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RESEARCH PAPER

A Hybrid Fuzzy Decision-Making Approach to Select the Best Online-Taxis Business

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Abstract

In the recent decade, significant growth of internet-based platforms and changes in people's moving preferences has led to an increase in the electronic taxis businesses. Hence, investigating the factors affected by such businesses can help increase their profits and, at the same, time their customers' satisfaction level. In this study, a hybrid fuzzy decision-making approach is proposed to examine the best online-taxis business selection problem. The proposed framework firstly determines the interrelationships between criteria and sub-criteria, by applying the Fuzzy Decision-making trial and evaluation laboratory (FDEMATEL) method. Then, the weights of the criteria and sub-criteria are calculated using an integrated Fuzzy Best-Worst Method (FBWM) and the Fuzzy Analytic network process (FANP). In this regard, at first, the local weights of indicators are calculated using the FBWM regardless of interrelationships between them. Then, the final (i.e. global) weights of indicators, considering their interrelationships, are measured employing the FANP method. Afterwards, the feasible alternatives are prioritized by employing the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) method. For each step of the proposed framework, a questionnaire is designed and distributed between experts. The results show that the most important criteria and sub-criteria for passengers are cost and reasonable price, respectively. Finally, some managerial insights are provided.

Keywords:
Startup-Based Business;
Online Taxis;
Multiple-Attribute Decision-Making;
Hybrid Methods

Introduction

With the development of Internet technology, the adoption of entrepreneurial Startup Businesses (SBs) (e.g., online taxi business) is growing [1]. People's travel structures are deeply dependent on the choice of travelers. To achieve sustainable development, entrepreneurial SBs (e-businesses) such as online taxi services are most important. In a case study in China, the impact of online taxi services on travelers' preferences has been shown. [2]. It is worth noting that investment in information technology has grown dramatically in the current world and has a very high investment share. Information technology has a significant impact on travelers' behavior [3]. E-businesses have a good potential to earn high revenues, which the online taxi is one of them. The profit of the online taxi companies is entirely dependent on travelers' welcome to them. Hence, they need to analyze customer behavior to maintain and improve their market share.

With the rise of entrepreneurial SB (especially online taxi business) in Iran, there has been much controversy between online business and traditional business. For example, several factors, such as technology, low cost, and trip security, affect travelers' demand for internet-

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based taxis in Tehran [4]. For years, the only option for passengers to move from one place to another place is their car or public transportation, which has created many problems for people. Nowadays, Internet taxis became popular, and the advent of internet taxis answered many of these problems. The benefits of this smart taxi system in people's lives have made it a unique position in the public transport community over time.

Only a few studies investigated the decision-making process in online taxis or related businesses. For example, Zhang et al. [2] conducted a study based on characteristics of travelers and travel in China, which showed that people's choice is more towards modern taxis than traditional ones. The authors designed a questionnaire to acquire data about travelers' preferences. Then, they applied a binary model to show the behavior of travelers. Munandar and Munthe [3] investigated the impact of technology on behavioral intention in online transportation in Thailand and Indonesia. This study showed that technology has a considerable impact on travelers' behavior. The authors conducted interviews with 500 students who used online taxis. Then, they analyzed their behavior by the logit binary method. Eboli and Mazzulla [5] examined the behavior of rail passengers in Italy. They used a structural equation model to show the relationship between customer satisfaction and rail service performance, which was conducted on a large scale by the Italian rail network. The obtained results showed that passengers would like to use the rail service based on some factors like technology and comfort. Si et al. [6] carried out a study about internet taxis in China. The authors identified factors affecting the behavior of travelers, which was done by a structural equation model. Afterwards, they applied the Logit model, and the results demonstrated that travelers' acceptance of Internet taxis was far greater than traditional taxis. Etminani-Ghasrodashti and Hamidi [4] conducted a study to analyze the behavior of internet taxis in Iran. To do this, they employed the structural equation models. The results showed that the main reasons for welcoming internet taxis are low cost, travel security, privacy, and technology.

As the literature shows, the problems related to online-taxis businesses have been less addressed in the literature, In contrast, the target problem is an applicable decision-making mechanism and is widely used in practice. On the other hand, although selecting the best online taxi company can be considered as a decision-making problem, no paper investigated this problem using multiple-attribute decision-making (MADM) methods. Hence, in this study, we attempt to investigate the mentioned problem. Comparing to Zhang et al. [2], Zhang et al. tried to determine that the traditional taxi is more attractive for travelers or the online ones. In this way, they applied the binary logit model to investigate the influencing factors behind the travelers' preference for conventional taxi and tailored taxi. One of the major drawbacks of their study is that alternatives are not considered in their paper. Indeed, their proposed approach only showed the importance of factors, and could not prioritize the potential alternatives. On the other side, the interrelationships between factors were ignored in their study. However, the current study develops a hybrid approach that is able to find the interrelationships among factors, and calculate the weight of factors, and prioritize the alternatives while considering such interrelationships. Comparing to the work conducted by Munandar et al. [3], they carried out the statistical hypotheses and employed the binary logit method to examine how technology affects the behavior of travelers. The limitation of their study is they entirely focused on the technology and did not consider the other indicators. On the other side, the other limitation of the mentioned research is that it could not prioritize the potential alternatives. In this regard, the comprehensive framework proposed in this study removes the mentioned issues. Also, Etminani-Ghasrodashti [4] only showed the main reasons for the travelers' willingness to online taxis, but they did not determine the most important indicators. On the other side, the current research has some other advantages over Etminani-Ghasrodashti [4], such as considering more indicators and identifying the interrelationships among indicators. Comparing to Si et al. [6], their proposed framework could not rank the potential alternatives and could not consider the interrelationships among indicators. Actually, based on the literature, there is a lack of an efficient and comprehensive decision-making method to study the online taxis business problem. Hence, to fill this gap, this research develops a hybrid fuzzy decision-making approach to investigate the behavior of passengers in selecting online taxis. The proposed hybrid approach simultaneously has the following advantages.

(I) The developed approach can identify the interrelationships among the indicators using the Fuzzy DEMATEL (FDEMATEL) method.

(II) The proposed method is capable of reducing the computing burden by lowering the required pairwise comparisons by employing the FBWM within the FANP framework.

(III) Owing to such reduction in subjective pairwise comparisons, the developed approach leads to higher reliability of the results by integrating the FBWM and FANP methods.

(IV) The proposed method considers distances to an ideal solution using the FTOPSIS method when ranking the alternatives.

(V) The developed approach captures the inherent uncertainty in the subjective inputs of experts in different steps of the proposed framework using the fuzzy set theory.

This study attempts to analyze the passengers' decision-making mechanism for selecting online taxis in Iran. At a glance, this study develops a hybrid fuzzy decision-making framework to identify the most important criteria/sub-criteria and prioritize alternatives for the online taxi business. In this way, at the outset, the main criteria, sub-criteria, and alternatives are identified. Afterward, the FDEMATEL method is employed to find the interrelationships among criteria/sub-criteria. Then, in order to reduce the cognitive burden and increase the reliability, a hybrid method based on the FBWM and FANP is applied to calculate the weight of the criteria/sub-criteria. Since selecting the best and the worst criteria by experts is not an easy task and experts may not reach a consensus on this issue, we apply the results of the FDEMATEL method to determine the best and the worst criteria. Finally, the FTOPSIS method is employed to prioritize the alternatives. Fig. 1 depicts the framework of this research. The main research questions of the current study are as follows:

- What are the main criteria /sub-criteria in selecting the best online taxi business?
- Which criteria are the most influential ones in this business?
- How could the feasible alternatives be prioritized?

The rest of this research is structured as follows. Section 2 presents the problem definition and decision tree. Section 3 is dedicated to defining the methodology of research. Computational results are presented in Section 4. Finally, Conclusions and suggestions for future studies are provided in Section 5.

