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Proposing a new methodology for prioritising the investment strategies in the private sector of Iran

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This article proposes a systematic and organised approach for group decision-making in the presence of the uncertainty involved in expert judgments as used in multi-criteria decision-making (MCDM) issues. This procedure comprises the selection of the optimum alternative with respect to the evaluation criteria under consideration, in particular to select the strategy of investing. However, the selection of the investment strategy is difficult on account of considering the numerous quantitative and qualitative parameters like benefits, opportunities, costs, and risks. However, it is possible that these parameters have a significant influence on each other. A decision-making trial and evaluation laboratory (DEMATEL), used to define the influential network of elements, can be employed to construct a network relationship map (NRM). On the other hand, according to whether the information is incomplete or unavailable, uncertainty is an inseparable part of making decision for solving the MCDM problems. Therefore, this article proposes a new hybrid model based on analytic hierarchical process (AHP), DEMATEL, and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) techniques under fuzzy environment to evaluate the problem of the selection of the investment strategy. To achieve the aim, a three-step process is presented to solve a sophisticated problem. First, the AHP method is employed to break down the investment problem into simple structure and calculate the importance weights of criteria by using a pairwise comparison process. Second, the DEMATEL technique is applied for considering interdependence and dependencies and computing the global weights of benefit, opportunities, cost, and risk (BOCR) factors. Finally, the fuzzy TOPSIS methodology is used for prioritising the possible alternatives. To demonstrate the potential application of the proposed model, a numerical example is illustrated and investigated. The results show that the proposed model has a high ability to prioritise the strategies of investing.

Keywords: investment strategy; multi-criteria decision-making (MCDM); decision-making trial and evaluation laboratory (DEMATEL); fuzzy logic; technique for order of preference by similarity to ideal solution (TOPSIS)

JEL classification: O16, C44, C51, D81

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1. Introduction

The increasing process of globalisation and the changing market are the main factors determining the importance of effective development, management and purchasing of commercial property as well as investment activities associated with these objects (Zavadskas Ustinovichius & Stasiulionis, 2004). In the last few decades, coinciding with a widespread move to globalisation and market-oriented strategies, a large number of countries provided comprehensive programmes to make a reliable environment for private investment. A clear consensus seems to have emerged on the positive effect of aggregate investment (public and private) on economic growth, both in developing and developed economies (Munthali, 2012).

A study conducted by the World Bank shows significant differences in the shares of private and public investment in national outputs of high, medium and low-income countries (World Bank, 2006). This study shows that there is a positive correlation between growth of national incomes and private investment ratios (Munthali, 2012). Beyond this, the various studies of cross-country equations show that private investment has a higher positive effect on economic growth in comparison with public investment (Erden, 2002). Therefore, according to the critical role of private investment, governors facilitate the flow of private capital by producing a climate of constancy and certainty for investment and business activity.

According to the key importance of investing, different models are developed to provide investors with enough information for making investment decisions. These methods can be grouped into two main classes including real options and traditional valuation methods. However, the traditional valuation models employing discounted cash flows (DCF) do not take into account some of the intrinsic attributes of the asset or investment opportunity (Mun, 2002). Based on the basic concepts of the DCF models, the expected value of cash flows comprises the unknown future cash flows (Uçal & Kahraman, 2009). These models use a discounting process based on the opportunity cost of capital to transfer the equity of an investment into a present value. However, the DCF techniques cannot properly handle the operating flexibility and strategic value aspects of various investments on account of their discretionary asymmetric nature and their dependence on future events that are uncertain at the time of the initial decision (Trigeorgis, 1996).

On the other hand, real options have a number of shortcomings. The main disadvantages of real options is its reliance on quantitative data and on the existence of a portfolio capable of replicating the cash flows associated with a given strategic decision, which can be very difficult to compute[1]. Likewise, this technique is less of a standard to guide future operations and the assumptions may be hidden, preventing management from effectively evaluating the assumption (Pengfei & Yimin, 2000).

However, the process of the investment strategy selection comprises an exhaustive analysis of different aspects of the parameters influencing the investment. This process, a challenging decision-making problem, is a critical and key procedure for the investors to obtain helpful knowledge on the resources of the investment to select the optimum resource of investment because they continually follow maximum benefit and minimum cost. Beyond the points mentioned, investors who can expand their imaginations to see a wider range of possible futures will be much better positioned to take advantage of the unexpected opportunities that will come along.

Moreover, investment decisions are complex and not taken as frequently as other decisions, precluding the formation of rules-of-thumb (Azzoni & Kalatzis, 2010); so that investors are always faced with a sophisticated problem and they should select the most appropriate option for investment among a pool of alternatives. On the other hand, the multi-criteria decision-making (MCDM) techniques are capable of modelling complex and sophisticated systems.

Technique for order of preference by similarity to ideal dolution (TOPSIS), one of the most popular methods of the MCDM techniques, is capable of prioritising alternatives with respect to the criteria under consideration. This technique is recently employed by different research to model the MCDM problems (Azimi, Yazdani-Chamzini, Fouladgar, Zavadskas, & Basiri, 2011; Balezentis, Balezentis, & Misiunas, 2012; Ghorabi & Attari, 2013; Kalibatas, Zavadskas, & Kalibatiene, 2011; Ramezani, Bashiri, & Atkinson, 2011; Sadeghzadeh & Salehi, 2011; Staniūnas, Medineckienė, Zavadskas, & Kalibatas, 2013; Zolfani & Antucheviciene, 2012; Zolfani, Rezaeiniya, & Saparauskas, 2012). This technique is widely applied by a large number of studies for the following reasons (Dadelo, Turskis, Zavadskas, & Dadeliene, 2013; Ginevičius, Podvezko, Novotny, & Komka, 2012; Lashgari, Fouladgar, Yazdani-Chamzini, & Skibniewski, 2011; Palevicius, Paliulis, Venckauskaite, & Vengrys, 2013; Simanaviciene, Liaudanskiene, & Ustinovichius 2012; Tamosaitiene, Sipalis, Banaitis, & Gaudutis, 2013; Streimikiene & Balezentiene, 2012; Streimikiene, 2013; Yazdani-Chamzini & Yakhchali, 2012; Yazdani-Chamzini, Fouladgar, Zavadskas, & Haji Moini, 2013; Zavadskas, Turskis, Volvaciovas, & Kildiene 2013; Zavadskas, Susinskas, Daniunas, Turskis, & Sivilevicius, 2012): (1) TOPSIS logic is rational and understandable; (2) the computation processes are straightforward; and (3) the concept permits the pursuit of best alternatives for each criterion depicted in a simple mathematical form.

As previously mentioned, the investment problems are sophisticated and require sufficient amounts of information to find the solution to the problem. A problem associated with this type of evaluation is that it is difficult to specify exact numerical estimates, especially when criteria are qualitative (Sotirov & Krasteva, 1994). In many situations, this information may be immeasurable and ill-defined that leads to the necessity of using expert judgments. In order to reflect the qualitative character of the information, the data are linguistically expressed. Much of the theoretical work on uncertainty and investment has been developed in the framework of risk-neutrality (Okoli et al., 2007). Therefore, it is necessary to develop new models to accurately prioritise and select the strategies of the private investment. Fuzzy logic is a powerful tool to handle the inherent uncertainty and complexity involved in real world problems. The combination of fuzzy logic and TOPSIS, called fuzzy TOPSIS, can take into account all aspects of a decision-making problem and can improve the results of the decision analysis (Büyüközkan & Çifçi, 2012).

However, the main weakness of the fuzzy TOPSIS technique is to assume that the criteria are independence. Whereas, the evaluation criteria are usually interdependence and indirect. Therefore, using the robust techniques taking into account the mutual relationships between criteria can be useful and the results will be more accurate. The Decision-Making Trial and Evaluation Laboratory (DEMATEL), a robust technique in formulating the sophisticated structures, can model the interdependence relations within a set of criteria under consideration. This method can provide a visual structural model by converting the relationships between cause and effect of the evaluation criteria (Gabus & Fontela, 1972, 1973; Fontela & Gabus, 1976). This helps authorities to formulate the complex relationship into weights of relationship.

On the other hand, in the case of complex problems, it is usually better to use opinions of a group of experts because it is difficult for a single person to possess knowledge and experience in all details of the problem (Sotirov & Krasteva, 1994).

