find a good solution for the

transportation operation and sends the next operation information to the truck driver. If there is a slack time for the next operation then the driver has a chance to select the route to make the operation. Otherwise, the driver must drive the vehicle on the predetermined route. When there exists slack time for the vehicle driver then the driver preference could be considered.

In this paper, two multi-attribute decision making (MADM) models are used in order to support the decision of the vehicle driver in the case of alternative routes. MADM models are widely used in selection problems in many industrial applications (Maniya and Bhatt, 2011; Pohekar and Ramachandran, 2004; Yang et al., 2011). In this present paper, linguistic assessments of the truck drivers for route selection are considered when there exists a slack time for the transportation operations. The ranking of the alternative routes are achieved by using fuzzy graph theory-matrix permanent (f-GT_MP) approach which is a relatively new and less known member of MADM. The results of the f-GT_MP are also compared with fuzzy TOPSIS method. Spearman rank correlation test is used to assess the correlation between the rank results of these two MADM models.

2 State of the art

A MADM problem with m alternatives that are evaluated by n attributes may be viewed as a geometric system with m points in the n-dimensional space. They are widely used in selection problems in many industrial applications (Maniya and Bhatt, 2011; Pohekar and Ramachandran, 2004; Yang et al., 2011). The decision makers cannot evaluate accurately the decision problems as it is not possible to obtain precise data about the assessments of the decision problems. We can divide these problem types into two main groups where decision parameters could be evaluated with fuzzy and crisp variables. There are many different alternative methods for MADM problems which can be used where the decision parameters are crisp or fuzzy. Analytical hierarchy process (AHP), analytic network process (ANP), decision-making trial and evaluation laboratory (DEMATEL), elimination and et choice translating reality (ELECTRE), and technique for order reference by similarity to ideal solution (TOPSIS) methods are the most commonly used MADM methods in the literature.

For example, AHP is a popularly used MADM technique in many research areas. Applications of AHP have been dominant in manufacturing, followed by the environmental management and agriculture field, power and energy industry, transportation industry, construction industry, and healthcare. Other remarkable application fields include education, logistics, e-business, IT, R&D, telecommunication industry, finance and banking, urban management, defence industry and military, government, marketing, tourism and leisure, archaeology, auditing, and the mining industry (Sipahi and Timor, 2010). Xie (2010) used AHP techniques for selection of 3PL vendors. Chen et al. (2011) used a negotiation mechanism to get some potential suppliers with outsourcing alternatives to be selected, and then used AHP to find the best selection.

For example, Mo (2009) used fuzzy AHP for evaluating 3PL providers. Wang et al. (2010) proposed an evaluation method to assess locations of logistic distribution centre (LDC). They used fuzzy AHP for the LDC assessment so that decision makers can express their preference with uncertainty. Wang (2013) proposed a trial in establishing a systematic instrument for evaluating the performance of the marine information systems. ANP was introduced for determining the relative importance of a set of interdependent

criteria concerned by the stakeholders. Hsu et al. (2013) utilised the DEMATEL approach to recognise the influential criteria of carbon management in green supply chain for improving the overall performance of suppliers in terms of carbon management. Zhou et al. (2011) proposed a fuzzy DEMATEL method for identifying critical success factors in emergency management.

TOPSIS and fuzzy TOPSIS methods are used for many MADM models (Chu, 2002a, 2002b; Chu and Lin, 2003; Dagdeviren et al., 2009; Durán and Aguilo, 2008; Pires et al., 2011; Sadi-Nezhad and Damghani, 2010; Yurdakul and Ic, 2009). Fuzzy TOPSIS as an extension to the classical TOPSIS method is preferred when the alternative/criteria assessment values are linguistic (Chu, 2002b). There are so many applications where fuzzy TOPSIS method is deployed (Afshar et al., 2011; Aiello et al., 2009; Amiri, 2010; Braglia et al., 2003; Chen and Tsao, 2008; Chu, 2002a, 2002b; Chu and Lin, 2003; Dagdeviren et al., 2009; Sadi-Nezhad and Damghani, 2010).

Some of the MADM methods are hybridised for some decision making problems in addition to direct usage of these aforementioned methods. For example, Pires et al. (2011) used AHP and TOPSIS for alternative screening and ranking to help decision makers in a Portuguese waste management system. Viswanadham and Samvedi (2013) proposed a supplier selection model based on supply chain ecosystem by using fuzzy TOPSIS and AHP. Baykasoglu et al. (2013) integrated fuzzy DEMATEL and fuzzy hierarchical TOPSIS methods for truck selection. Senthil et al. (2014) developed a hybrid method which uses AHP and TOPSIS to get the final ranking of third-party contractors. Kannan et al. (2014) proposed a framework which is using fuzzy TOPSIS to select green suppliers for a Brazilian electronics company in their paper.

