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A FUZZY INTERVAL BASED MULTI-CRITERIA HOMOGENEOUS GROUP DECISION MAKING TECHNIQUE: AN APPLICATION TO AIRPORTS RANKING PROBLEM

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Abstract: *This paper aims to develop and introduce a fuzzy Interval based Multi-criteria homogeneous Group Decision making technique (IMGD) to make appropriate decision under fuzzy environment. In fuzzy multi-criteria group decision making process, a group of decision makers often considers several subjective criteria for ranking a set of alternatives. Due to vague and imprecise information, decision makers generally utilize linguistic variables which are mandatorily converted into triangular or trapezoidal fuzzy numbers. The total process then becomes very complex and time consuming. The current investigation advocates fuzzy intervals instead of triangular or trapezoidal fuzzy numbers for simplification of the complex situation and ease of calculation. In this method, fuzzy intervals of performance ratings and weights assessed by homogeneous group decision makers under subjective criteria are converted into first mean fuzzy intervals then into normalized crisp numbers. The normalized crisp performance ratings and normalized crisp weights are combined together to determine initially individual contribution and then into aggregate contribution to each alternative for final ranking and selection of the alternative. The new model is demonstrated with an application to airports ranking and selection problem for better clarification and verification. The outcome of the proposed is validated with the results obtained by well-known existing MCDM techniques. The analysis shows that the proposed method is applicable, useful and effective for appropriate decision making under fuzzy MCDM environment.*

Key words: *Airport selection, Decision making under uncertainty, Homogeneous Group decision making, FMCDM.*

1. Introduction

The ranking and selection procedure of airports in general involves multiple alternatives, multiple conflicting subjective criteria and a group of experts. Therefore multi criteria decision making techniques are required to employ for finding the

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ranking order of airports. The decision making procedures becomes hard while decision is to make under fuzzy environments considering many subjecting criteria. It becomes more complex while multiple decision makers' perception are required to incorporate in the decision. An airport ranking problem may be different from the others by type and nature of criteria, involvement of decision makers and number of alternative. Past researchers have suggested several techniques for ranking and selection of airports. A detailed literature survey on airport ranking and selection proposed and suggested by past researchers is carried out and presented in this section.

Zhao et al. (2019) chooses civil airport site considering bird economical preservation by expert base selection in Dalian, China. Hammad et al. (2017) proposed a model for multi-objective optimization. Mixed integer linear programming model has been applied for solving a bi-level program. Fu et al. (2016) investigated the relocation case of a china airport considering the perspective towards risk of bird strike. Markov chain is applied to analyze the birds' flying procedure and to frame new algorithm in estimating bird strikes with aircraft.

Merkisz-guranowska (2016) developed a method having multiple layers for solving the location selection problem on airport that involves three methods to allow significant progress than the already available approaches. The initial method extends the problem adding up criteria and constructing genetic algorithm. The second method applies theory of fuzzy set whereas the third method advocates the proposed Min approach. Yang et al. (2016) extended ease of access for indicator to airports by transportation on surface and airside. The relation between airport size and scale of aircraft network is determined by structural equation model.

Bo et al. (2014)obtained the advantage of the multiple phase layer fuzzy logic approach which has the ability to remove evaluation disenchantment due to nonsensicalness in the brainpower of human being while multidirectional changes occurs. Liao and Bao (2014) solved the dilemma of airport location selection as a MADM problem and the perception of expert group were expressed with crisp decision matrix affecting the TFN to elucidate preference of the decision makers and built a numerical approach to evaluate, rank and select alternatives. Yang et al. (2014) applied a pair of ranking techniques to assess and ranking airport locations. The primary technique (WLSM) was accepted by the decision makers to calculate the weight and change the linguistic terms into crisp numbers. The subsequent technique was TOPSIS. It was used to compute closeness coefficients to find the ranking order of the alternatives.