Analytic hierarchy process (AHP) is an appropriate technique for calculating the importance weights of the criteria. This technique is widely applied by different researchers to analyse a wide spectrum of engineering and management problems. The main reasons for using an AHP-based decision analysis approach are (Fouladgar, Yazdani-Chamzini, Zavadskas, Yakhchali, & Ghasempourabadi, 2012d): (1) AHP can measure all tangible and intangible criteria in the model; (2) AHP is a relatively simple, intuitive approach that can be accepted by managers and other decision-makers; (3) AHP allows for more complex relationship among the decision levels and attributes by deconstructing the problem into a hierarchical structure; and (4) AHP employs a two-by-two comparison process to conveniently model a complex problem.

On the other hand, solving a sophisticated problem in the framework of benefit, opportunity, cost, and risk (BOCR) factors is a structured and organised methodology that has been successfully employed in many different fields (Bobylev, 2011; Chen, Lee, & Kang, 2010; Yazgan, Boran, & Goztepe, 2010; Lee, Chen, & Kang, 2011). However, taking into account the aspects of the BOCR of an alternative, including the positive and negative criteria all together, helps decision-makers to fulfil a more comprehensive way in real world problems (Fouladgar, Yazdani-Chamzini, Zavadskas, & Haji Moini, 2012a).

Since the AHP, DEMATEL, and fuzzy TOPSIS techniques have a large number of advantages, this study applies a robust model based on an integrated AHP, DEMATEL, and fuzzy TOPSIS methodology to help authorities to model the complex and multi-criteria problems in order to make an appropriate decision with regard to the evaluation criteria under consideration. Therefore, there are four main advantages to propose this methodology: (1) all types of the relationships including interdependence and independence among criteria can be taken into account and the problem of ranking is completely logical; (2) the process applied for modelling the problem is simple and straightforward; (3) the proposed model employs an easy mathematical form instead of the conventional complex forms like analytic network process (ANP) to solve the problem of decision-making; and (4) the interdependence relationship weights are incorporated into the comparison processes.

The main aim of this article is to propose a new integrated approach based on AHP, DEMATEL, and TOPSIS under fuzzy environment to provide a powerful framework for prioritising the investment strategies in the private sector of Iran. The proposed approach incorporates mutual relationship into decision-making process. This technique can help authorities to accurately make decisions. To validate the proposed model, a real case study is illustrated and the conclusions derived from the model are illustrated.

The article is organised as follows. Section 2 presents a brief overview of the AHP methodology. Section 3 explains the process of modelling the DEMATEL technique. Section 4 explains the basic concepts of fuzzy logic and goes one step beyond and examines the steps of the TOPSIS technique under fuzzy environment. The proposed model is clearly presented in section 5. An application of the proposed model is illustrated in section 6. Finally, conclusions are discussed in the last section.

2. Analytic hierarchy process

AHP, first introduced by Saaty (1980), is an effective and robust technique to model the sophisticated decision problems. This method solves a complex problem by deconstructing it into several simple sub-problems by using the hierarchical levels, in which the goal is situated in the top level, the second and third levels contain of main and sub-criteria, respectively, the feasible alternatives are located in the last level. The AHP method is a multi-criteria method of analysis based on an additive weighting process, in which several relevant attributes are represented through their relative importance (Chou, Sun, & Yen, 2012). This technique uses a process of pair-wise comparisons to obtain the relative importance of the attributes, in which the importance of the attributes is acquired by a two-by-two comparison that are quantified using 1–9 scales given in Table 1. Three principal concepts of the AHP method are (Lashgari, Yazdani–Chamzini, Fouladgar, Zavadskas, Shafiee, & Abbate, 2012): (1) defining the analytical hierarchy process; (2) determining priorities; and (3) the logical consistency of the assumptions.

The inconsistency rate of the AHP model is determined by adopting the following steps:

Step 1: The weighted sum vector (*WSV*) should be analysed by multiplying a paired comparison matrix by the relative weight vector:

$$WSV = D \times W \tag{1}$$

Step 2: The Consistency Vector (*CV*) should be analysed by dividing the elements of the WSV by the relative weights vector.

Step 3: Determining the maximum eigenvector of pair-wise comparison matrix($\lambda_{\max}$). For achieving this aim, it is needed to determine the average of the CV factors.

Step 4: Determining the second Inconsistency Index (*II*) using following equation:

$$II = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

where n is the number of comparisons.

Step 5: Determining the consistency rate (*CR*) from the following equation:

$$IR = \frac{II}{RCI} \tag{3}$$

*RCI*is a random consistency index which is derived from Table 2. This table is based on the simulations that Saaty (1980) provided with the average consistencies (*RCI*values) of randomly generated matrices (up to size 11 × 11) for a sample size of 500.

When the consistency rate is smaller or equal to 0.1, pair-wise comparisons are consistent and the process can be continued; otherwise, the decision-maker should reconsider pair-wise comparisons.

3. Decision-Making Trial and Evaluation Laboratory

The DEMATEL technique was first developed by Gabus and Fontela (1972) to formulate the interdependent relationships among the evaluation criteria and the strength of

Table 1. Pair-wise comparison scale and example (Saaty, 1980).

Intensity	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values
Reciprocals	Reciprocals for inverse comparison.

Source: Author’s calculations.

Table 2. Random consistency index table.

n	1	2	3	4	5	6	7	8	9	10
RCI	1.51	1.45	1.41	1.32	1.24	1.12	0.9	0.58	0	0

Source: Author's calculations.

interdependence. Visualising the structure of complicated causal relationships with matrices or digraphs is useful and valuable for decision-makers (Tseng, 2011). These digraphs or matrices depict the relations among the elements of the decision matrix through a number representing the strength of influence.

According to the unique capabilities of the DEMATEL method, it has been widely employed in a spread spectrum of applications like e-learning (Tzeng, Chiang, & Li, 2007), knowledge management (Wu, 2008), service quality (Tseng, 2009), portfolio selection (Ho, Tsai, Tzeng, & Fang, 2011), model development (Tsai & Hsu, 2010), web-advertising (Wei, Huang, Tzeng, & Wu, 2010), risk evaluation (Chang & Cheng, 2011; Yang, Shieh, & Tzeng, 2013), manufacturing & logistics systems (Tzeng & Huang, 2012), intersection safety factors (Zhou, Sun, Li, & Yang, 2013), and urban regeneration project (Liao, Ye, Fu, & Ma, 2012). The merit of using the DEMATEL technique is to model a system including a set of criteria $C = \{C_1, C_2, \ldots, C_n\}$and the certain relations by a mathematical formula. The DEMATEL technique can be defined as follows:

Step 1: Determine the direct-influence matrix by scores. The evaluator team is required to indicate the degree of direct influence that factor i will have on factor j as indicated bya_{ij}. It is supposed that the comparison scales, 0, 1, 2, 3 and 4, stand for five levels including no influence, very low influence, low influence, medium influence, high influence, and very high influence, respectively. From any group of direct matrices of evaluators, an average matrix $A = [a_{ij}]_{n\times n}$can be derived, in which each element being the mean of the same elements in the various direct matrices of the evaluators (Hsu, Wang, & Tzeng, 2012). The average matrix A for all expert opinions by averaging the H experts' scores can be computed as follows:

$$A.a_{ij} = \frac{1}{H}\sum_{k=1}^{H} x_{ij}^{k} \tag{4}$$

Therefore, an initial direct-influence matrix is resulted from the result of this comparison. The initial direct-influence matrix A is an $n \times n$ matrix, where $a_{ij}$is denoted as the degree to which the ith criterion affects the jth criterion. The average matrix A is shown by the following equation:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \tag{5}$$

Step 2: Calculate the normalised direct-influence matrix$S$. The normalised direct-influence matrix is obtained by standardising the matrix$A$ through Equations (6) and (7):

$$S = m \cdot A \tag{6}$$

$$m = \min\left[\frac{1}{\max\limits_{i}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\limits_{j}\sum_{i=1}^{n}|a_{ij}|}\right] \tag{7}$$

Step 3: Measure the total-influence matrix T. After calculating the normalised direct-influence matrix, The network relationship map (NRM) can be obtained by using Equation (8), in which I denotes the identity matrix; i.e. a continuous decrease of the indirect effects of problems along the powers of$X$, e.g. $X^2, X^3, \cdots, X^q$and $\lim\limits_{q\to\infty} X^q = [0]_{n\times n}$, where $X = [x_{ij}]_{n\times n}$, $0 \leqslant x_{ij} \leqslant 1$, $0 < \sum_{j=1}^{n} x_{ij} \leqslant 1$and $0 < \sum_{i=1}^{n} x_{ij} \leqslant 1$. If at least one row or column of summation is equal to 1, but not all, then $\lim\limits_{q\to\infty} X^q = [0]_{n\times n}$(Hung, Chou, & Tzeng, 2011). The total-influence matrix can be defined as presented in the following formula:

$$\begin{aligned} T &= X + X^2 + \cdots + X^q = X(I + X + X^2 + \cdots + X^{q-1})(I - X)(I - X)^{-1} \\ &= X(I - X^q)(I - X)^{-1} \end{aligned} \tag{8}$$

when $q \to \infty$, $X^q = [0]_{n\times n}$, then

$$(T = X(I - X)^{-1})$$

where $T = [t_{ij}]_{n\times n}$, $i,j = 1, 2, \cdots, n$.