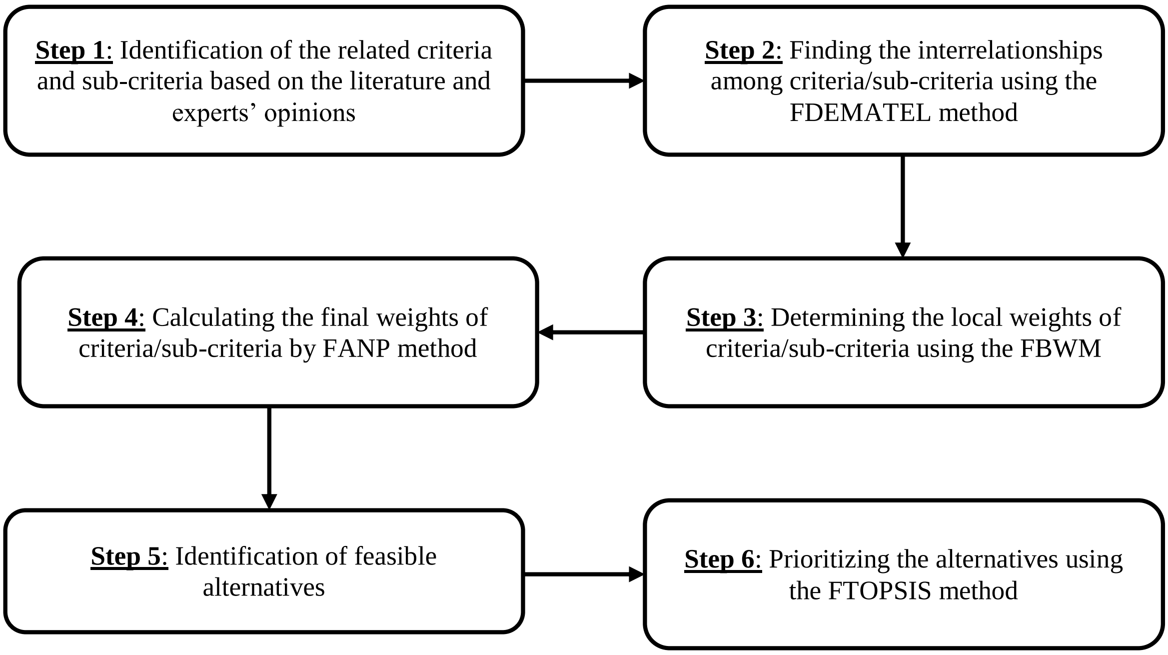


Fig. 1. The research framework

Research problem

Suppose that someone wants to travel from her/him home to her/his workplace. For some reasons (e.g., traffic or contagious diseases) this person does not want to use public transport such as a bus. Hence, she/he tries to get an internet taxi that is affordable for her in terms of time and cost. Given the growth of the online taxi business, this person should select one of these SBs to take a taxi. Thus, this person faces a decision-making problem according to her/him criteria and alternatives. The alternatives are those companies that are operated in the related business. On the other hand, there are various criteria (sub-criteria) for this decision-making problem (e.g. cost, time, and service, and quality) [6]. The mentioned decision-making problem is illustrated in Fig. 2.

Fig. 2. Schematic of the research problem

In the following, the main criteria and sub-criteria considered in this study are presented. In general, this research categorizes the related criteria into four main classes: time, cost, service, and quality. Below, the concept and attributes of the mentioned criteria have been described:

Time: Undoubtedly, one of the most important criteria for each passenger is travel time. Most passengers use online taxis to save time. The sub-criteria which are related to time are as follows [6]:

- **Reach time**: The time it takes for a taxi to arrive at the pick-up point.
- **Arrival time**: The time it takes for a taxi to reach its destination.

Cost: In every industry, whether manufacturing or service, the cost of product or service is an important factor for customers. Obviously, customers expect reasonable costs in the online taxi business, which makes it an important competitive factor. The sub-criteria which are related to costs are as follows [6]:

- **Reasonable price**: For long routes, the price will rise reasonably.
- **Discount**: Variety in discounts on convenience.
- **Free travel**: The number of free trips donated to loyal customers.
- **Traffic region price**

Quality: Certainly, quality plays an essential role in each business and is considered as an important competitive advantage. In this regard, quality is one of the crucial criteria for passengers in an online taxi business, too. The sub-criteria that are related to quality are as follows [6,7]:

- **Vehicle Quality**: The car quality is defined with safety, facilities for the disabled, type of the car, and the car interior.
- **Driver Quality**: The quality of the taxi driver is defined by features like safe driving, respecting passenger rights, driver appearance, and proper routing.
- **Application (App.) Quality**: Features like App. Speed, App. Appearance, facilitate payment, the voice of the customer and, the voice of the process.
- **The number of cars:** The number of taxis available when requesting a passenger in the vicinity of the passenger.

Services: Extra services have a decisive role in attracting customers. Usually, people prefer to use a company with more and better services. In this study, the following sub-criteria considered for services [6,7]:

- **Transportation modes**: The type of transportation (e.g., car or motorcycle) can be one of the criteria for customers to select an alternative. Besides, sometimes, customers of internet taxis are not passengers themselves but would like to move things. So, the options to move things is also essential for customers of the online taxi business.
- **Insurance**: Insurance is a crucial issue for the majority of travelers.
- **Women driver**: Many female travelers prefer to travel with a woman driver. Hence, the existence of women drivers can be a helpful service for the company.
- **Advertisement**: Given the high importance of advertising to attract customers, this factor is considered as a sub-criteria of the services.

On the other hand, in this research, three active online taxi business companies in Iran with nicknames A, B, and C have been considered as alternatives. Based on the above definitions, the main criteria/sub-criteria of the research problem are given in Table 1.

Table 1. Indicators of the research problem

Criteria	Sub-criteria
Services	Advertisement
	Women driver
	Insurance
	TM
Cost	Discount
	Free travel
	Traffic region price
	Reasonable price
Quality	Number of cars
	Application quality
	Driver quality
	Vehicle quality
Time	Reach time
	Arrival time

Methodology

This section presents a brief description of the methods applied in this research. As mentioned before, in this study, the FDEMATEL method is employed to identify interrelationships among criteria/sub-criteria. Then, a hybrid method based on the FBWM and FANP approaches is applied to calculate the weight of criteria/sub-criteria. Eventually, the FTOPSIS method is utilized to ranking the alternatives. We assume that the readers are already familiar with the area of fuzzy set theory and related notions. These include discussions such as triangular fuzzy numbers, basic calculations of triangular fuzzy numbers, crisp numbers, membership functions, non-membership functions, linguistic variables. Any related book or article, for example, Sir and Çalışkan [8], Skalna et al. [9] can give further information to those interested in this field. Suppose that $\tilde{a} = (l, m, u)$ represents a triangular fuzzy number (TFN). The Graded Mean Integration Representation (GMIR), denoted by $R(\tilde{a})$, is defined by relation (1) as follows:

$$R(\tilde{a}) = \frac{l + 4m + u}{6} \tag{1}$$

FDEMATEL

FDEMATEL method [10] examines the relationships between criteria and sub-criteria and identifies all the influential and effective criteria by the relationship matrix. This method is one of the MADM methods. As the name implies, all calculations are performed in a fuzzy environment. This technique is based on directed graphs that use expert judgment to identify the system's factors and apply the principles of graph theory. Lin and Wu [10] provided the following steps for performing the FDEMATEL method:

Step 1: Create a group of experts to gather their knowledge to solve the problem.