3 Multi-agent systems for load planning

An agent is a computer system that is situated in its environment, and that is capable of autonomous action in this environment in order to meet its design objectives (Wooldridge and Jennings, 1995). It is generally used for reaching their design objectives. An agent is a component that can exhibit reasoning behaviour under both proactive (goal directed) and reactive (event-driven) stimuli (Wooldridge, 2002). Generally, more than one agent is used in industrial problems. When more than one software agents are suited together collaboratively or competitively, these systems are called as *multi-agent* systems (Baykasoglu and Kaplanoglu, 2011). Multi-agent systems are generally used where the problem domains are particularly complex.

A multi-agent-based load consolidation system is previously proposed by the authors' of this paper. The system could be used by logistics service providers. The electronic system is automatically coordinating the pick-up and delivery operations of the trucks. Truck and order agents are two main agent types in that system. Truck agents are defined to the system according to logistics service provider fleet capacity. Order agents are created within the electronic system when an order is given by a customer to the logistics service providers. Whenever an order agent enters to the system it collaborates with the truck agents and these agent types find a pick-up and delivery operation plan. Details about the working principles of this system could be found in the paper (Baykasoglu and Kaplanoglu, 2011).

Figure 1 Transportation network and alternative routes for an operation (see online version for colours)

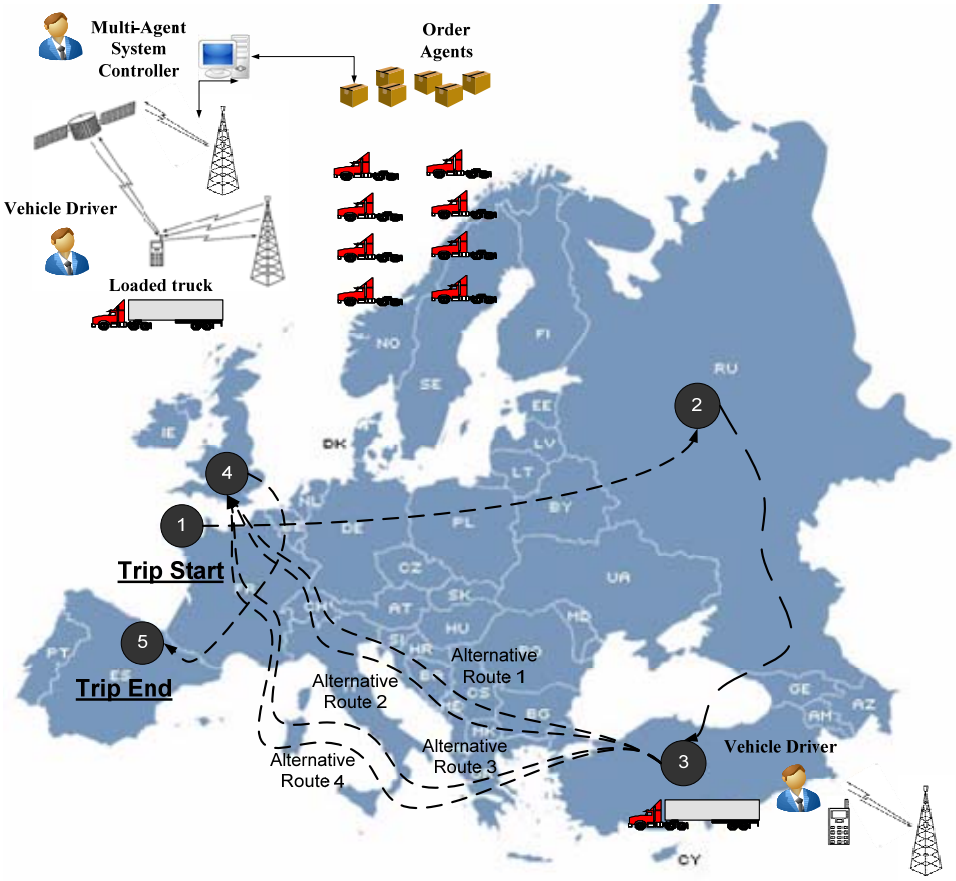


Figure 1 shows the simple working principle of the aforementioned multi-agent-based system. Multi-agent-based software is running in the central computers of the logistics service providers. The decision of the software is transmitted to the mobile devices of the truck drivers (smart phones or navigation units). Drivers of the vehicles get the instructions from the central computer and do the transportation operations.