Step 4: Compute the values of influence and relation. In this step, the NRM is constructed based on the vectors r and s representing the sums of rows and columns respectively. These vectors are described as Equations (9) and (10).

$$r = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{9}$$

$$s = [s_j]_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} \tag{10}$$

where $r_i$denote the sum of the ith row and the sum of the jth column in matrix T, respectively. r_i displays the sum of direct and indirect effects of criterion $j$on another criteria. As well as, $\%r_i + s_i i$ effects that criterion j has received from another criteria. Levels of influence on others and the strength of the central role that factor $r_i + s_i$ plays in the problem are calculated with the help of the values of and. If is positive, it shows that other factors are influenced by factor $r_i - s_i$(Ho, Tsai, Tzeng, & Fang, 2011). Vice versa, if $r_i - s_i$ is negative, factor is influenced by other factors. The value of indicates the strength of the central role; so that, the criteria having higher values of have stronger relationships with other criteria, while those having lower values of $r_i + s_i$ have less of a relationship with others (Tsai, Chou, & Lai, 2010). Therefore, the NRM can be established and a causal graph can be obtained by mapping the data-set. This helps authorities to make a decision more correctly, surely, and reliably.

4. Fuzzy TOPSIS

4.1. *Fuzzy set theory*

Fuzzy set theory was developed by Zadeh (1965) to take into account the inherent uncertainty and complexity involved in process of modelling a real world problem.

Fuzzy theory enables decision-makers to simply formulate a sophisticated problem by using the linguistic terms instead of precise and strict values. Fuzzy sets are defined by membership function, which shows the grade of belongings to the set under consideration. If an element x fully belongs to a set, $\mu_A(x) = 1$, and if an element x does not belong to the set under consideration, $\mu_A(x) = 0$ (Yazdani-Chamzini & Yakhchali, 2012). The higher is the membership value, the greater is the belongingness of an elementxto the set A.

A fuzzy number Ãcan be shown as $\tilde{A} = (a, b, c)$ that Ã is defined as a triangular fuzzy number (TFN). Where a, b, and c are crisp numbers and $a \geqslant b \geqslant c$, so that; a and c represent fuzzy probabilities between the lower and upper boundaries of evaluation information.

If assume two TFNs $\tilde{A} = (a_1, b_1, c_1)$, $\tilde{B} = (a_2, b_2, c_2)$.then mathematical operations can be defined as given in the following:

$$\tilde{A} \oplus \tilde{B} = (a_1, b_1, c_1) \oplus (a_2, b_2, c_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2 \tag{11}$$

$$\begin{aligned} \tilde{A} \otimes \tilde{B} &= (a_1, b_1, c_1) \otimes (a_2, b_2, c_2) \\ &= (a_1 a_2, b_1 b_2, c_1 c_2) \text{ for } a_1, a_2 > 0; b_1, b_2 > 0; c_1, c_2 > 0 \end{aligned} \tag{12}$$

$$\tilde{A} - \tilde{B} = (a_1, b_1, c_1) - (a_2, b_2, c_2) = (a_1 - c_2, b_1 - b_2, c_1 - a_2 \tag{13}$$

$$\tilde{A} \div \tilde{B} = (a_1, b_1, c_1) \div (a_2, b_2, c_2) = (a_1/c_2, b_1/b_2, c_1/a_2) \tag{14}$$

$$\tilde{A}^{-1} = (a_1, b_1, c_1)^{-1} = (1/c_1, 1/b_1, 1/a_1) \text{ for } a_1 > 0; b_1 > 0; c_1 > 0 \tag{15}$$

The vertex method to calculate the distance between $\tilde{A}$, $\tilde{B}$ is defined as follows:

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2) + (c_1 - c_2)]} \tag{16}$$

4.2. Fuzzy linguistic variable

The fuzzy linguistic variable is a variable that whose values are words or sentences in a natural language (Fouladgar, Yazdani-Chamzini, & Zavadskas, 2012b). It helps experts to evaluate the importance of the criteria and to rate the alternatives with respect to various criteria. These variables can be defined as different linguistic values. A 5-point scale for defining the rating of alternatives is deliberately adopted as presented in Table 3 and Figure 1.

Table 3. Membership function of linguistic scale.

Linguistic value	Fuzzy number
Very poor (VP)	(0.0,1.0,2.5)
Poor (P)	(1.5,3.0,4.5)
Fair (F)	(3.5,5.0,6.5)
Good (G)	(5.5,7.0,8.5)
Very good (VG)	(7.5,9.0,10)

Source: Author's calculations.

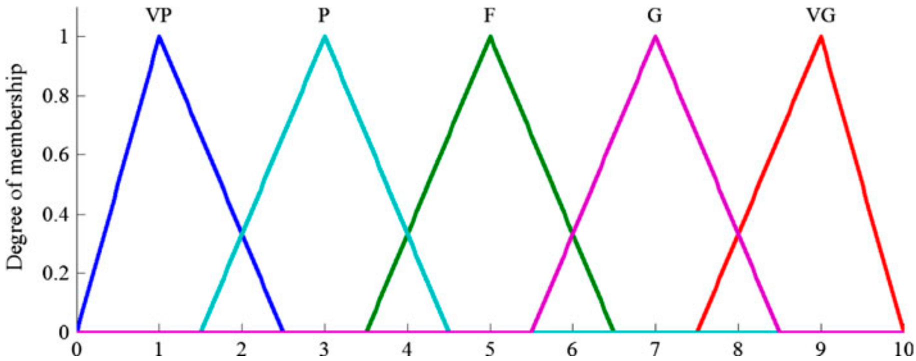

Figure 1. Linguistic variables for preference rating of each alternative.
Source: Author's calculations.

4.3. Fuzzy TOPSIS methodology

The problem of selecting plays a significant role in the process of decision-making. According to the importance of selecting, a number of techniques are developed to evaluate and select the best alternative among a pool of alternatives. These techniques can be grouped into several main methods, including expert systems, Delphi decision-making process, paired comparison, grid analysis, influence diagram, pro/con approach, decision tree, game theory, cost/benefit analysis, multi-voting technique, linear programming, trial and error approach, MCDM analysis, and affinity diagrams (Lashgari et al., 2011).

In the previous section, the method of calculating the relative weights of main and sub-factors using the ANP technique is illustrated. However, it should be noted that the ANP methodology would have been employed for prioritising the feasible alternatives provided that a small number of alternatives are taken into account. According to the number of the alternatives applied in this study, it is not logical to form a huge number of the pair-wise comparison matrices on account of taking a numerous amount of time. Therefore, TOPSIS, a branch of the MCDM methods, is applied to rank the feasible alternatives. This technique is a robust method for ranking the feasible alternatives with respect to the evaluation criteria under consideration. The TOPSIS methodology, introduced by Hwang and Yoon (1981), uses the basic concept of positive and negative ideal solution in which the alternative chosen should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution (Fouladgar, Yazdani-Chamzini, & Zavadskas, 2011; Yazdani-Chamzini & Yakhchali, 2012).