Step 2: Determine the evaluation criteria as well as their scales. In this step, the factors and indicators of the research are identified using expert opinions. The evaluation criteria are selected according to the areas mentioned in this paper. The linguistic scales used in this method and the corresponding values are given in Table 2. The triangular fuzzy numbers are used in this study to quantify linguistic scales. As can be seen, this spectrum is the same as the DEMATEL method, except that fuzzy numbers have been used instead of crisp numbers.

Table 2. Linguistic variables and their equivalent TFNs [11]

Linguistic terms	Linguistic values	Triangular fuzzy numbers
No influence (No)	(1, 1, 1)	$\tilde{1}$
Very low influence (VL)	(2, 3, 4)	$\tilde{3}$
Low influence (L)	(4, 5, 6)	$\tilde{5}$
High influence (H)	(6, 7,8)	$\tilde{7}$
Very high influence (VH)	(8, 9,9)	$\tilde{9}$

Step 3: Create a fuzzy matrix with the initial direct connection by gathering expert opinions. To measure the relationships between criteria, we need to put them in a square matrix and ask experts to compare them in pairs based on how much they influence each other. In this process, experts express their views based on Table 2. Assuming that we have n criteria and p experts, so we have p fuzzy matrices, each of them corresponds to the views of an expert with triangular fuzzy numbers including its elements.
Step 4: Normalize the fuzzy matrix with a direct connection. To this goal, the linear scale conversion is used as a normalization formula to convert normal scales to comparable scales.

$$\tilde{a}_{ij} = \sum_{j=1}^{n} \tilde{Z}_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} r_{ij} \right) \ and \ r = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} r_{ij} \right) \quad (2)$$

$$\tilde{X} = \begin{bmatrix} \tilde{X}_{11} & \cdots & \tilde{X}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{X}_{m1} & \cdots & \tilde{X}_{mn} \end{bmatrix} \ and \ \tilde{X}_{ij} = \frac{\tilde{Z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{r_{ij}}{r} \right) \quad (3)$$

Step 5: Calculate the total fuzzy matrix. In this step, we first calculate the inverse of the normal matrix, then subtract it from the matrix I, and finally multiply the normal matrix by the resulting matrix.

$$[l''_{ij}] = X_l \times (1 - X_l)^{-1} \quad (3)$$
$$[m''_{ij}] = X_m \times (1 - X_m)^{-1} \quad (5)$$
$$[r''_{ij}] = X_r \times (1 - X_r)^{-1} \quad (6)$$

Step 6: Create and analyze the diagram. To do this, we first calculate the sum of the elements of each row D_i and the sum of the elements of each column R_i of the fuzzy matrix. The sum of the elements of each row D for each factor indicates the extent to which a factor affects the other factors in the system. The sum of the elements of the column for each factor indicates the effectiveness of that factor from other factors of the system. Then we quickly get the values of $D + R$ and $D - R$.

To draw a causal diagram, we need to make these two values non-fuzzy, like the definite DEMATEL method. Here we use the CFCS method to deactivate these two values. Therefore, the horizontal vector $D + R$ is the effectiveness of the desired factor on the system (which could be considered as the initial importance weight of this factor). In other words, the higher the $D + R$ value, the more interactive it is with other system factors. The vertical vector $D - R$ shows the impact power of each factor. In general, if $D - R$ is positive, the variable is a causal variable, and if it is negative, it is considered a disability. After disabling the numbers, a coordinate system is drawn. In this step, the longitudinal axis shows the values of $D + R$ and $D - R$ is the transverse axis. So, the horizontal vector in the coordinate system is the rate of impact and impact of the system's desired factor. In other words, the higher this value for a factor, the more interaction it has with other system factors.

Also, setting up a threshold value and obtaining the internal dependence matrix to explain the structural relationship between the factors (while maintaining the complexity of the whole system at a controllable level) is necessary to adjust the threshold value P to filter out minor effects on the matrix T. Only factors whose effect on the matrix T is greater than the threshold value shown in an internal dependency matrix. Usually, the threshold value p is selected by experts and the results of the literature review.

FBWM

The Best Worst Method is one of the most recent MADM methods that was presented by Rezaei [12] as an improvement to pair-wise comparison matrix (PCM) based methods (e.g., AHP and ANP). The main advantages of the BWM compared to PCM-based methods (like AHP) are i) considerable reduction in the cognitive burden related to numerous pair-wise comparisons ii) The reliability of this method's output (weights of factors) is high because of low inconsistency in the DM's opinions as to the result of lower pair-wise comparisons ii) this method can be easily combined with other MADM methods. Guo and Zhao [13] extended the BWM method to a fuzzy environment. The use of fuzzy numbers eliminates the ambiguities of the respondent's words.

Now the steps necessary to implement FBWM can be explained as below [14].

Step 1: Determine the Best and the Worst criteria

In the first step, the best and the worst criteria are determined. Traditionally, DMs determine these criteria, but in this research, we apply the obtained results from FDEMATEL to do this. Therefore, the criteria with the highest D+R are considered the best and the one with the lowest D+R as the worst. If for some criteria, D+R is the same, the best/worst criteria would be selected using expert opinion.

Step 2: Form the comparison vectors for the best and the worst criteria

Suppose that $c_1, \ldots, c_n$ are the selected criteria. We define the triangular fuzzy number $\tilde{a}_{ij}$ as the comparison of criterion c_i towards criterion c_j, given in the form of linguistic variables by decision-makers. Based on Table 3, it can then be transformed into a triangular fuzzy number.

Table 3. Transformation table of linguistic variables [14]

Linguistic terms	Membership function
Equally important (EI)	(1, 1, 1)
Weakly important (WI)	(0.6667, 1, 1.5)
Fairly important (FI)	(1.5, 2, 2.5)
Very important (VI)	(2.5, 3, 3.5)
Absolutely important (AI)	(3.5, 4, 4.5)

If "B" and "W" indicate the best and the worst criteria respectively, Best-to-Others vector, $\tilde{A}_{B,}$ and Others-to-Worst vector, $\tilde{A}_W$, can be defined by $\tilde{A}_B = (\tilde{a}_{B1}, \tilde{a}_{B2}, \ldots, \tilde{a}_{Bn})$ and $\tilde{A}_W = (\tilde{a}_{1W}, \tilde{a}_{2W}, \ldots, \tilde{a}_{nW})$, respectively. It is obvious that $\tilde{a}_{BB} = \tilde{a}_{WW} = (1,1,1)$.

Step 3: Determine the optimal weights $\widetilde{w}_j^*$

By considering $\widetilde{w}_j = (l_j^w, m_j^w, u_j^w), \widetilde{a}_{Bj} = (l_{Bj}, m_{Bj}, u_{Bj}), \tilde{a}_{jW} = (l_{jW}, m_{jW}, u_{jW})$ and $\tilde{\xi}^* = (k^*, k^*, k^*)$, the non-linear optimization model expressed in Eq. 7 can determine the optimal weights $\widetilde{w}_j^*$ for $all\ 1 \leq j \leq n$, and $\tilde{\xi}^*$:

$$\min \tilde{\xi}^*$$
$$s.t. \begin{cases} \left| \frac{(l_B^w, m_B^w, u_B^w)}{(l_j^w, m_j^w, u_j^w)} - (l_{Bj}, m_{Bj}, u_{Bj}) \right| \leq (k^*, k^*, k^*) & \text{for all j} \\ \left| \frac{(l_j^w, m_j^w, u_j^w)}{(l_W^w, m_W^w, u_W^w)} - (l_{jW}, m_{jW}, u_{jW}) \right| \leq (k^*, k^*, k^*) & \text{for all j} \\ \sum_{j=1}^{n} R(\widetilde{w}_j) = 1 & \text{for all j} \\ l_j^w \leq m_j^w \leq u_j^w & \text{for all j} \\ l_j^w \geq 0 & \text{for all j} \end{cases} \tag{7}$$

Step 4: Check the Consistency Ratio (CR)

The previous step can generate the optimal weights, but there are still some doubts that the opinions received from the decision-maker may be inconsistent. So, the consistency of the given answers should be checked and $\tilde{\xi}^* = (k^*, k^*, k^*)$ plays a crucial role to decide whether the given answers are consistent or not. Table 4 shows the Consistency Index (CI) and the maximum possible value of k^* for each possible $\tilde{a}_{BW}$. The consistency ratio is obtained by $CR = {\xi^*}/_{\text{CI}}$ whatever CR is closer to zero, the results have higher consistency

Table 4. Consistency Index (CI) based on [14]

	(EI)	(WI)	(FI)	(VI)	(AI)
$\tilde{a}_{BW}$	(1, 1, 1)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(7/2, 4, 9/2)
CI	3.00	3.80	5.29	6.69	8.04

FANP

FANP is a branch of the MADM methods that calculates the weights of indicators according to their interrelationships. FANP method steps [15,16]:

1- Identifying the criteria, sub-criteria or research options: In this step, the factors and components of the research should be extracted through methods such as research literature or opinions and questions from experts. One of the techniques that can be used in this step is fuzzy Delphi.