Fuzzy ELECTRE-I and fuzzy TOPSIS were used for ranking and selection of the airports (Belbag et al., 2013). The authors considered multiple important criteria such as costs, climatic condition, environmental condition, geographical condition, potential demand, infrastructure, social effects, the extension possibility, and legal regulations and restrictions. Carmona-Benítez et al. (2013) solved the issues of airport location to maximize the total anticipated aircraft passenger requirement as the indispensable aspects by utilizing the wealth index for computing passengers' requirements. Huang B. et al. (2013) employed the GIS method to rank and choose airport location by collecting the geographic information of the intricateairspace area and using programming of super-map to make the geographic catalog. The airspace construction of multifaceted airspace region was compared. Subsequently, the locations of airport were ranked and selected. Zhao and Sun (2013) compared new-fangled airport location selections by two different index methods. The authors measured the evaluating index relative weight and calculated total numerical differences of the schemes.

Postorino and Praticò (2012) applied the multi-criteria decision making model in determination of the position of airports contained by a multi-airport organization. Sur and Majumder (2012) applied the entropy weighting method for evaluation and selection of airport location. Construction related cost per individual was considered a criterion in the model.

The gap analysis of the above literature survey clearly explores that though previous researchers have applied some existing MCDM approaches, still there exists absolute necessity of introducing new MCDM model for solving and making appropriate decision regarding airport ranking and selection under new criteria and specific environment.

The objective of the current paper is to develop and introduce a novel MCDM model under fuzzy environment for making appropriate decision in industrial application and demonstrated by illustration suitable example on airport ranking and selection.

The paper is presented by dividing it into some sections for better illustration. Section 1 presents the short introduction and literature survey. Section 2 presents the proposed mathematical algorithm which is the heart of the paper. Section 3 covers the numerical example along with solution and discussions. Section 4 furnishes some essential concluding remarks and scope for further research.

2. Proposed Algorithm

Let, there is a decision making problem involving multiple alternatives, multiple subjective criteria with vague information and a group of homogeneous decision making experts. For solving such a decision making problem under FMCDM the following algorithm is constructed and proposed.

Step 1: Formation of decision making committee comprising of experts from different important sections of the organizations. The member of the decision making committee can be expressed as follows.

$$D = \left[D_1 \quad \ldots \quad D_k \quad \ldots \quad D_p \right] \tag{1}$$

Here, D_i denotes the i[th] decision maker or expert. Whereas, 'p' is the number of decision makers.

Step 2: Make a list of the available feasible alternatives. The set of listed alternatives are under consideration for performance assessment. The alternatives can be represented in the form of a row matrix as shown in the Eq. (2).

$$A = \left[A_1 \quad \ldots \quad A_i \quad \ldots \quad A_m \right] \tag{2}$$

Here, A_i denotes the i[th] alternative. m is the number of alternatives.

Step 3: Identify the significant criteria for decision making regarding evaluation and selection of the alternatives. The set of decision criteria can be represented in the form of the transpose of a row matrix as shown in the Eq. (3).

$$C = \left[C_1 \quad \ldots \quad C_j \quad \ldots \quad C_n \right]^T \tag{3}$$

Here, C_j denotes the j[th] criterion.

Step 4: Decision matrix: Formation of decision matrix involves alternatives, criteria, decision makers and performance ratings. Each alternative is assessed with respect to each criterion as per the preference of the decision makers in terms of linguistic variables. If all criteria are subjective, then only linguistic variables are used by the decision makers for estimating the performance rating of the alternatives with respect to criteria. The decision matrix is formed by the decision maker applying their knowledge, preference and perceptions.

$$M_L = \begin{matrix} \\ \\ C_1 \\ \cdots \\ C_n \end{matrix} \begin{bmatrix} & A_1 & & \cdots & & A_i & & \cdots & & A_m & \\ D_1 & \cdots & D_p & \cdots & D_1 & \cdots & D_p & \cdots & D_1 & \cdots & D_p \\ x_{11(1)} & \cdots & x_{11(p)} & \cdots & x_{1i(1)} & \cdots & x_{1i(p)} & \cdots & x_{1m(1)} & \cdots & x_{1m(p)} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{n1(1)} & \cdots & x_{n1(p)} & \cdots & x_{ni(1)} & \cdots & x_{ni(p)} & \cdots & x_{nm(1)} & \cdots & x_{nm(p)} \end{bmatrix} \tag{4}$$

Here, $x_{ji(k)}$ denotes the linguistic performance rating of ith alternative with respect jth criterion, assessed by kth decision maker.