However, the TOPSIS method is criticised for handling the inherent uncertainty and complexity involved in the process of modelling real-life problems. As well as, it is very difficult for the evaluators to express the preferences using exact numerical values and this result more desirable for the researchers to use fuzzy logic evaluation (Tseng, 2011). Fuzzy logic is a powerful and robust tool for formulating the uncertainty that has demonstrated its capabilities and effectiveness as a practical problem-solving tool in the different areas of science, engineering, and management. Table 4 lists a number of the studies using fuzzy TOPSIS to model different problems.

Fuzzy TOPSIS solves a problem with m alternatives A_1, A_2, A_3, ..., A_m, evaluated based on *n* dimensions, C_1, C_2, . . ., C_n. To form fuzzy TOPSIS matrix, first a judgment matrix is constructed as C_1 C_2 … C_n

Table 4. A list of the studies using fuzzy TOPSIS (after 2009).

Proposed by	Year	Application
Wang, Cheng and Huang	2009	Supplier selection
Wang, Lee and Cheng	2009	Healthcare Industry
Nejati, Nejati and Shafaei	2009	Service quality
Kannan, Murugesan and Senthil, Haq	2009	Supply chain management
Zeydan and Çolpan	2009	performance measurement
Amiri	2010	Project selection
Tan, Shen, Langston and Liu	2010	Project selection
Singh and Benyoucef	2011	E-sourcing
Fouladgar et al.	2011	Strategy selection
Afshar, Mariño, Saadatpour and Afshar	2011	Water resource systems
Özgen, Tuzkaya, Tuzkaya and Özgen	2011	Machine tool selection
Kavosi and Mavi	2011	Quality management
Awasthi, Chauhan, Omrani and Panahi	2011	Evaluating transportation service quality
Lashgari.et al.	2012	Equipment selection
Fouladgar et al.	2012c	Risk evaluation
Lashgari et al.	2012	Shaft sinking method selection
Yazdani-Chamzini and Yakhchali	2012	Tunnel boring machine selection
Awasthi and Chauhan	2012	Sustainability evaluation
Cui, Guo, Li and Li	2012	Pollution assessment
Uysal and Tosun	2012	Maintenance management system selection
Arslan and Çunkaş	2012	Performance evaluation
Yazdani-Chamzini and Yakhchali	2012	Handling equipment selection
Khazaeni, Khanzadi and Afshar	2012	Risk analysis
Samvedi, Jain and Chan	2013	Risk analysis
Ahani, Bahrami and Shariflu	2013	Knowledge management
Tian, Yu, Yu and Ma	2013	Information source selection
Maity and Chakraborty	2013	Grinding wheel abrasive material selection
Bas	2013	Supply chain management
Balezentiene, Streimikiene and Balezentis	2013	Sustainable energy

Source: Author's calculations.

$$\begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \tag{17}$$

where $\tilde{x}_{ij}$, i=1, 2, …, m; j=1, 2, …, are linguistic triangular fuzzy numbers. Note that $\tilde{x}_{ij}$is the performance rating of the ith alternative, A_i, with respect to the jth criterion, C_j assessed by k evaluators concerning the same evaluation criteria, that is, getting the arithmetic mean of $\tilde{x}^k_{ij}$, where $\tilde{x}^k_{ij}$ is the rating of alter $\tilde{R}\tilde{x}^k_{ij} = (a^k_{ij}, b^k_{ij}, c^k_{ij})$ native $\tilde{R} = [\tilde{r}_{ij}]_{m \times n} A_i$ with respect to criterion C_j evaluated by kth evaluator, .

The normalised fuzzy decision matrix denoted by $\tilde{R}$ as shown in Equation (18):

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n} \tag{18}$$

The weighted normalized Fuzzy decision matrix is shown as follows:

$$\tilde{V} = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \cdots & \tilde{v}_{1n} \\ \tilde{v}_{21} & \tilde{v}_{22} & \cdots & \tilde{v}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{v}_{m1} & \tilde{v}_{m2} & & \tilde{v}_{mn} \end{bmatrix} = \begin{bmatrix} w_1\tilde{r}_{11} & w_2\tilde{r}_{12} & \cdots & w_n\tilde{r}_{1n} \\ w_1\tilde{r}_{21} & w_2\tilde{r}_{22} & \cdots & w_n\tilde{r}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1\tilde{r}_{m1} & w_2\tilde{r}_{m2} & & w_n\tilde{r}_{mn} \end{bmatrix} \quad (19)$$

where$w_j$is the weight of the jth criterion.

Fuzzy TOPSIS is summarised as follows:

Step 1. Choose the linguistic rating$\tilde{x}_{ij}$: i=1, 2, . . .,m; j=1, 2, . . ., n for alternatives with respect to criteria and the proper linguistic variables $\tilde{w}_j$: j=1, 2, . . ., n for weight of the criteria.

Step 2. Form the weighted normalised fuzzy decision matrix.$\tilde{v}$.by Equation (19).

Step 3. Identify the positive ideal solution A^+ and the negative ideal solution A^-. The fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) can be obtained through Equations (20) and (21).

$$A^* = (\tilde{v}_1^+, \tilde{v}_2^+, \tilde{v}_3^+, ..., \tilde{v}_n^+) = \{\max_i v_{ij}(i = 1, 2, ..., n)\} \quad (20)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \tilde{v}_3^-, ..., \tilde{v}_n^-) = \{\min_i v_{ij}(i = 1, 2, ..., n)\} \quad (21)$$

Step 4. The distance of each alternative from the positive ideal solution A^+ and the negative ideal solution A^- can be calculated using Equations (22) and (23).

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+) \ , \ i = 1, 2, ..., m \quad (22)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \ , \ i = 1, 2, ..., m \quad (23)$$

Step 5. Calculate the closeness coefficient. This step solves the closeness coefficient by Equation (24).

$$CC_i^* = \frac{d_i^-}{d_i^- + d_i^*} \quad (24)$$

5. The proposed model

The proposed model can be defined as presented in the following steps:

Step 1: Identify the evaluation criteria and classify them based on the BOCR factors.

Step 2: Construct pair-wise comparison matrices based on the scale given in Table 1 for calculating the importance weights of the main and sub-factors. Assume that there is no dependence among the BOCR factors (i.e. construct the AHP model). The local weights of sub-factors arise from this step.

Step 3: Visualise the structure of complicated causal relationships with matrices or digraphs and obtain the central role of each factor (i.e. construct the DEMATEL model). The interdependent weights of the factors are derived from this step.

Step 4: Calculate the global weights of the BOCR factors by multiplying the weights resulted from step 2 and the interdependent weights derived from step 3.

Step 5: Calculate the global weights of the evaluation indicators by multiplying the weights of the sub-factors obtained in step 2 with those of the factors to which it belongs that is acquired in the previous step.

Step 6: Define a linguistic scale for describing the preference ratings of the alternatives.

Step 7: Aggregate the fuzzy values resulted from the previous step.

Step 8: Obtain the preference ratings of the alternatives by using the fuzzy TOPSIS technique based on the global weights yield in step 5 and the ratings obtained from the previous step.

Step 9: Prioritise the investment strategies in descending order and select the highest rank as the first choice.

Schematic diagram of the proposed model for selecting the optimal working strategy is provided in Figure 2.

5.1. An implementation of the proposed model in the private sector

In order to demonstrate the potential application of the proposed model a case study is illustrated. For achieving the aim, selection of the investment strategy in the private sector of Iran is evaluated and explained. Based on the Iranian Constitution, the economy of Iran consists of three sectors: private, cooperative, and state. The private sector

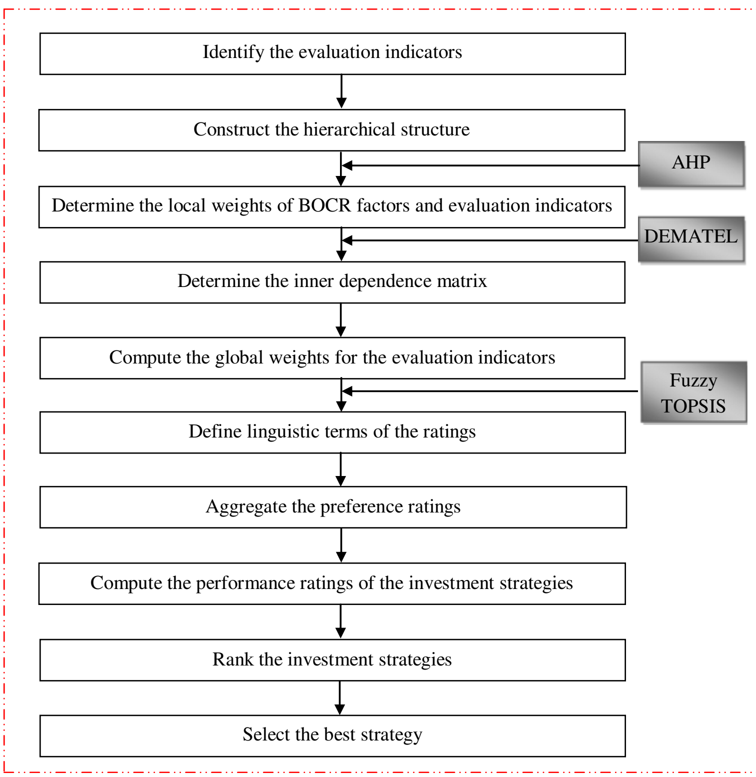

Figure 2. Schematic diagram of the proposed model.
Source: Author's calculations.