2- Determining the relationships between factors and components: One of the steps of the FANP method is to obtain internal relations. This is achieved by a method such as fuzzy DEMATEL or collective opinions of experts.

3- Forming pairwise comparison tables and calculating weights: According to the network diagram of the research, we form pairwise comparison tables and obtain the weight of criteria and sub-criteria. Pair comparisons are completed based on the 9-phase fuzzy spectrum. The process is done so that the fuzzy pairwise comparisons are first given to the experts. After the merging process, the weights using one of the following weight calculation techniques are calculated.

- Chang Development Analysis
- Bakli's geometric mean
- Mikhailov's fuzzy preference method

4- Formation of the initial supermatrix: According to the weights obtained in the third step, the initial supermatrix of ANP is created. This supermatrix is the relative weight and was calculated in the third step.

5- Balanced supermatrix: In this step, we get the balanced supermatrix. The balanced supermatrix is obtained from the normalization of the primary supermatrix.

6- Marginal Supermatrix and the final weight of the criteria: From the weighted matrix's ability, the limit matrix is obtained, which is the final weight of the criteria and sub-criteria or research options.

FTOPSIS

One of the very well-known methods for ranking alternatives is the TOPSIS. This method is based on forming two vectors of Positive Ideal Solution (PIS), the solution with best values for all criteria, and Negative Ideal Solution (NIS), the solution with the worst values for all criteria [17]. The underlying assumption behind this method, which is close to the rationality of the human mind when it comes to selecting the best choice, is to opt for alternatives with the shortest distance from PIS while having the longest distance from NIS. Owing to the discussion about inherent imprecision and vagueness of human judgment, it would be appropriate to consider the fuzzy version of TOPSIS for ranking alternatives. Regarding the fuzziness of this method, FPIS and FNIS is used rather than PIS and NIS. The following steps summarise how this method works [18].

Step 1: Form the weighted normalised version of $\widetilde{DM}$

Assume that the arbitrary element $\tilde{x}_{ij}$ of $\widetilde{DM}$ can be represented as (l_{ij}, m_{ij}, u_{ij}). Let us define u_j^+ and l_j^- as $\max_i u_{ij}$ and $\min_i l_{ij}$ respectively. Now, it naturally comes to mind to normalise the element $\tilde{x}_{ij}$ by Eq. 3 as follows:

$$\tilde{n}_{ij} = \begin{cases} \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right) & \text{if criterion j is positive} \\ \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right) & \text{if criterion j is negative} \end{cases} \tag{8}$$

Finally, the normalised matrix $\tilde{N} = [\tilde{n}_{ij}]_{m\times n}$ is obtained. In order to consider the effect of weighting vector on this matrix, we need the weighted normalised version of $\widetilde{DM}$ denoted by $\tilde{S} = [\tilde{s}_{ij}]_{m\times n}$ with the definition of element $\tilde{s}_{ij}$ as follows:

$$\tilde{s}_{ij} = \tilde{w}_j \otimes \tilde{n}_{ij} \tag{9}$$

Step 2: Determine the FPIS and the FNIS

At this point, the alternative with the best value and the alternative with the worst value for each criterion j should be determined by sorting the triangular fuzzy numbers $\tilde{s}_{ij}$ in column j. This means that a type of comparison between two triangular fuzzy numbers is required. Fuzzy numbers are just partially ordered, and so they cannot be compared directly. One way to overcome this obstacle is to use a defuzzification method [9]. As discussed before, the COA version of BNP would satisfy this purpose. Therefore, $FPIS_j$ and $FNIS_j$ are determined by statements in Eq. 10 as follows:

$$FPIS_j = \tilde{s}_{ij} \ with \max_i\{BNP\ (\tilde{s}_j)\}\ , \qquad FNIS_j = \tilde{s}_{ij} \ with \min_i\{BNP\ (\tilde{s}_j)\} \tag{10}$$

Where $\tilde{s}_j$ denotes the j-th column of $\tilde{S}$. Now it is possible to form $FPIS$ and $FNIS$ sets by statements in Eq. 11:

$$FPIS = \{FPIS_j : 1 \le j \le n\} \quad , \quad FNIS = \{FNIS_j : 1 \le j \le n\} \tag{11}$$

Step 3: Calculate the relative closeness to the FPIS and the FNIS

By using modified geometrical distance introduced by Hsieh and Chen [19], the distance between particular alternative $i, FPIS$ and $FNIS$ can be calculated. Suppose that $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, then the modified geometrical distance between them is defined in Eq. 12:

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{4}[(l_1 - l_2)^2 + 2 \times (m_1 - m_2)^2 + (u_1 - u_2)^2]} \tag{12}$$

With this regard, the distances between alternative i and both $FPIS$ and $FNIS$ are defined by statements in Eq. 13:

$$d_i^+ = \sum_{j=1}^{j=n} d(\tilde{s}_{ij}, FPIS_j) \quad , \quad d_i^- = \sum_{j=1}^{j=n} d(\tilde{s}_{ij}, FNIS_j) \tag{13}$$

If the relative closeness of alternative i with respect to $FPIS$ and $FNIS$ is defined by Eq. 14, the rationale that discussed this method can entail the alternative with the greatest value of CC should be ranked as first and so on.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{14}$$

Hybrid method

In this section, we provide explanations and justifications about the proposed hybrid method. In this research, we aim at developing a comprehensive decision-making approach that simultaneously can find the interrelationships among indicators, calculate the weights of indicators, and rank the potential alternatives. In this way, FDEMATEL is known as one of the most powerful methods for determining the interrelationships among indicators, and we have applied this approach. On the other side, usually, the ANP/FANP method is employed to calculate the weights of indicators when there are interrelationships among them. Nonetheless, by increasing the number of the indicators, the number of pairwise comparison matrices of the mentioned method is increased, drastically. This drawback leads to an increase in the computing burden and a decrease in the reliability of results. Thus, we have employed the FBWM within the FANP, which leads to a decrease in the computing burden and an increase in the reliability of results. Eventually, to rank the potential alternatives, we have utilized the FTOPSIS method that is known as one of the effective decision-making methods for alternatives ranking. On the other hand, due to the imprecision/uncertainty of the business environment, decision-makers prefer to use the tools to cope with this uncertainty. In general, the main advantages of the developed approach are as follows:

(a) Identifying the interrelationships among indicators using FDEMATEL.

(b) Decreasing the cognitive burden while increasing the reliability of the results by employing FBWM within the framework of FANP.

(d) Using an effective ranking idea (i.e. considering the distance of each alternative to the ideal solution) using FTOPSIS.
(e) Investigating the problem under the fuzzy environment.