For example, a transportation plan of a truck-trip is given in Figure 1. Trip of the truck is starting at node 1. Truck must go from nodes 1 to 5 to finish its operation. However, the trip plan may not be fixed at the start of the operations. The route of transportation may change based on dynamic arrivals of the orders.

There may be slack time in 3PL company transportation operations based on the attributes of the orders which are dynamically arriving to the multi-agent system. Slack time may give opportunity to truck drivers. They can spend their leisure time whether on origin, destination or on a point between origin and destination.

When the truck driver completes a transportation operation then he receives the next operation information from the multi-agent-based truck control unit. Multi-agent-based truck control unit tries to find a good solution for the transportation operation and sends the next operation information to the truck driver. There may be two kinds of slack time

for the truck operations; before delivery point and before pick-up point. Figure 2 shows the slack time of a vehicle before a delivery operation. If there is a slack time for the next delivery operation then driver may have a chance to select one of the available routes due to the extra time for operation completion.

Figure 2 Slack time representation before a delivery operation

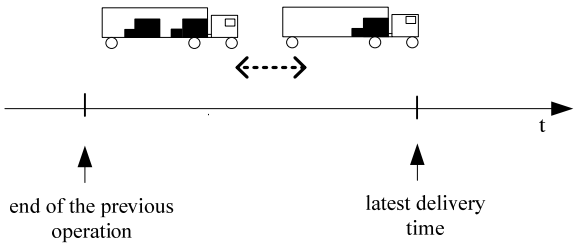
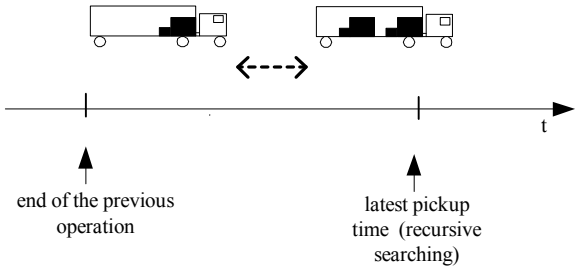


Figure 3 shows the similar case of slack time when there exists some extra time to complete a pick-up operation.

Figure 3 Slack time representation before a pickup operation



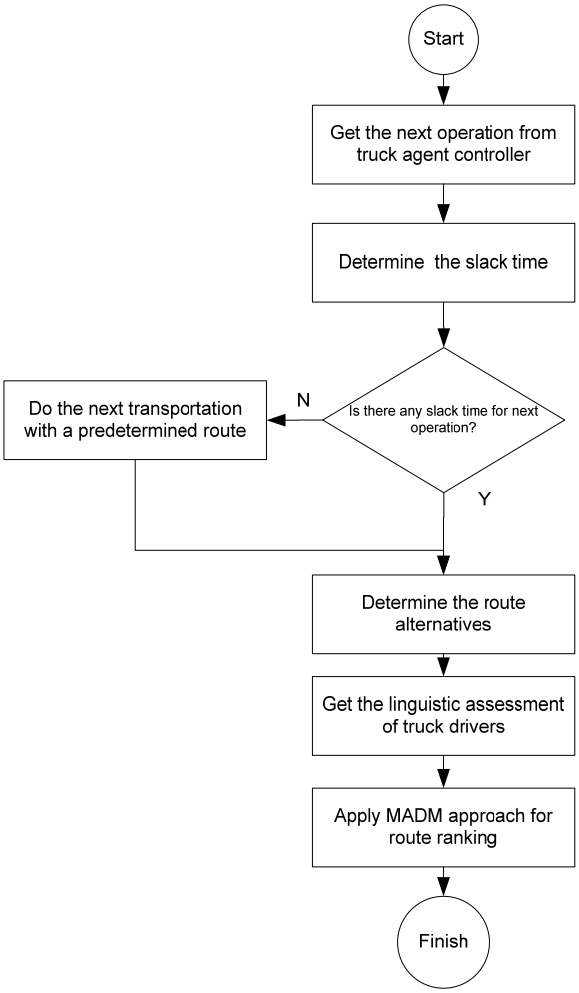
4 Methodology

The transportation operation is received from the multi-agent-based vehicle dispatching system automatically. After receiving the transportation operation order the truck driver makes his preference if there exist a slack time. Figure 4 shows the simplified flowchart of the proposed model.

4.1 Determining the route alternatives and decision criteria

We assume that for a specified origin–destination (O–D) pair, information on the possible routes is available. Given a set of O–D pairs, there could be many feasible routes for a driver. Different routes between O–D pairs are considered as route alternatives.