Table 5. Final list of the main and sub-criteria.

Goal	Main criteria	Sub-criteria	Alternatives
Selecting the best investment strategy	Benefit factors (B)	Profitability (C1)	Petrochemicals, oil, and gas (A1)
		Efficiency (C2)	Utilities (A2)
		Exchangeability (C3)	Telecommunication (A3)
		Credit (C4)	Transport (A4)
	Opportunity factors (O)	Reliability (C5)	Mines & Metals (A5)
		Sustainability (C6)	Banking and insurance (A6)
		Robustness (C7)	Nonequity securities (A7)
	Cost factors (C)	Initial capital cost (C8)	Foreign currency (A8)
		Tax (C9)	Stocks (A9)
		Existence of competition (C10)	Coin (A10)
	Risk factors (R)	Sociopolitical (11)	Manufacturing (A11)
		Security (C12)	
		Regret (C13)	

Source: Author's calculations.

consists of those activities concerned with construction, agriculture, animal husbandry, industry, trade, and services that supplement the economic activities of the state and cooperative sectors (Alfoneh, 2013). According to the World Bank report published in 2010, the Domestic credit to private sector (% of GDP) in Iran was 36.66 in 2009[2]. The scenarios employed in this study are system scenarios where both tangible and intangible parameters are considered. As previously mentioned, this article proposes a model for selecting the optimum investment strategy based on a novel hybrid methodology taking into account the mutual relationships of the criteria and proposes a strategy for investing in the private sector of Iran.

According to the importance of the investment, a decision-making team is established, including 15 experts with a minimum of five years experience and a strong background in the field of investing. For achieving the aim, the interview technique is utilised in which evaluators are asked to mention all factors they regard as relevant to the selection of the optimum investment strategy. Also the feasible alternatives for investing in the private sector of Iran are identified. After several revisions, the final list comprising 13 evaluation criteria is extracted. These factors can be classified into four main parts: BOCR. The ultimate list including factors (main criteria) and sub-factors (sub-criteria) are presented in Table 5. Consequently, the structure of the problem of selecting the best strategy for investing is depicted in Figure 3.

Assuming that there is no dependence among the BOCR factors, the importance weights of the evaluation criteria are computed. To this end, a questionnaire using the AHP questionnaire format is constructed, and then experts are asked to fill the judgment matrix based on the scale given in Table 1. For instance, in the process of interview with one of the experts, the benefit factor (B) and risk factor (C) are compared by asking 'How important is "B" when it is compared with "R"?' and the answer '3' is received. This number is located in the relevant cell against the relative weights. The computations of the consistency rate show that this rate is smaller than 0.1; as a result,

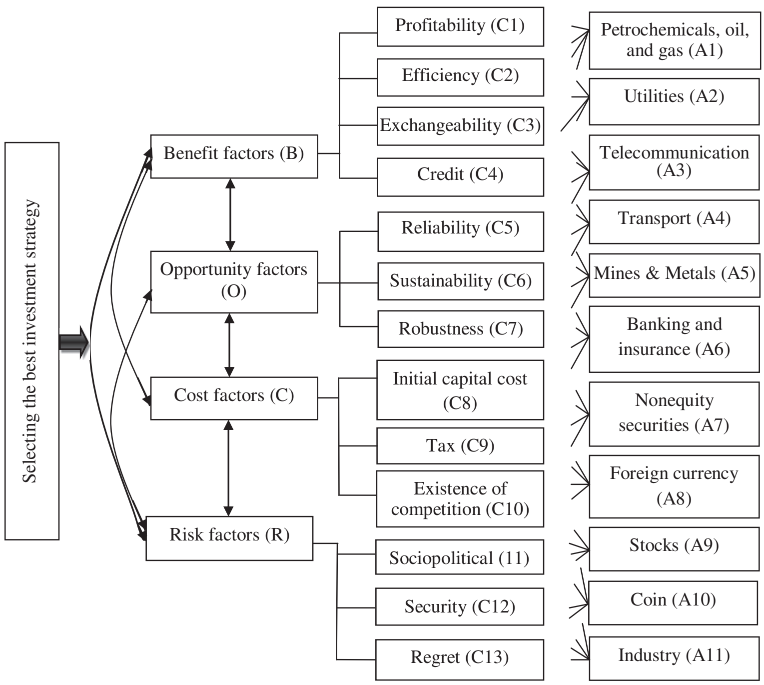

Figure 3. Structure of the investment problem.
Source: Author's calculations.

the questionnaires are valid. The final comparison matrix is obtained by the geometric mean to the individual responses be transferred into the group comparison matrix. The final comparison matrix acquired by the evaluator team is shown in Table 6. In order to valid the final questionnaire, the group consistency ratio (GCR) is computed by using Equation (25), as listed in the last row of the matrix.

$$GCI = (\lambda_{\max} - n)/n \tag{25}$$

The importance weights of the main and sub-criteria are computed by the process of the AHP methodology and the results are presented in Table 7.

Then, the interdependence relationships among the BOCR factors are virtualised with the aid of the DEMATEL method. This step is developed to find all aspects of the interdependence and dependence relationships between the BOCR factors. For this aim, the DEMATEL analysis based on the impact-relation maps is conducted to calculate the key role of each factor. First, the direct-influence matrix $A$for criteria is established based on the expert's knowledge. Then, the normalised direct-influence matrix for criteria is computed. Third, the total relation matrix is computed as presented in Table 8. For example, benefit factor (B) will directly impact opportunity factor (O) with an impact level of 0.509. Likewise, benefit factor (B) will impact itself with an impact level of 0.306. Finally, the NRM is formed by the r and s as the total direct-influence matrix listed in the last column and row of Table 8.

After determining the total relation matrix, the quantitative values of $r_i - s_i$ and $r_i + s_i$are derived from this matrix as shown in Table 9. The r_i+s_i value indicates how

Table 6. Final comparison matrix.

	B				O			C			R		
B	1.00				3.56			1.33			3.16		
O	0.28				1.00			0.45			0.36		
C	0.75				2.24			1.00			2.00		
R	0.32				2.78			0.50			1.00		
GCR	0.03												
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	1.00	1.12	2.65	3.77									
C2	0.89	1.00	2.32	2.89									
C3	0.38	0.43	1.00	2.12									
C4	0.27	0.35	0.47	1.00									
C5					1.00	1.32	2.24						
C6					0.76	1.00	2.17						
C7					0.45	0.46	1.00						
C8								1.00	7.45	4.53			
C9								0.13	1.00	0.32			
C10								0.22	3.12	1.00			
C11											1.00	5.34	3.21
C12											0.19	1.00	0.30
C13											0.31	3.34	1.00
GCR	0.008				0.002			0.017			0.02		

Source: Author's calculations.

Table 7. Local weights of criteria.

Criteria	Local weights obtained by AHP
B	0.422
O	0.104
C	0.291
R	0.183
C1	0.394
C2	0.338
C3	0.167
C4	0.100
C5	0.447
C6	0.368
C7	0.184
C8	0.719
C9	0.080
C10	0.201
C11	0.644
C12	0.098
C13	0.258

Source: Author's calculations.

important a criterion is, while the level of the direct impact of this criterion on other criteria is assigned by the $r_i - s_i$value. Therefore, a high and positive value for $r_i - s_i$indicates that this criterion have a significant impact on other criteria.