Implementation

This section is dedicated to presenting the computational results obtained from the implementation of the proposed framework. At first, we describe the attributes of the experts who help us for data gathering.

- Characteristic of the first expert team leader: A software engineer and full-stack Developer, skilled in Java, Hibernate and Programming. He is an Engineering professional focused on Information Technology.
- Characteristic of the second expert team leader: Experienced senior software developer with a demonstrated history of working in large-scale applications and enterprise-grade services. He is skilled in Java, Object-Oriented Programming (OOP).
- Characteristic of the third expert team leader: Experienced data and software engineer with a demonstrated history of working in the information technology and services industry, skilled in Web technologies, Python, Java, Spark, and Spring Framework.

FDEMATEL

At first, we apply the FDEMATEL method to determine the interrelationships among the criteria/sub-criteria. To do this, a questionnaire is distributed between three groups of experts. The average of opinions of three teams of experts for criteria based on linguistic values is given in Table 5. Also, the normalized fuzzy matrix and the total relation fuzzy matrix are given in Tables 6 and 7.

Table 5. The average of opinions of three teams of experts

Criteria \ Criteria	Cost	Time	Quality	Services
Cost	(0,0,0)	(1,1,1)	(1,1,1)	(1,1,1)
Time	(6.67,7.67,8.33)	(0,0,0)	(1,1,1)	(1,1,1)
Quality	(3.33,4.33,5.33)	(4.67,5.67,6.67)	(0,0,0)	(2,3,4)
Services	(5.33,6.33,7.33)	(5.33,6.67,7.33)	(2,3,4)	(0,0,0)

Table 6. The normalized fuzzy matrix

Criteria \ Criteria	Cost	Time	Quality	Services
Cost	(0,0,0)	(0.05,0.05,0.05)	(0.05,0.05,0.05)	(0.05,0.05,0.05)
Time	(0.36,0.41,0.45)	(0,0,0)	(0.05,0.05,0.05)	(0.05,0.05,0.05)
Quality	(0.18,0.23,0.29)	(0.25,0.3,0.36)	(0,0,0)	(0.11,0.16,0.21)
Services	(0.29,0.34,0.39)	(0.29,0.36,0.39)	(0.11,0.16,0.21)	(0,0,0)

Table 7. Fuzzy total relation matrix

Criteria \ Criteria	Cost	Time	Quality	Services
Cost	(0.07,0.09,0.11)	(0.09,0.11,0.12)	(0.07,0.08,0.08)	(0.07,0.08,0.08)
Time	(0.42,0.51,0.58)	(0.07,0.09,0.012)	(0.09,0.10,0.12)	(0.09,0.10,0.12)
Quality	(0.35,0.51,0.70)	(0.32,0.44,0.56)	(0.05,0.13,0.15)	(0.15,0.23,0.31)
Services	(0.46,0.63,0.81)	(0.37,0.50,0.61)	(0.16,0.24,0.32)	(0.06,0.10,0.15)

The crisp counterpart of the fuzzy total relation matrix based on Eq. 1 is as follows:

Table 8. The crisp total relation matrix

Criteria \ Criteria	Cost	Time	Quality	Services	*D*
Cost	0.08866	0.10867	0.07666	0.07666	0.35065
Time	0.50441	0.0945	0.10247	0.10247	0.80386
Quality	0.5153	0.44096	0.08996	0.2275	1.27373
Services	0.63524	0.49309	0.23851	0.10097	1.46781
R	1.74362	1.13723	0.5076	0.5076	

Finally, the causal diagram of the criteria is depicted in Fig. 3. As shown in this figure, time, quality, and service indicators affect the cost indicator. On the other side, quality, and service criteria affect the time criteria. Also, the time has an impact on the cost.

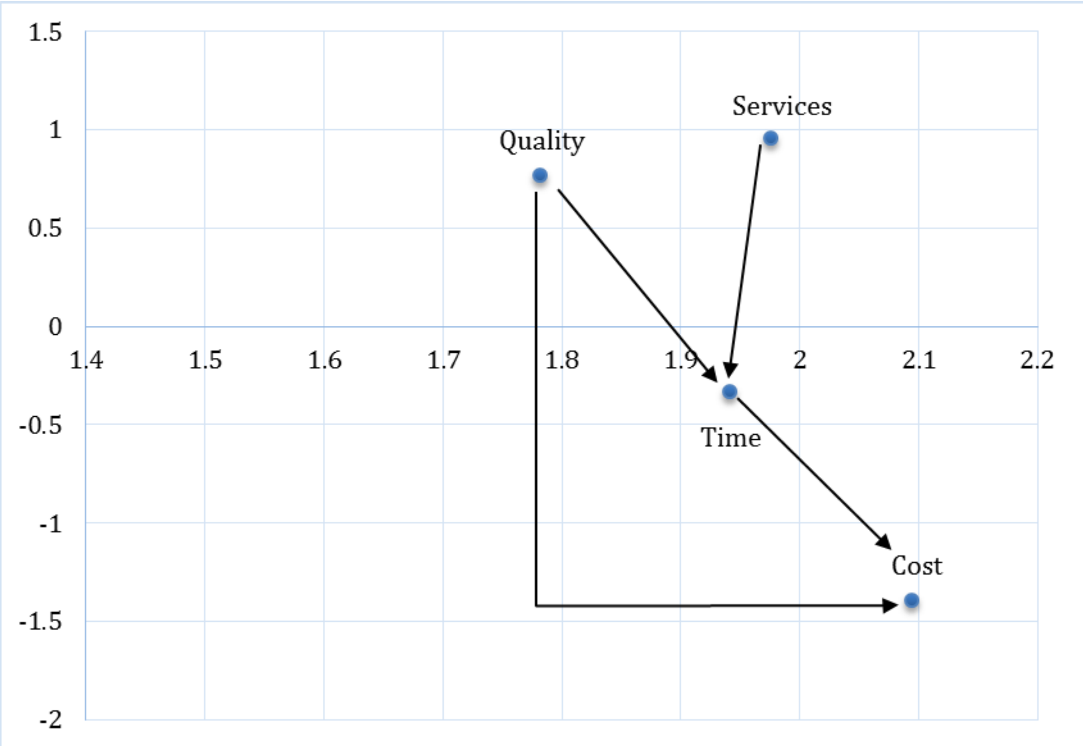


Fig 3. The causal diagram of criteria

By applying a similar method, the interrelationships between sub-criteria are derived as Table 9. It should be noted that "$a_{ij} = 1$" means that the sub-criteria *i* has a considerable effect on the sub-criteria *j*.

Finally, FDEMATEL is implemented for finding the best and the worst criteria and sub-criteria. Based on the results, among criteria, the cost is the best criteria (with D+R=1.893) and quality is the worst criteria (with D+R=1.568). By utilizing a similar manner, for each criterion, the best and the worst sub-criteria are given in Table 10.

Table 9. Interrelationships between sub-criteria

	Arrival T	Reach T	Vehicle Q	Driver Q	App Q	No. Cars	R price	Traffic region	F Travel	Discount	TM	Insurance	Woman driver	Advertisement
Arrival T	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Reach T	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Vehicle Q	1	1	0	0	0	0	1	0	0	0	0	0	0	0
Driver Q	1	1	0	0	0	0	1	0	0	0	0	0	0	0
App Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. Cars	1	0	0	0	0	0	1	0	0	0	0	0	0	0
R price	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Traffic region	0	0	0	0	0	0	1	0	0	0	0	0	0	0
F Travel	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discount	0	0	0	0	0	0	1	0	0	0	0	0	0	0
TM	1	1	0	0	0	0	1	0	0	0	0	0	0	0
Insurance	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Woman driver	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Advertisement	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Table 10. The best and the worst sub-criteria

Criteria	The best	The worst
Services	Transportation mode	Women driver
Cost	Reasonable price	Traffic region price
Quality	Vehicle quality	App. Quality
Time	Arrival time	Reach time

FBWM

In this section, the FBWM is applied to calculate the weights of the criteria/sub-criteria. The average of opinions of three groups of experts is given in Tables A.1-A.9 in Appendix A. The obtained results from solving the FBWM model using LINGO software are given in Tables 11-15.