Figure 4 Flowchart of the proposed model

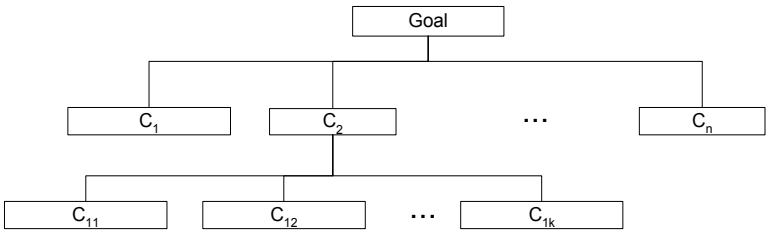


Truck drivers make their evaluations about routes based on a criteria set. The criteria set is static for each of the decision making process. The criteria and their hierarchy are determined as follows;

A. Difficulty	*B. Economy*	*C. Security*	*D. Scenery*
A1. Risk of accident	B1. Transportation time	C1. Road safety	D1. Enjoyable restaurants
A2. Turn difficulties	B2. Transportation distance	C2. Precaution for robbery	D2. Visiting places
A3. Density of traffic signals	B3. Fuel consumption	C3. Roadside assistance	D3. Closeness to relatives and friends
A4. Road quality	B4. Vehicle depreciation		D4. Silence of route

Each of these feasible routes may have different preference (scores/values) for the truck driver. After receiving the alternative routes from multi-agent-based system truck drivers make linguistic assessment about alternative routes based on the criteria set. Selecting an alternative route is the goal statement. Figure 5 shows the goal statement and criteria representation.

Figure 5 Representation of goal, criteria and hierarchy



4.2 Fuzzy graph theoretical-matrix permanent approach

Many different state of the art methods were proposed in the literature to handle and solve MADM problems like AHP, ANP, TOPSIS, PROMETHEE, VIKOR, ELECTRE, GRA, LINMAP, conjoint analysis, multi-attribute utility theory, etc. (Baykasoglu, 2013). In this paper, f-GT_MP approach is used to prioritise vehicle routes in a multi-agent-based transportation environment. This approach is based on matrix permanent computation.

Permanents were introduced in 1812 simultaneously by Binet and Cauchy (Minc, 1978). Permanent describes the number of perfect matching in a bipartite graph. Let $A = (a_{ij})$ be an $m \times n$ matrix, $m \leq n$. The permanent of A, written as $Per(A)$ is defined as (Minc, 1978):

$$Per(A) = \sum_{\sigma} a_{1\sigma(1)} a_{2\sigma(2)}, \ldots, a_{m\sigma(m)} \tag{1}$$

where the summation extends over all one-to-one functions from $\{1,\ldots,m\}$ to $\{1,\ldots,n\}$.

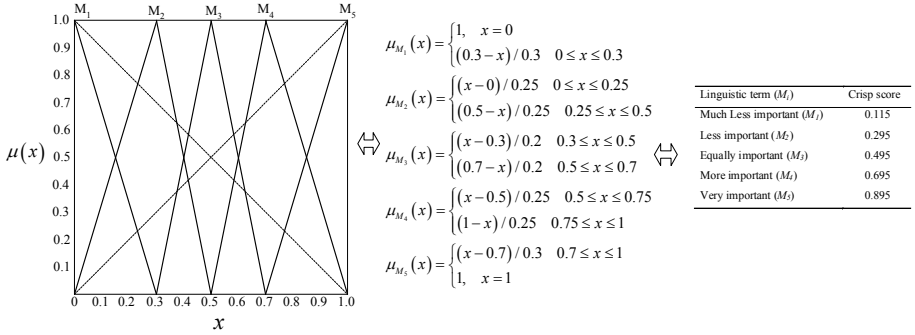
The details of this method and its application procedures to MADM problems can be found in Baykasoglu's studies [7, 8]. A criteria rating matrix (ψ) is used for any alternative evaluation. This is an $N * N$ matrix as follows;

$$[\Psi] = \begin{bmatrix} C_{11} & 0 & \ldots & 0 \\ 0 & C_{22} & \ldots & 0 \\ . & \ldots & . & . \\ 0 & \ldots & 0 & C_{nn} \end{bmatrix}$$

Relative importance (or interaction) between criteria r_{ij} can be assigned a value between 0 and 1. The values of r_{ij} can be obtained from the decision maker. Relative importance (interaction) matrix is denoted by β. Figures 6 and 7 show the fuzzy number conversion for ψ and β evaluation matrices [7, 8].

$$[\beta] = \begin{bmatrix} 0 & r_{12} & \dots & r_{1n} \\ r_{21} & 0 & \dots & r_{2n} \\ . & \dots & . & . \\ r_{n1} & \dots & \dots & 0 \end{bmatrix}$$