Moreover, risk (R), with the highest value of $r_i + s_i$, has the most relationships with other criteria. Whereas, opportunity (O) is located in the second place.

Table 8. The total relation matrix for the BOCR factors.

	B	O	C	R	r
B	0.306	0.509	0.495	0.521	1.830
O	0.775	0.563	1.032	1.135	3.506
C	0.426	0.443	0.509	0.701	2.078
R	0.731	0.690	1.142	0.742	3.305
s	2.238	2.205	3.178	3.099	

Source: Author's calculations.

Table 9. The influences given/received for factors.

	s	r	$r_i + s_i$	$r_i - s_i$
B	2.238	1.830	4.068	−0.407
O	2.205	3.506	5.711	1.301
C	3.178	2.078	5.257	−1.099
R	3.099	3.305	6.404	0.206

Source: Author's calculations.

In order to make a strong decision analysis, a discussion with the evaluator team is conducted to determine the appropriate threshold value. It should be noted that r-s there is not a standard and systematic process for obtaining the threshold value. Therefore, the threshold value is obtained based on the knowledge of the expert team. For this reason the threshold value for this problem is 0.72; so that, the values above these thresholds are merely taken into account in the process of modelling the decision problem. Therefore, the influence relation map can be acquired by mapping a dataset of (r + s, r - s), as seen in Figure 4. From the figure, it can be evident that O and R are the positively-affected criteria. Whereas, B and C are the negatively-affected criteria. Moreover, it can be evident that opportunity (O), with the highest value of r-s is the most effective factor for the problem under consideration (master sender). Whereas, cost (C), with lowest value of $r - s$, is the least effective factor (master receiver).

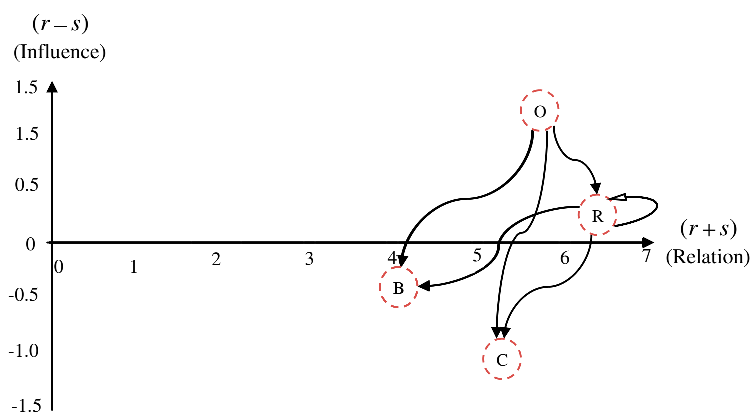

Figure 4. The influence relation map.
Source: Author's calculations.

Table 10. Global weights of criteria.

Criteria	Weights derived from DEMATEL technique	Weights obtained from combination of DEMATEL and AHP	Global weights
B	4.068	1.717	0.342
O	5.711	0.594	0.119
C	5.257	1.53	0.305
R	6.404	1.172	0.234

Source: Author's calculations.

Table 11. Global weights of the indicators.

Criteria	Importance weights	Global weights
B	0.342	-
O	0.119	-
C	0.305	-
R	0.234	-
C1	0.394	0.135
C2	0.338	0.116
C3	0.167	0.057
C4	0.100	0.034
C5	0.447	0.053
C6	0.368	0.044
C7	0.184	0.022
C8	0.719	0.219
C9	0.080	0.024
C10	0.201	0.061
C11	0.644	0.151
C12	0.098	0.023
C13	0.258	0.060

Source: Author's calculations.

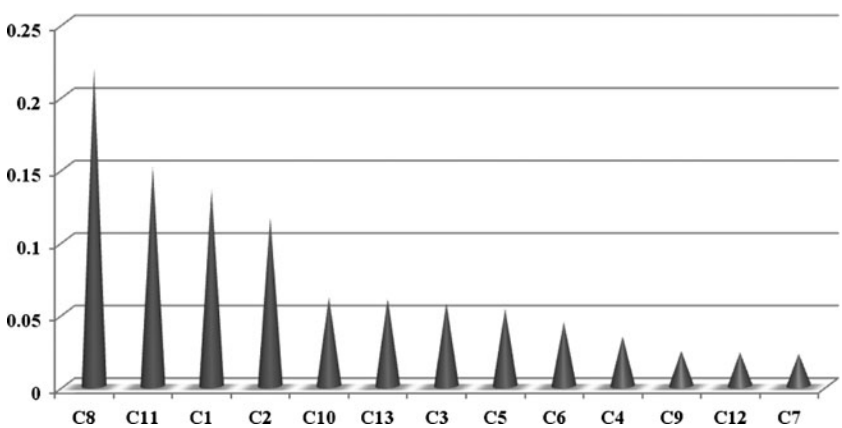

Figure 5. Global weights of the indicators.
Source: Author's calculations.

In next step, the values of are multiplied with the relative weights obtained by the AHP technique to take into account the central role of the BOCR factors. The values calculated are listed in Table 10. Then, these values are normalised as shown in Table 10. It

Table 12. A sample of questionnaire filled.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
C1	VG	G	G	G	VG	VG	G	VG	G	VG	G
C2	G	VG	G	F	G	G	F	G	G	G	G
C3	P	F	P	F	VP	F	G	VG	F	VG	P
C4	G	F	G	G	F	VG	G	VG	F	VG	F
C5	G	P	F	G	F	G	F	G	VG	G	G
C6	F	F	F	F	F	F	F	G	G	G	G
C7	G	P	F	G	P	F	P	VG	P	G	G
C8	VG	F	F	G	VG	G	VP	P	P	F	VG
C9	F	F	P	P	P	P	P	VG	P	F	G
C10	F	P	P	F	P	G	G	G	F	F	G
C11	G	VP	VP	F	F	F	G	G	G	G	F
C12	G	P	F	P	VP	G	F	G	VP	G	P
C13	P	F	P	F	P	P	F	G	F	VG	F

Source: Author's calculations.

can be seen that the global weights obtained from the proposed model is significantly different from the output of the AHP technique. It is due to the fact that the proposed model considers the interdependence relations among the evaluation criteria.

This step includes calculating the global weights of the evaluation criteria by multiplying the local weights obtained by the AHP model with the final interdependence weights of the factor to which it belongs. The results obtained from this step are listed in Table 11. Figure 5 schematically shows the importance weights of the evaluation indicators.

After calculating the relative weights of the evaluation criteria, a linguistic scale for describing the preference ratings of the feasible alternatives is proposed as shown in Table 3. The expert team employs these linguistic terms to form the decision matrices. A sample of questionnaire filled by team expert is depicted in Table 12. Then, the aggregated decision matrix is calculated by the following equation as presented in Table 13.

$$\tilde{x}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}), k = 1, 2, ..., K \tag{26}$$

$$x_{ij1} = \frac{1}{K}\sum_{k=1}^{k} x_{ijk1} \tag{27}$$

$$x_{ij2} = \frac{1}{K}\sum_{k=1}^{k} x_{ijk2}$$

$$x_{ij3} = \frac{1}{K}\sum_{k=1}^{k} x_{ijk3}$$

$x_{ij}^{k}$is the rating of alternative $A_i$with respect to the jth criterion assessed by,kth decision-maker.

After determining the importance ratings of alternatives, normalisation of these values is made by converting the aggregated values in the closed interval [0,1] with the aid

Table 13. Aggregated decision matrix.