Table 11. The results of FBWM for the criteria

Criteria	Services	Cost	Quality	Time
Optimal weights	0.1838209	0.4270383	0.1131517	0.2759890
	ξ^{*}=0.5191369 CI=8.04 → CR=$\frac{0.5191369}{8.04}=0.0645$			

Table 12. The results of FBWM for the sub-criteria of services

Criteria	Advertisement	Women driver	Insurance	TM
Optimal weights	0.2092153	0.9967375E-01	0.2665962	0.4245147
	ξ^{*}=0.5768200 CI=8.04 → CR=$\frac{0.5768200}{8.04}=0.0717$			

Table 13. The results of FBWM for the sub-criteria of cost

Criteria	Discount	Free travel	Reasonable price	Traffic region price
Optimal weights	0.1985230	0.1910574	0.4427545	0.1329386
	ξ^{*}= 0.6715728 CI=8.04 → CR=$\frac{0.6715728}{8.04}=0.0835$			

Table 14. The results of FBWM for the sub-criteria of quality

Criteria	No. cars	App. Quality	Driver quality	Vehicle quality
Optimal weights	0.2061219	0.1120466	0.2414275	0.4404041
ξ^{*}= 0.8017642 CI=8.04 → CR=$\frac{0.8017642}{8.04}$ = 0.099				

Table 15. The results of FBWM for the sub-criteria of time

Criteria	Reach time	Arrival time
Optimal weights	0.2517814	0.7482186
ξ^{*}= 0 CI=6.69 → CR=0		

FANP

In the previous step, the initial weights of the criteria/sub-criteria were calculated by the FBWM method. The final weights of the criteria/sub-criteria are calculated based on interrelationships among them applying the FANP method. The decision tree of the research problem in Super Decisions software is illustrated in Fig. B.1 in Appendix B. It should be noted that to enter the obtained results (weights) from the FBWM to SuperDecisions software, we utilize the "Misc → Direct data entry" toolbar in the pairwise comparison section (see Fig. 4), which allows us to enter the weight of criteria/sub-criteria, directly. Fig. 5 shows the results which are obtained by SuperDecisions. According to Fig. 5, Reasonable price is the most important sub-criteria and App. Quality is the least important sub-criteria for the passengers.

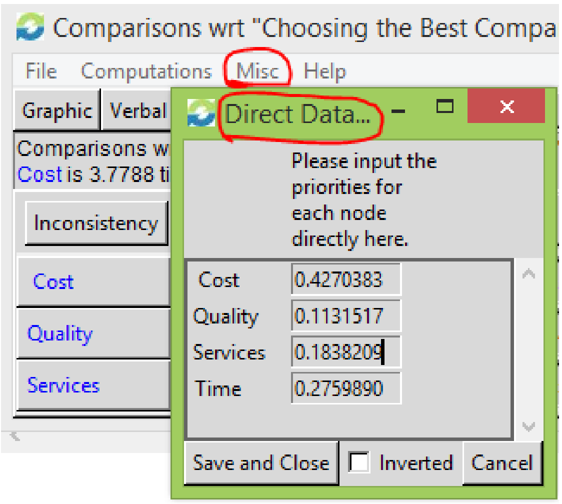
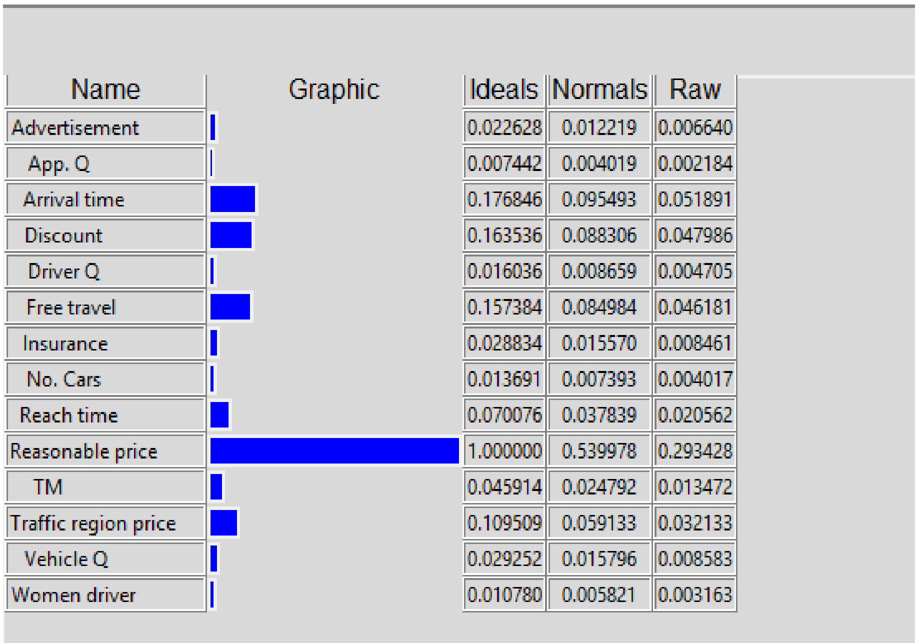


Fig. 4. Toolbar that was utilized to direct data entry



Name	Ideals	Normals	Raw
Advertisement	0.022628	0.012219	0.006640
App. Q	0.007442	0.004019	0.002184
Arrival time	0.176846	0.095493	0.051891
Discount	0.163536	0.088306	0.047986
Driver Q	0.016036	0.008659	0.004705
Free travel	0.157384	0.084984	0.046181
Insurance	0.028834	0.015570	0.008461
No. Cars	0.013691	0.007393	0.004017
Reach time	0.070076	0.037839	0.020562
Reasonable price	1.000000	0.539978	0.293428
TM	0.045914	0.024792	0.013472
Traffic region price	0.109509	0.059133	0.032133
Vehicle Q	0.029252	0.015796	0.008583
Women driver	0.010780	0.005821	0.003163

Fig. 5. The obtained results of SuperDecisions software

FTOPSIS

This section is dedicated to ranking the alternatives applying the FTOPSIS method. To form the decision matrix, the opinions of three teams of experts have been gathered based on the linguistic variables proposed by Chen et al. (2010), which is shown in Table 16. The decision matrix based on the linguistic variables is presented in Table 17, and the average fuzzy decision matrix is given in Table 18. In Table 17, in expression (a1, a2, a3), a1 denotes the first expert group opinion, a2 shows the second expert group opinion and a3 represents the third expert group opinion.