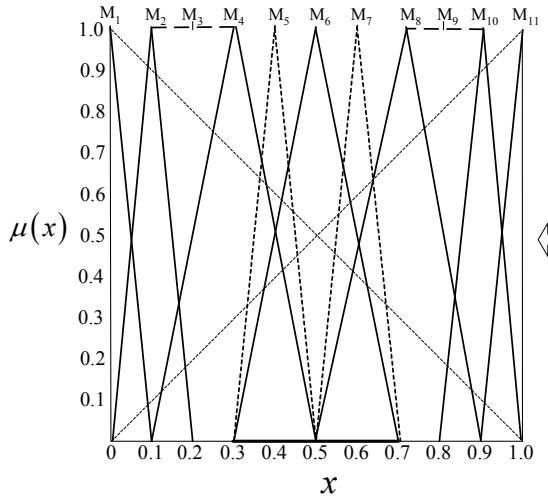
Figure 6 Linguistic terms to fuzzy number conversation for comparing criteria



Linguistic term (M_i)	Crisp score
Much Less important (M_1)	0.115
Less important (M_2)	0.295
Equally important (M_3)	0.495
More important (M_4)	0.695
Very important (M_5)	0.895

Source: Baykasoglu (2013)

Figure 7 Linguistic terms to fuzzy number conversation for evaluating criteria scores for alternatives



Linguistic term (M_i)	Crisp score
Exceptionally low (M_1)	0.045
Extremely low (M_2)	0.135
Very low (M_3)	0.255
Low (M_4)	0.335
Below average (M_5)	0.420
Average (M_6)	0.500
Above average (M_7)	0.590
High (M_8)	0.665
Very high (M_9)	0.745
Extremely high (M_{10})	0.865
Exceptionally high (M_{11})	0.955

Source: Baykasoglu (2013)

Finally, alternative evaluation matrix (ζ) is obtained as;

$$\xi = \psi + \beta = \begin{bmatrix} C_1 & r_{12} & r_{13} & .. & .. & r_{1n} \\ r_{21} & C_2 & r_{23} & .. & .. & r_{2n} \\ r_{31} & r_{32} & C_3 & .. & .. & r_{3n} \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ r_{n1} & r_{n2} & r_{n3} & .. & .. & C_n \end{bmatrix}$$

The permanent of matrix ξ, $per(\xi)$ gives the rating for the alternative.

4.3 Fuzzy TOPSIS approach

4.3.1 Determining the alternatives and getting the linguistic assessment of the decision maker

The alternatives and criteria are directly used from the previous analysis. In this step, the route alternatives are determined. The alternative routes are listed by the multi-agent-based decision support system. Table 1 shows the linguistic values which are used for rating the route alternatives. Decision maker assesses the alternatives according to criteria by using the scale given in Table 1.

Table 1 Linguistic values for the rating of alternatives

Linguistic term	*Linguistic values*
Very poor (VP)	(1, 1, 1)
Poor (P)	(2, 3, 4)
Fair (F)	(4, 5, 6)
Good (G)	(6, 7, 8)
Very good (VG)	(8, 9, 9)

Given fuzzy assessment values are held in $\tilde{Y}$ matrix. $\tilde{y}_{ij}$ holds the specific assessment of the decision maker for alternative route i according to criteria j where (i = 1, 2,…,k), (j = 1, 2,…,l) and k is the number of alternative routes and l is the number of criteria at the lowest level of the decision hierarchy.

4.3.2 Normalise fuzzy assessment matrix

Normalised value $\tilde{n}_{ij} = (n_{ij,l}, n_{ij,m}, n_{ij,u})$ is calculated as;

$$\tilde{n} = \frac{\tilde{x}_{ij}}{\sqrt{\sum_{i=1}^{m} \left(s\left(\tilde{x}_{ij}, 0\right)^2 \right)}}, \quad j = 1, \ldots, n$$

where

$$s\left(\tilde{x}_{ij}, 0\right) = \frac{1}{4}\left(x_{ij,l} + 2x_{ij,m} + x_{ij,u}\right)$$

4.3.3 Calculation of the weighted normalised decision matrix

The weighted matrix $\tilde{v}_{ij} = (v_{ij,l}, v_{ij,m}, v_{ij,u})$ is calculated as;

$$\tilde{v}_{ij} = w_j * \tilde{n}_{ij}$$

The weights of the criteria are determined after negotiating with the decision makers. In this context, decision makers use a scale (1 – for 'very low',…, and 9 – for 'very high').