	A1			A2			A3			A4			A5			A6		
C1	(6.04,	7.54,	8.78)	(4.76,	6.26,	7.64)	(4.56,	6.06,	7.50)	(4.76,	6.26,	7.63)	(6.57,	8.07,	9.52)	(6.32,	7.82,	9.09)
C2	(5.25,	6.75,	8.25)	(6.54,	8.04,	9.35)	(4.87,	6.37,	7.78)	(3.18,	4.68,	6.18)	(2.89,	4.39,	5.89)	(4.78,	6.28,	7.74)
C3	(1.12,	2.55,	4.05)	(3.11,	4.61,	6.11)	(0.89,	2.07,	3.57)	(2.92,	4.42,	5.92)	(0.34,	1.55,	3.05)	(3.11,	4.61,	6.11)
C4	(4.87,	6.37,	7.87)	(2.58,	4.08,	5.58)	(4.15,	5.65,	7.11)	(4.56,	6.06,	7.48)	(2.76,	4.26,	5.76)	(6.14,	7.64,	8.98)
C5	(5.93,	7.43,	8.76)	(1.06,	2.41,	3.91)	(2.67,	4.17,	5.67)	(5.02,	6.52,	7.94)	(3.12,	4.62,	6.12)	(5.21,	6.71,	8.17)
C6	(2.53,	4.03,	5.53)	(3.22,	4.72,	6.22)	(3.21,	4.71,	6.21)	(2.53,	4.03,	5.53)	(3.24,	4.74,	6.24)	(2.86,	4.36,	5.86)
C7	(5.24,	6.74,	8.19)	(1.36,	2.82,	4.32)	(2.94,	4.44,	5.94)	(3.97,	5.47,	6.94)	(1.43,	2.88,	4.38)	(3.22,	4.72,	6.22)
C8	(6.86,	8.36,	9.51)	(3.43,	4.93,	6.43)	(3.42,	4.92,	6.42)	(4.21,	5.71,	7.14)	(5.87,	7.37,	8.82)	(4.26,	5.76,	7.19)
C9	(3.03,	4.53,	6.03)	(3.29,	4.79,	6.29)	(1.12,	2.47,	3.97)	(1.04,	2.39,	3.89)	(1.23,	2.65,	4.15)	(1.43,	2.89,	4.39)
C10	(2.69,	4.19,	5.69)	(1.11,	2.61,	4.11)	(1.43,	2.71,	4.21)	(3.24,	4.74,	6.24)	(2.03,	3.53,	5.03)	(5.05,	6.55,	7.99)
C11	(4.74,	6.24,	7.67)	(0.34,	1.84,	3.34)	(0.14,	1.26,	2.76)	(3.36,	4.86,	6.36)	(3.56,	5.06,	6.56)	(3.34,	4.84,	6.34)
C12	(5.24,	6.74,	8.15)	(0.96,	2.46,	3.96)	(2.26,	3.76,	5.26)	(1.12,	2.43,	3.93)	(0.62,	1.87,	3.37)	(4.79,	6.29,	7.76)
C13	(1.03,	2.28,	3.78)	(2.87,	4.37,	5.87)	(1.22,	2.64,	4.14)	(3.47,	4.97,	6.47)	(1.21,	2.55,	4.05)	(1.23,	2.66,	4.16)

	A7			A8			A9			A10			A11		
C1	(4.56,	6.06,	7.52)	(6.43,	7.93,	9.10)	(4.23,	5.73,	7.23)	(7.04,	8.54,	9.64)	(4.77,	6.27,	7.71)
C2	(3.12,	4.62,	6.12)	(5.13,	6.63,	8.06)	(4.46,	5.96,	7.42)	(5.26,	6.76,	8.08)	(5.07,	6.57,	8.01)
C3	(4.67,	6.17,	7.60)	(6.21,	7.71,	9.07)	(3.21,	4.71,	6.21)	(6.78,	8.28,	9.45)	(1.23,	2.64,	4.14)
C4	(5.21,	6.71,	8.12)	(5.89,	7.39,	8.80)	(3.42,	4.92,	6.42)	(6.34,	7.84,	9.20)	(3.32,	4.82,	6.32)
C5	(3.34,	4.84,	6.34)	(5.21,	6.71,	8.16)	(6.78,	8.28,	9.43)	(4.57,	6.07,	7.54)	(5.31,	6.81,	8.19)
C6	(3.52,	5.02,	6.52)	(5.34,	6.84,	8.29)	(4.74,	6.24,	7.74)	(4.78,	6.28,	7.73)	(5.09,	6.59,	7.99)
C7	(1.43,	2.86,	4.36)	(6.78,	8.28,	9.41)	(1.58,	3.08,	4.58)	(5.13,	6.63,	8.04)	(5.11,	6.61,	8.04)
C8	(0.23,	1.39,	2.89)	(1.05,	2.41,	3.91)	(1.21,	2.56,	4.06)	(1.23,	2.58,	4.08)	(7.21,	8.71,	9.78)
C9	(1.53,	2.99,	4.49)	(6.32,	7.82,	9.22)	(1.43,	2.88,	4.38)	(3.46,	4.96,	6.46)	(5.13,	6.63,	8.00)
C10	(4.65,	6.15,	7.61)	(4.56,	6.06,	7.48)	(3.24,	4.74,	6.24)	(3.06,	4.56,	6.06)	(4.79,	6.29,	7.71)
C11	(5.05,	6.55,	7.97)	(5.22,	6.72,	8.06)	(4.85,	6.35,	7.78)	(4.78,	6.28,	7.71)	(3.32,	4.82,	6.32)
C12	(3.23,	4.73,	6.23)	(4.78,	6.28,	7.63)	(0.24,	1.39,	2.89)	(5.12,	6.62,	8.02)	(1.76,	3.26,	4.76)
C13	(3.41,	4.91,	6.41)	(4.95,	6.45,	7.82)	(3.45,	4.95,	6.45)	(6.59,	8.09,	9.40)	(3.08,	4.58,	6.08)

Source: Author's calculations.

Table 14. Weighted decision matrix.

	A1			A2			A3			A4			A5			A6		
C1	(0.05,	0.08,	0.11)	(0.01,	0.05,	0.09)	(0.01,	0.05,	0.08)	(0.01,	0.05,	0.08)	(0.06,	0.10,	0.13)	(0.05,	0.09,	0.12)
C2	(0.04,	0.07,	0.10)	(0.07,	0.09,	0.12)	(0.04,	0.06,	0.09)	(0.01,	0.03,	0.06)	(0.00,	0.03,	0.05)	(0.03,	0.06,	0.09)
C3	(0.00,	0.01,	0.02)	(0.02,	0.03,	0.04)	(0.00,	0.01,	0.02)	(0.02,	0.03,	0.03)	(0.00,	0.01,	0.02)	(0.02,	0.03,	0.04)
C4	(0.01,	0.02,	0.03)	(0.00,	0.01,	0.02)	(0.01,	0.02,	0.02)	(0.01,	0.02,	0.03)	(0.00,	0.01,	0.02)	(0.02,	0.03,	0.03)
C5	(0.03,	0.04,	0.05)	(0.00,	0.01,	0.02)	(0.01,	0.02,	0.03)	(0.03,	0.03,	0.04)	(0.01,	0.02,	0.03)	(0.03,	0.04,	0.05)
C6	(0.00,	0.01,	0.02)	(0.01,	0.02,	0.03)	(0.01,	0.02,	0.03)	(0.00,	0.01,	0.02)	(0.01,	0.02,	0.03)	(0.00,	0.01,	0.03)
C7	(0.01,	0.01,	0.02)	(0.00,	0.00,	0.01)	(0.00,	0.01,	0.01)	(0.01,	0.01,	0.02)	(0.00,	0.00,	0.01)	(0.01,	0.01,	0.01)
C8	(0.01,	0.03,	0.07)	(0.08,	0.11,	0.15)	(0.08,	0.11,	0.15)	(0.06,	0.09,	0.13)	(0.02,	0.06,	0.09)	(0.06,	0.09,	0.13)
C9	(0.01,	0.01,	0.02)	(0.01,	0.01,	0.02)	(0.02,	0.02,	0.02)	(0.02,	0.02,	0.02)	(0.01,	0.02,	0.02)	(0.01,	0.02,	0.02)
C10	(0.02,	0.03,	0.05)	(0.03,	0.05,	0.06)	(0.03,	0.05,	0.06)	(0.02,	0.03,	0.04)	(0.03,	0.04,	0.05)	(0.00,	0.01,	0.03)
C11	(0.01,	0.03,	0.06)	(0.09,	0.12,	0.15)	(0.10,	0.13,	0.15)	(0.03,	0.06,	0.09)	(0.03,	0.06,	0.09)	(0.03,	0.06,	0.09)
C12	(0.00,	0.00,	0.01)	(0.01,	0.02,	0.02)	(0.01,	0.01,	0.02)	(0.01,	0.02,	0.02)	(0.01,	0.02,	0.02)	(0.00,	0.01,	0.01)
C13	(0.04,	0.05,	0.06)	(0.03,	0.04,	0.05)	(0.04,	0.05,	0.06)	(0.02,	0.03,	0.04)	(0.04,	0.05,	0.06)	(0.04,	0.05,	0.06)