Table 16. Transformation of linguistic variables into triangular fuzzy numbers

Degree of importance	Equivalent triangular fuzzy number
Very Poor (VP)	(0, 0, 0.2)
Poor (P)	(0.05, 0.2, 0.35)
Medium Poor (MP)	(0.2, 0.35, 0.5)
Fair (F)	(0.35, 0.5, 0.65)
Medium Good (MG)	(0.5, 0.65, 0.8)
Good (G)	(0.65, 0.8, 0.95)
Very Good (VG)	(0.8, 1, 1)

Table 17. Decision matrix based on the linguistic variables

	A	B	C
Arrival time	(MP,P,MP)	(P,P,MP)	(MP,P,P)
Reach time	(MP,P,MP)	(P,P,MP)	(MP,P,P)
Vehicle Q	(G,G,MG)	(G,MG,MG)	(G,G,G)
Driver Q	(G,MG,MG)	(MG,F,F)	(G,MG,G)
App Q	(G,G,G)	(G,MG,G)	(MG,F,MG)
No. cars	(MG,MG,MG)	(G,G,G)	(MG,MG,MG)
Reasonable price	(MP,MP,F)	(MP,F,F)	(MP,F,F)
Traffic region price	(F,MP,F)	(MP,P,MP)	(F,MP,F)
Free travel	(MG,MG,MG)	(F,F,F)	(MG,MG,MG)
Discount	(F,MG,F)	(F,MG,F)	(MP,F,MP)
TM	(VG,G,G)	(G,MG,G)	(G,G,G)
Insurance	(G,G,G)	(MG,MG,MG)	(G,G,G)
Women driver	(G,MG,G)	(VG,VG,VG)	(F,F,MG)
Advertisement	(MG,F,MG)	(F,F,MG)	(MG,F,MG)

Table 18. The average of fuzzy decision matrix

	A	B	C
Arrival time	(0.15,0.3,0.45)	(0.1,0.25,0.4)	(0.1,0.25,0.4)
Reach time	(0.15,0.3,0.45)	(0.1,0.25,0.4)	(0.1,0.25,0.4)
Vehicle Q	(0.6,0.75,0.9)	(0.55,0.7,0.85)	(0.65,0.8,0.95)
Driver Q	(0.55,0.7,0.85)	(0.4,0.55,0.7)	(0.6,0.75,0.9)
App Q	(0.65,0.8,0.95)	(0.6,0.75,0.9)	(0.45,0.6,0.75)
No. cars	(0.5,0.65,0.8)	(0.65,0.8,0.95)	(0.5,0.65,0.8)
Reasonable price	(0.25,0.4,0.55)	(0.3,0.45,0.6)	(0.3,0.45,0.6)
Traffic region price	(0.3,0.45,0.6)	(0.15,0.3,0.45)	(0.3,0.45,0.6)
Free travel	(0.5,0.65,0.8)	(0.35,0.5,0.65)	(0.5,0.65,0.8)
Discount	(0.4,0.55,0.7)	(0.4,0.55,0.7)	(0.25,0.4,0.55)
TM	(0.7,0.867,0.967)	(0.6,0.75,0.9)	(0.65,0.8,0.95)
Insurance	(0.65,0.8,0.95)	(0.5,0.65,0.8)	(0.65,0.8,0.95)
Women driver	(0.6,0.75,0.9)	(0.8,1,1)	(0.4,0.55,0.7)
Advertisement	(0.45,0.6,0.75)	(0.4,0.55,0.7)	(0.45,0.6,0.75)

The obtained results from FTOPSIS are shown in Table 19.

Table 19. FTOPSIS results

Alternatives	d_i^+	d_i^-	CC_i	Normalized weight	Rank
A	0.4237651	0.3922181	0.4806694	0.3623511	#1
B	0.4561141	0.3578884	0.439665	0.3314401	#2
C	0.4784082	0.3272574	0.4061951	0.3062089	#3

Discussions and managerial insights

Determining the most appropriate online taxi company among several alternatives under multiple attributes is a complicated process. In this regard, providing a decision support model helps to address this issue. Hence, this research investigates selecting the best online-taxis business under the fuzzy environment. To do this, a comprehensive decision-making approach based on the FDEMATEL, FBWM, FANP, and FTOPSIS methods was developed offering several advantages discussed in Section 3.5.

In terms of managerial insights, this study provides an excellent perspective to the managers for selecting the leading indicators of the e-taxi business. This research has generated a suitable list of indicators, including four criteria and 14 sub-criteria. These criteria, along with their definitions, can help managers to be better acquainted with the main aspects of the e-taxi business environment. The weights obtained for the criteria can also serve as a pointer for managers to set their priorities in the e-taxi business area. In addition, a practical integrated model has been developed to evaluate and rank available alternatives. By applying this model, managers can identify and select alternatives that have better performance than others.

Also, according to the results of the research, four criteria (reasonable price, arrival time, discount and free travel) are the most effective sub-criteria in the use of Internet taxis by passengers, so it is better to explain how to improve these factors in companies.

1- Reasonable price:

This criterion ranks first in influencing customer choice so that in a company, they can set the reasonable price by calculating the total cost and then multiply it by the percentage of profit margin and then adding the amount to our expenses. Also, the costs and the percentage of profit margin should be considered fairly. In this way, they can offer a reasonable price for their service. On the other side, companies should consider this point that by decreasing the price, the demand for their taxis is increased that leads to increased profit.

2- Time to arrive:

This criterion is at the second rate. Naturally, when the driver arrives, the quality function of the routing system is used. In this regard, Internet taxi companies should make a plan for improving the arrival times. For example, they can negotiate with the relevant organizations to obtain permission to use notable routes that can drastically decrease the arrival time.

3- Discount and Free travel:

Discount and Free travel criteria were ranked as third and fourth, respectively. One of the policies that any company that wants to strengthen itself in terms of marketing is the policy of offering discount packages to its customers. One of the most common discount offers is offering free travel to the customer. At first glance, giving discounts might not be an economic strategy. However, it leads to an increase in customer satisfaction which in turn increases the customers' loyalty and increases the profits in the long term.

On the other hand, although some sub-criteria have more weights and better ranks, managers of the online-taxis business should not forget other sub-criteria, especially those that affect the top criteria. For example, a reasonable price is the most critical sub-criteria, while it is affected by some low-weighted factors like insurance and driver quality. Hence, the lack of attention to influencing factors (the sub-criteria that affect the other ones) can lead to the company's loss of competitive advantage. This study has obtained the interrelationships among criteria/sub-criteria that can help managers to make better decisions.

Conclusions

Nowadays, e-businesses are rising drastically. One of the essential businesses that have attracted enormous interest is online taxis. This study investigates the online taxis business by developing a hybrid fuzzy approach based on the FDEMATEL, FBWM, FANP, and FTOPSIS methods. In this way, the related criteria and sub-criteria are determined based on the literature review and expert opinions. Then, we employed FDEMATEL to identify the interrelationships between criteria and sub-criteria. Afterwards, a combination of FBWM and FANP methods is applied to obtain the global weights of criteria/sub-criteria. Finally, the potential alternatives are ranked using the FTOPSIS method. The proposed approach has several advantages such as determining the interrelationships among indicators, reducing computing burden, increasing the reliability of the results, and consideration of distances to an ideal solution, simultaneously. Based on the obtained results, time, quality, and service criteria have affected the cost indicator. Also, the quality has affected the time service, and time has affected the cost criteria. On the other side, results showed that cost and quality are the most and least important criteria, respectively. Also, reasonable price, arrival time, discount, and free travel are the most critical sub-criteria in the research problem. It should be noted that the consistency ratio for all the results is less than 0.1 that indicates the reliability and validity of the obtained results. Future research can combine artificial intelligence and decision-making methods to study the research problem and compare the results with the hybrid approach developed in this paper.