Step 5: Decision matrix in interval: Linguistic terms of decision matrix are transformed into intervals. An interval is expressed by two values viz. lower and upper. It is required for quantification of the assessment of the alternatives with respect to criteria. The decision matrix in interval can be represented in following matrix form.

$$\mathrm{M}_{In} = \begin{matrix} \\ \\ C_1 \\ \cdots \\ C_n \end{matrix} \begin{bmatrix} & A_1 & & \cdots & & A_i & & \cdots & & A_m & \\ D_1 & \cdots & D_p & \cdots & D_1 & \cdots & D_p & \cdots & D_1 & \cdots & D_p \\ r_{11(1)} & \cdots & r_{11(p)} & \cdots & r_{1i(1)} & \cdots & r_{1i(p)} & \cdots & r_{1m(1)} & \cdots & r_{1m(p)} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{n1(1)} & \cdots & r_{n1(p)} & \cdots & r_{ni(1)} & \cdots & r_{ni(p)} & \cdots & r_{nm(1)} & \cdots & r_{nm(p)} \end{bmatrix} \tag{5}$$

$r_{ji(k)}$ denotes the fuzzy interval expressing the performance rating of ith alternative under jth criterion by kth decision maker.

Step 6 Determine the geometric mean of performance rating using the following Eq. (6).

$$\left[r_{ij(L)}, r_{ij(L)} \right] = \left[\left(\prod_{k=1}^{p} r_{ji(k)(L)} \right)^{\frac{1}{p}}, \left(\prod_{k=1}^{p} r_{ji(k)(U)} \right)^{\frac{1}{p}} \right] \tag{6}$$

Step 7: Determine the mean crisp performance rating using the Eq. (7a)

$$t_{ji} = \sqrt{r_{ij(L)} \times r_{ji(L)}} \tag{7a}$$

The mean crisp performance rating s of the alternative with respect to criteria are accommodated in a matrix as provided below.

$$M_{CD} = \begin{matrix} \\ C_1 \\ \cdots \\ C_j \\ \cdots \\ C_n \end{matrix} \begin{matrix} A_1 \quad \cdots \quad A_i \quad \cdots \quad A_m \\ \begin{bmatrix} t_{11} & \cdots & t_{1i} & \cdots & t_{1m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ t_{j1} & \cdots & t_{ji} & \cdots & t_{jm} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ t_{t1} & \cdots & y_{ni} & \cdots & t_{nm} \end{bmatrix} \end{matrix} \tag{7b}$$

Here t_{ji} is mean crisp performance rating of the ith alternative with respect to jth criterion.

Step 8: Construct the weight matrix in linguistic variables. Importance weights of the different criteria may vary from criteria to criteria, decision maker to decision maker and problem to problem. In the current problem each decision maker estimates impotence weight for each criterion based on own experience, knowledge and perception. Varying degrees of linguistic variables are used for the purpose of measuring the importance weights of the criteria which are accommodated in the following matrix.

$$W_{LV}=\begin{array}{c} \\ C_1 \\ \cdots \\ C_j \\ \cdots \\ C_n \end{array}\begin{array}{c} \begin{array}{ccccc} D_1 & \cdots & D_k & \cdots & D_m \end{array} \\ \begin{bmatrix} y_{11} & \cdots & y_{1k} & \cdots & y_{1m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ y_{j1} & \cdots & y_{jk} & \cdots & y_{jm} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ y_{n1} & \cdots & y_{nk} & \cdots & y_{nm} \end{bmatrix} \end{array} \tag{8}$$

Here, y_{jk} is the linguistic weight of j^{th} criterion provided by the k^{th} decision maker. Here, m is the number of decision makers and *n* is the number of criteria.