4.3.4 Determining the positive ideal solutions and negative ideal solutions

The set of positive ideal solutions and negative ideal solutions are given as follows;

$$A^+ = \left\{\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+\right\} = \left\{\left(\tilde{v}_{uj} \mid j \in J\right), \left(\tilde{v}_{dj} \mid j \in J'\right)\right\}$$

$$A^- = \left\{\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\right\} = \left\{\left(\tilde{v}_{dj} \mid j \in J\right), \left(\tilde{v}_{uj} \mid j \in J'\right)\right\}$$

where J is associated with the positive criteria, J' is associated with the negative criteria.

4.3.5 Computing the distance of each alternative from positive and negative ideal solution

Distances of each alternative from positive and negative ideal solutions are calculated as follows;

$$d_i^+ = \sqrt{\sum_j^n \left(s\left(\tilde{v}_j^+, \tilde{v}_{ij}\right)^2\right)}, \quad i = 1, 2, \ldots, m; \tag{2}$$

$$d_i^- = \sqrt{\sum_j^n \left(s\left(\tilde{v}_j^-, \tilde{v}_{ij}\right)^2\right)}, \quad i = 1, 2, \ldots, m; \tag{3}$$

4.3.6 Computing the relative distance of each alternative and ranking the alternatives

The relative distances of each alternative from positive and negative ideal solution are calculated as follows;

$$cl_i^+ = \frac{d_i^+}{d_i^+ + d_i^-}, \quad i = 1, 2, \ldots, k \tag{4}$$

$$cl_i^- = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, 2, \ldots, k \tag{5}$$

Finally, the best alternative could be determined by using cl_i^+ and cl_i^- parameters.

5 Route selection by using f-GT_MP approach

An example route selection for a vehicle transportation operation is shown in this section. A route decision making between Turkey and France for an import operation is selected

for a logistics operation. The multi-agent system proposed three alternative routes for this transportation operation. Evaluation of these alternatives in terms of four main and related sub-criteria is shown next;

For route-1:

$$[\xi]^{A}_{R1} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & A_3 & A_4 \end{array} \\ \begin{bmatrix} 0.745 & 0.115 & 0.295 & 0.895 \\ 0.295 & 0.420 & 0.115 & 0.495 \\ 0.495 & 0.295 & 0.500 & 0.495 \\ 0.115 & 0.695 & 0.895 & 0.590 \end{bmatrix} \end{array}$$

$$[\xi]^{B}_{R1} = \begin{array}{c} \\ B_1 \\ B_2 \\ B_3 \\ B_4 \end{array} \begin{array}{c} \begin{array}{cccc} B_1 & B_2 & B_3 & B_4 \end{array} \\ \begin{bmatrix} 0.045 & 0.115 & 0.495 & 0.895 \\ 0.895 & 0.420 & 0.695 & 0.895 \\ 0.495 & 0.295 & 0.500 & 0.695 \\ 0.115 & 0.115 & 0.295 & 0.590 \end{bmatrix} \end{array}$$

$$[\xi]^{C}_{R1} = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 0.255 & 0.895 & 0.695 \\ 0.115 & 0.420 & 0.495 \\ 0.295 & 0.495 & 0.420 \end{bmatrix} \end{array}$$

$$[\xi]^{D}_{R1} = \begin{array}{c} \\ D_1 \\ D_2 \\ D_3 \\ D_4 \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & D_2 & D_3 & D_4 \end{array} \\ \begin{bmatrix} 0.255 & 0.295 & 0.895 & 0.495 \\ 0.695 & 0.335 & 0.695 & 0.495 \\ 0.115 & 0.115 & 0.500 & 0.895 \\ 0.295 & 0.695 & 0.115 & 0.420 \end{bmatrix} \end{array}$$

$$[\xi]_{R1} = \begin{array}{c} \\ A \\ B \\ C \\ D \end{array} \begin{array}{c} \begin{array}{cccc} A & B & C & D \end{array} \\ \begin{bmatrix} per[\xi]^{A}_{R1} & 0.495 & 0.495 & 0.895 \\ 0.495 & per[\xi]^{B}_{R1} & 0.695 & 0.695 \\ 0.495 & 0.295 & per[\xi]^{C}_{R1} & 0.695 \\ 0.115 & 0.295 & 0.295 & per[\xi]^{D}_{R1} \end{bmatrix} \end{array}$$

$$per[\xi]^{A}_{R1} = 1.0910; \quad per[\xi]^{B}_{R1} = 0.6042;$$
$$per[\xi]^{C}_{R1} = 0.4071; \quad per[\xi]^{D}_{R1} = 1.0937;$$
$$per[\xi]_{R1} = 2.1102$$

Similar calculations are performed for route-2 and route-3.

$$per[\xi]_{R2} = 2.9335; \quad per[\xi]_{R3} = 8.3416.$$

Based on these computations we can get the following ranking: *Route* $3 \succ$ *Route* $2 \succ$ *Route* 1. Route 3 is the best alternative for driver.