	A7			A8			A9			A10			A11		
C1	(0.01,	0.05,	0.08)	(0.05,	0.09,	0.12)	(0.00,	0.04,	0.07)	(0.07,	0.11,	0.14)	(0.01,	0.05,	0.09)
C2	(0.00,	0.03,	0.06)	(0.04,	0.07,	0.09)	(0.03,	0.06,	0.08)	(0.04,	0.07,	0.09)	(0.04,	0.07,	0.09)
C3	(0.03,	0.04,	0.05)	(0.04,	0.05,	0.05)	(0.02,	0.03,	0.04)	(0.04,	0.05,	0.06)	(0.01,	0.01,	0.02)
C4	(0.01,	0.02,	0.03)	(0.02,	0.02,	0.03)	(0.00,	0.01,	0.02)	(0.02,	0.03,	0.03)	(0.00,	0.01,	0.02)
C5	(0.01,	0.02,	0.03)	(0.03,	0.04,	0.04)	(0.04,	0.05,	0.05)	(0.02,	0.03,	0.04)	(0.03,	0.04,	0.05)
C6	(0.01,	0.02,	0.03)	(0.02,	0.03,	0.04)	(0.02,	0.03,	0.04)	(0.02,	0.03,	0.04)	(0.02,	0.03,	0.04)
C7	(0.00,	0.00,	0.01)	(0.01,	0.02,	0.02)	(0.00,	0.00,	0.01)	(0.01,	0.01,	0.02)	(0.01,	0.01,	0.02)
C8	(0.16,	0.19,	0.22)	(0.13,	0.17,	0.20)	(0.13,	0.17,	0.20)	(0.13,	0.17,	0.20)	(0.00,	0.02,	0.06)
C9	(0.01,	0.02,	0.02)	(0.00,	0.00,	0.01)	(0.01,	0.02,	0.02)	(0.01,	0.01,	0.02)	(0.00,	0.01,	0.01)
C10	(0.00,	0.02,	0.03)	(0.00,	0.02,	0.03)	(0.02,	0.03,	0.04)	(0.02,	0.03,	0.04)	(0.00,	0.02,	0.03)
C11	(0.00,	0.03,	0.06)	(0.00,	0.03,	0.05)	(0.01,	0.03,	0.06)	(0.01,	0.03,	0.06)	(0.03,	0.06,	0.09)
C12	(0.01,	0.01,	0.01)	(0.00,	0.01,	0.01)	(0.02,	0.02,	0.02)	(0.00,	0.00,	0.01)	(0.01,	0.01,	0.02)
C13	(0.02,	0.03,	0.04)	(0.01,	0.02,	0.03)	(0.02,	0.03,	0.04)	(0.00,	0.01,	0.02)	(0.02,	0.03,	0.05)

Source: Author's calculations.

Table 15. Fuzzy TOPSIS results.

Alternatives	D_j^+	D_j^-	CC_j	Rank
A1	0.605	0.456	0.430	9
A2	0.485	0.577	0.543	3
A3	0.487	0.573	0.541	4
A4	0.589	0.467	0.442	8
A5	0.607	0.457	0.429	10
A6	0.530	0.527	0.499	6
A7	0.551	0.514	0.483	7
A8	0.476	0.585	0.552	2
A9	0.523	0.539	0.508	5
A10	0.456	0.604	0.570	1
A11	0.639	0.421	0.397	11

Source: Author's calculations.

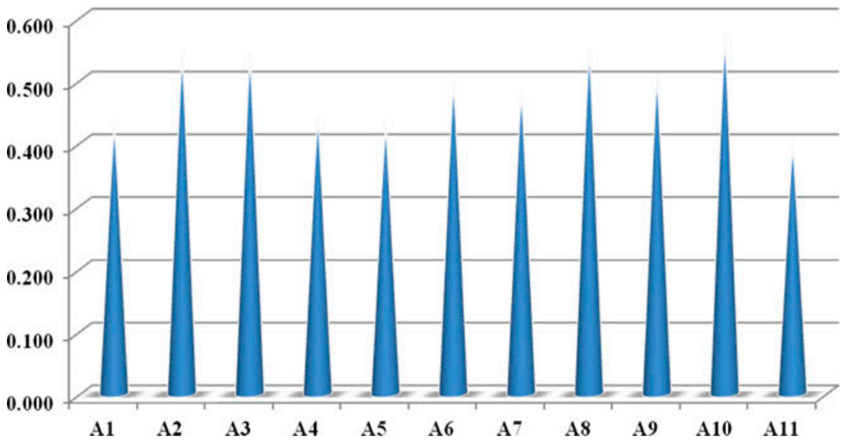

Figure 6. Final ranking of alternatives.
Source: Author's calculations.

of the linear scale transformation functions defined as presented in the following equations to establish the normalised fuzzy matrix:

$$\text{The larger, the better type,}\, r_{ij} = \frac{[x_{ij} - \min\{x_{ij}\}]}{[\max\{x_{ij}\} - \min\{x_{ij}\}]} \tag{28}$$

$$\text{The smaller, the better type,}\, r_{ij} = \frac{[\max\{x_{ij}\} - x_{ij}]}{[\max\{x_{ij}\} - \min\{x_{ij}\}]} \tag{29}$$

Then, by multiplying each value with their weights, weighted normalised A^- matrix is formed as depicted in Table 14.

Since the first seven criteria are benefit type and the second six criteria CC_j are cost type, the FPIS and the FNIS can be defined as$\tilde{v}_i^+ = w_j \otimes (1, 1, 1)$and. The distance of each alternative from and is calculated by using Equations (22) and (23). Finally, the fuzzy TOPSIS calculates the similarities to an ideal solution by Equation (24). The results of the fuzzy TOPSIS technique are shown in Table 15.

According to the values, the ranking of the alternatives in descending order are A10, A8, A2, A3, A9, A6, A7, A4, A1, A5 and A11. The proposed model results indicate that A10 is the best alternative with CC value of 0.57. Rankings of risks according to CC_i values are depicted in Figure 6.

6. Discussion

According to the results derived from the empirical study, the researchers make the following discussions. From Figure 4, the impact-relation map gives an important message. If a decision-maker wishes to invest in the private sector of Iran, opportunity factor (O) should be taken into account first. Because this criterion is influenced by the other criteria least and influences the other criteria most. This demonstrates the key role of opportunities in the process of investing in the private sector of Iran.

The proposed model based on three methods AHP, DEMATEL, and fuzzy TOPSIS has several advantages. First, according to the importance weights of the BOCR factors and sub-factors, investors can recognise the importance of main and sub-criteria and how they can influence the investment strategies without taking into account the interdependence relations among the criteria under consideration. Contrary to what is motioned, another scenario can be taken into account by the information resulted from the DEMATEL technique. This technique considers direct and indirect effects to handle the cause-effect relationships involved in the criteria. This can result in a better performance in the process of investing.

On the other hand, the TOPSIS technique is a robust method to rank the feasible alternatives under a systematic approach. This technique takes shorter time for the process of ranking in comparison with other techniques like AHP and ANP. As well as, the merit of using fuzzy logic is to model a complex system by using linguistic terms. The advantages of both techniques can be obtained in the form of the fuzzy TOPSIS technique.

7. Conclusions

In this article, an integrated model based on four techniques including AHP and DEMATEL, TOPSIS, and fuzzy methods to evaluate different investment strategies in order to select the best one. Since different indicators have a significant influence on the process of selection the best strategy for investing, using a BOCR framework to group the sub-criteria into the BOCR factors.

However, the results of the AHP model can be applied for calculating the relative weights of main and sub-criteria while the relationships among criteria are independent. For selecting the most appropriate investment strategy under terms of the interdependence among the criteria, it is better to use the techniques that can model the cause-effect relations among the evaluation criteria. The DEMATEL method is one of the most commonly used methods in handling the cause-effect relations. After applying the DEMATEL method, the weights of the indicators are significantly different from the weights obtained by the AHP model. This shows that the proposed model is more adapted with real-life problems. This leads to model a sophisticated problem more effectively. Results of the proposed approach shows that the strategy A10 (investing in coin) outperforms other strategies. It is suggested to investigate more studies to uncover invaluable new study problems.

Notes

1. www.essec.edu
2. data.worldbank.org.

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