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Appendices

A. Average of expert opinions for FBWM method

Table A.1. Pairwise comparisons for the best criterion according to the experts’ opinions

Expert	Criteria	Services	Cost	Quality	Time
1	Cost (Best criterion)	(2.5,3,3.5)	(1,1,1)	(3.5,4,4.5)	(1.5,2,2.5)
2		(1.5,2,2.5)	(1,1,1)	(3.5,4,4.5)	(0.6667,1,1.5)
3		(2.5,3,3.5)	(1,1,1)	(3.5,4,4.5)	(1.5,2,2.5)
Average		(2.17,2.67,3.17)	(1,1,1)	(3.5,4,4.5)	(1.5,1.67,2.17)

Table A.2. Pairwise comparisons for the worst criterion according to the experts’ opinions

	Quality (Worst criterion)			
Expert / Criteria	1	2	3	Average
Services	(0.6667,1,1.5)	(1.5,2,2.5)	(0.6667,1,1.5)	(0.94,1.33,1.83)
Cost	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)
Quality	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Time	(2.5,3.3.5)	(2.5,3.3.5)	(2.5,3.3.5)	(2.5,3,3.5)

Table A.3. Pairwise comparisons for the best sub-criteria of services according to the experts’ opinions

Expert	Criteria	Advertisement	Women driver	Insurance	TM
1	TM (Best criterion)	(1.5,2,2.5)	(3.5,4,4.5)	(1.5,2,2.5)	(1,1,1)
2		(1.5,2,2.5)	(3.5,4,4.5)	(0.6667,1,1.5)	(1,1,1)
3		(2.5,3,3.5)	(3.5,4,4.5)	(1.5,2,2.5)	(1,1,1)
Average		(1.83,2.33,2.83)	(3.5,4,4.5)	(1.22,1.67,2.17)	(1,1,1)

Table A.4. Pairwise comparisons for the worst sub-criteria of services according to the experts' opinions

	Women driver (Worst criterion)			
Expert / Criteria	1	2	3	Average
Advertisement	(1.5,2,2.5)	(2.5,3,3.5)	(1.5,2,2.5)	(1.83,2.33,2.83)
Women driver	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Insurance	(2.5,3,3.5)	(1.5,2,2.5)	(2.5,3,3.5)	(2.17,2.67,3.17)
TM	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)

Table A.5. Pairwise comparisons for the best sub-criteria of cost according to the experts' opinions

Expert	Criteria	Discount	Free travel	Reasonable price	Traffic region price
1	**Reasonable price (Best criterion)**	(2.5,3,3.5)	(2.5,3,3.5)	(1,1,1)	(3.5,4,4.5)
2		(2.5,3,3.5)	(2.5,3,3.5)	(1,1,1)	(3.5,4,4.5)
3		(2.5,3,3.5)	(2.5,3,3.5)	(1,1,1)	(3.5,4,4.5)
Average		(2.5,3,3.5)	(2.5,3,3.5)	(1,1,1)	(3.5,4,4.5)

Table A.6. Pairwise comparisons for the worst sub-criteria of cost according to the experts' opinions

	Traffic region price (Worst criterion)			
Expert / Criteria	1	2	3	Average
Discount	(1.5,2,2.5)	(1.5,2,2.5)	(1.5,2,2.5)	(1.5,2,2.5)
Free travel	(1.5,2,2.5)	(1.5,2,2.5)	(1.5,2,2.5)	(1.5,2,2.5)
Reasonable price	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)
Traffic region price	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)

Table A.7. Pairwise comparisons for the best sub-criteria of quality according to the experts' opinions

Expert	Criteria	No. cars	App. Quality	Driver quality	Vehicle quality
1	**Vehicle quality (Best criterion)**	(2.5,3,3.5)	(3.5,4,4.5)	(1.5,2,2.5)	(1,1,1)
2		(2.5,3,3.5)	(3.5,4,4.5)	(1.5,2,2.5)	(1,1,1)
3		(2.5,3,3.5)	(3.5,4,4.5)	(2.5,3,3.5)	(1,1,1)
Average		(2.5,3,3.5)	(3.5,4,4.5)	(1.83,2.33,2.83)	(1,1,1)

Table A.8. Pairwise comparisons for the worst sub-criteria of quality according to the experts' opinions

	App. Quality (Worst criterion)			
Expert / Criteria	1	2	3	Average
No. cars	(1.5,2,2.5)	(2.5,3,3.5)	(1.5,2,2.5)	(1.83,2.33,2.83)
App. Quality	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Driver quality	(2.5,3,3.5)	(2.5,3,3.5)	(2.5,3,3.5)	(2.5,3,3.5)
Vehicle quality	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)	(3.5,4,4.5)

Table A.9. Pairwise comparisons for the worst sub-criteria of time according to the experts' opinions

Expert	Criteria	Reach time	Arrival time
1	**Arrival time (Best criterion)**	(2.5,3,3.5)	(1,1,1)
2		(2.5,3,3.5)	(1,1,1)
3		(2.5,3,3.5)	(1,1,1)
Average		(2.5,3,3.5)	(1,1,1)

B. Decision tree of the research problem in Super Decisions software

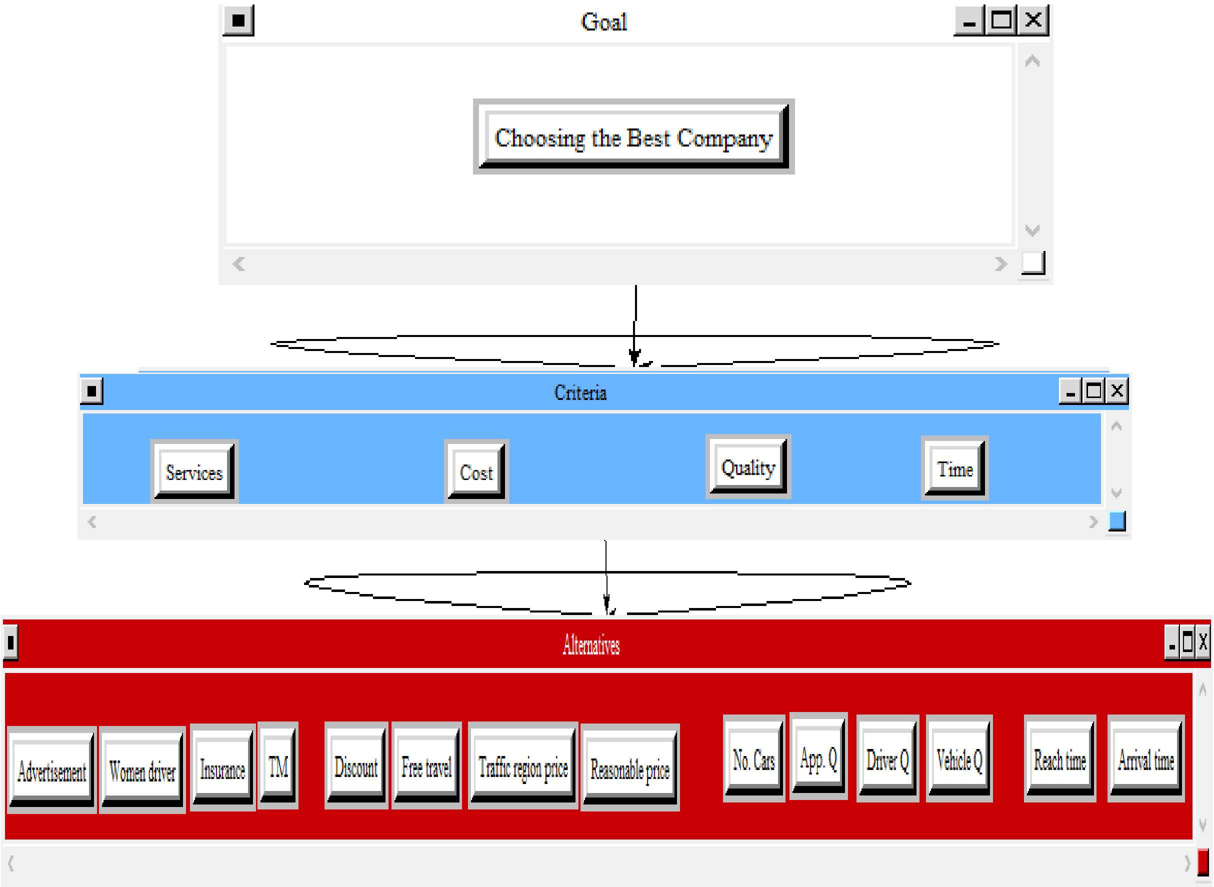

Fig. B.1. Decision tree in SuperDecisions software