6 Route selection by using fuzzy TOPSIS approach

In this section, fuzzy TOPSIS method is applied for ranking the route alternatives. First, three different alternatives are assessed by the decision maker. Table 2 shows the evaluation of the vehicle driver who performs the transportation operation. Linguistic terms given in Table 1 are used in order to assess the route alternatives. Linguistic values based on the linguistic terms are given in Table 3.

Table 2 Linguistic route evaluation

Criteria	*Route-1*	*Route-2*	*Route-3*
1	VG	F	VG
2	G	G	VG
3	VG	G	VG
4	VG	G	G
5	P	G	G
6	F	G	G
7	F	G	G
8	P	F	F
9	VG	F	G
10	F	F	G
11	VG	G	G
12	F	G	VG
13	F	F	VG
14	F	G	VG
15	VG	P	F

Table 3 Values of route evaluation

Criteria	*Route-1*	*Route-2*	*Route-3*
1	(8, 9, 9)	(4, 5, 6)	(8, 9, 9)
2	(6, 7, 8)	(6, 7, 8)	(8, 9, 9)
3	(8, 9, 9)	(6, 7, 8)	(8, 9, 9)
4	(8, 9, 9)	(6, 7, 8)	(6, 7, 8)
5	(2, 3, 4)	(6, 7, 8)	(6, 7, 8)
6	(4, 5, 6)	(6, 7, 8)	(6, 7, 8)
7	(4, 5, 6)	(6, 7, 8)	(6, 7, 8)
8	(2, 3, 4)	(4, 5, 6)	(4, 5, 6)
9	(8, 9, 9)	(4, 5, 6)	(6, 7, 8)
10	(4, 5, 6)	(4, 5, 6)	(6, 7, 8)
11	(8, 9, 9)	(6, 7, 8)	(6, 7, 8)
12	(4, 5, 6)	(6, 7, 8)	(8, 9, 9)
13	(4, 5, 6)	(4, 5, 6)	(8, 9, 9)
14	(4, 5, 6)	(6, 7, 8)	(8, 9, 9)
15	(8, 9, 9)	(2, 3, 4)	(4, 5, 6)

Normalised fuzzy assessment matrix is given in Table 4.

Table 4 Normalised fuzzy assessment

Criteria	*Route-1*	*Route-2*	*Route-3*
1	(0.6, 0.7, 0.7)	(0.3, 0.4, 0.4)	(0.6, 0.7, 0.7)
2	(0.5, 0.5, 0.6)	(0.5, 0.5, 0.6)	(0.6, 0.7, 0.7)
3	(0.6, 0.6, 0.6)	(0.4, 0.5, 0.6)	(0.6, 0.6, 0.6)
4	(0.5, 0.5, 0.6)	(0.5, 0.5, 0.6)	(0.6, 0.7, 0.7)
5	(0.2, 0.3, 0.4)	(0.6, 0.7, 0.8)	(0.6, 0.7, 0.8)
6	(0.4, 0.5, 0.5)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)
7	(0.4, 0.5, 0.5)	(0.5, 0.6, 0.7)	(0.5, 0.6, 0.7)
8	(0.3, 0.4, 0.5)	(0.5, 0.7, 0.8)	(0.5, 0.7, 0.8)
9	(0.7, 0.7, 0.7)	(0.3, 0.4, 0.5)	(0.5, 0.6, 0.7)
10	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.6, 0.7, 0.8)
11	(0.6, 0.7, 0.7)	(0.5, 0.5, 0.6)	(0.5, 0.5, 0.6)
12	(0.5, 0.6, 0.7)	(0.7, 0.7, 0.7)	(0.3, 0.4, 0.5)
13	(0.4, 0.4, 0.5)	(0.4, 0.4, 0.5)	(0.7, 0.8, 0.8)
14	(0.3, 0.4, 0.5)	(0.5, 0.6, 0.7)	(0.7, 0.7, 0.7)
15	(0.8, 0.9, 0.9)	(0.2, 0.3, 0.4)	(0.4, 0.5, 0.6)

The weighted normalised matrix which is given in Table 6 is calculated by using the weights given in Table 5.

Table 5 Weights of criteria

Criteria	*DM**	*Weight of criteria*
1	9	0.105
2	5	0.058
3	2	0.023
4	8	0.093
5	4	0.047
6	5	0.058
7	3	0.035
8	3	0.035
9	8	0.093
10	6	0.070
11	7	0.081
12	8	0.093
13	7	0.081
14	7	0.081
15	4	0.047
Total:	86	1

Note: *DM: decision maker

Table 6 Weighted normalised decision matrix

Criteria	*Route-1*	*Route-2*	*Route-3*
1	(0.063, 0.071, 0.071)	(0.031, 0.039, 0.047)	(0.063, 0.071, 0.071)
2	(0.026, 0.031, 0.035)	(0.026, 0.031, 0.035)	(0.035, 0.040, 0.040)
3	(0.013, 0.015, 0.015)	(0.010, 0.011, 0.013)	(0.013, 0.015, 0.015)
4	(0.042, 0.049, 0.056)	(0.042, 0.049, 0.056)	(0.056, 0.063, 0.063)
5	(0.009, 0.013, 0.018)	(0.027, 0.031, 0.036)	(0.027, 0.031, 0.036)
6	(0.021, 0.026, 0.031)	(0.031, 0.037, 0.042)	(0.031, 0.037, 0.042)
7	(0.013, 0.016, 0.019)	(0.019, 0.022, 0.025)	(0.019, 0.022, 0.025)
8	(0.009, 0.014, 0.018)	(0.018, 0.023, 0.027)	(0.018, 0.023, 0.027)
9	(0.061, 0.068, 0.068)	(0.030, 0.038, 0.045)	(0.045, 0.053, 0.061)
10	(0.028, 0.035, 0.042)	(0.028, 0.035, 0.042)	(0.042, 0.049, 0.056)
11	(0.049, 0.055, 0.055)	(0.037, 0.043, 0.049)	(0.037, 0.043, 0.049)
12	(0.045, 0.053, 0.061)	(0.061, 0.068, 0.068)	(0.030, 0.038, 0.045)
13	(0.029, 0.036, 0.043)	(0.029, 0.036, 0.043)	(0.058, 0.065, 0.065)
14	(0.027, 0.033, 0.040)	(0.040, 0.046, 0.053)	(0.053, 0.060, 0.060)
15	(0.035, 0.040, 0.040)	(0.009, 0.013, 0.018)	(0.018, 0.022, 0.027)

After finding the weighted normalised decision matrix, the positive and negative ideal solutions are found. The A^+ and A^- sets of the truck selection problem are computed as follows;

$$A^+ = \{(0.063, 0.071, 0.071), (0.035, 0.040, 0.040), \ldots, (0.035, 0.040, 0.040)\}$$
$$A^- = \{(0.031, 0.039, 0.047), (0.026, 0.031, 0.035), \ldots, (0.009, 0.013, 0.018)\}$$

Then, distance of each alternative from positive and negative ideal solutions are calculated by using equations (1) and (2). The distance values are given in Table 7.

Table 7 Distance values

Alternative	D^+	d^-
1	0.050	0.0517
2	0.061	0.0392
3	0.037	0.0592

Finally, relative distances of the truck alternatives are calculated by using equations (3) and (4). The relative distances of each alternative to positive and negative ideal solution are given in Table 8.

Table 8 Relative distances

Alternative	cl^+	cl^-
1	0.491	0.509
2	0.609	0.391
3	0.385	0.615

As the most preferred alternative should *simultaneously* have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution, which also certainly reflects the rational of human choice (Baykasoglu et al., 2013). Preference order of the truck alternatives are;

$$Route\ 3 \succ Route\ 1 \succ Route\ 2$$

As it can be seen from the results both methods determined route 3 as the best alternative, however route 1 and 2 are placed in different orders. In such cases, Spearman rank correlation coefficient (R) is useful to determine the measure of association between ranks obtained by different MCDM methods (Gibbons, 1971). If U_a and V_a denote the ranks achieved by two different MCDM methods for the same alternative a, then coefficient R is defined as;

$$R = 1 - \frac{6\sum_{a=1}^{A} D_a^2}{A(A^2 - 1)}$$

where a = number of alternatives; a = 1, 2,…,A; A = total number of alternatives; D_a = difference between ranks ($U_a - V_a$); R = 1 represents perfect association between the ranks; R = 0 represents no association between the ranks; R = –1 represents perfect disagreement between the ranks (Raju and Kumar, 1999). The ranking obtained from f-GT_MP approach is 3, 2, 1 and ranking obtained from fuzzy TOPSIS method is 3, 1, 2. The squared difference is 2. There are three alternatives for the proposed example selection problem then R could be calculated as *0.75* which may be considered close to R = 1 perfect association.

7 Conclusions

Modern communication and information technologies are providing good opportunities for transportation industry. Multi-agent-based technologies could be used for vehicle dispatching in real time. However, truck driver preference plays an important role for the transportation success. Truck driver route preference is especially crucial for the transportation performances because morale, motivation and psychological conditions of drivers have a considerable effect on transportation operation success. In this paper, driver route preference model is developed along with MADM-based approaches.

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