Step 9: Conversion of linguistic weights into corresponding intervals. This conversion is absolutely necessary for quantification of assessment. The importance weights of the criteria in terms of interval can be represented in the following matrix.

$$W_{in}=\begin{array}{c} \\ C_1 \\ \cdots \\ C_j \\ \cdots \\ C_n \end{array}\begin{array}{c} \begin{array}{ccccc} D_1 & \cdots & D_k & \cdots & D_p \end{array} \\ \begin{bmatrix} z_{11} & \cdots & z_{1k} & \cdots & z_{1p} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ z_{j1} & \cdots & z_{jk} & \cdots & z_{jp} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ z_{n1} & \cdots & z_{nk} & \cdots & z_{np} \end{bmatrix} \end{array} \tag{9}$$

$z_{jk}=\left(z_{jk(L)},z_{jk(U)}\right)$ denotes the importance weight of the jth criterion assigned by k^{th} decision maker.

Step 10: Calculate the average criteria weight in interval by calculating the arithmetic mean of the lower and upper values separately by using Eq. (10).

$$\left(u_{j(L)},u_{j(U)}\right)=\left(\frac{1}{p}\sum_{i=1}^{p}z_{jk(L)},\frac{1}{p}\sum_{i=1}^{p}z_{jk(U)}\right) \tag{10}$$

Step 11: Compute the crisp weight for each criterion using the Eq. (11).

$$v_j=\sqrt{u_{j(L)}\times u_{j(U)}} \tag{11}$$

$u_{j(L)}$ denotes the lower value of the interval and $u_{j(U)}$ denotes the upper value of the interval. v_j is the geometric mean of $u_{j(L)}$ and $u_{j(U)}$.

Step 12: Measure the normalized crisp weight using the following normalization Eq.(12).

$$w_j=\frac{v_j}{\sum_{i=1}^{n}v_j} \tag{12}$$

Here, w_j denotes the normalized crisp weight of the *j*th criterion.

Step 13: Determine individual contribution. This investigation suggests implementation of trigonometric functions for measuring the contribution of individual criterion towards the performance evaluation of the alternatives under consideration. Individual contribution of each criterion to each alternative is computed by applying the Eq. (13).

$$s_{ij} = \lambda \times \left(1 - \cos w_j\right) \times \sin t_{ji} \qquad (13)$$

λ is a modifier. If the modifier is less than unity it can be termed as reducer. If the modifier is greater than unity it can be termed as amplifier. The exact value depends upon the data of the associated problem and the decision of the decision makers.

Step 14: Determine total contribution. It is the aggregate of the total individual contribution of all the criteria under consideration applying the Eq. (14).

$$S_i = \lambda \times \sum_{j=1}^{n} \left(1 - \cos w_j\right) \times \sin t_{ji} \qquad (14)$$

Arrange the alternative according to decreasing order of the total contribution of.
Select the best alternative with the highest total contribution.

3. Illustrative Example

The proposed algorithm has been illustrated by a suitable decision making problem on airport selection. The problem is discussed by subdivided it into two subsections viz. problem definition, calculation and discussion as described below.

3.1 Problem Definition

The proposed algorithm is demonstrated by illustrating a suitable example on airport selection considering subjective criteria though homogeneous group decision making. This example is partially cited from Wang et al. (2007).

In this example, a decision making committee is formed with four rational decision makers having necessary knowledge in the domain. The decision makers are denoted by D1, D2, D3 and D4. The members of the decision making committee unanimously decided to consider a set of 15 subjective criteria vz. C1: Return to capital (operation profit), C2: Cleanness and comfort at terminal, C3: Trolley move toward travelers, C4: Direction and signal, C5: Aerodrome controlling system, C6: Security, C7: Check-in and check-out system and time, C8: Take-off and loading time, C9: Traffic connecting city, C10: Crew courtesy, C11: Airport scale, C12: Parking lots, C13: Noise pollution system, C14: Navigation controlling system, and C15: Aircraft safety control.

Three alternative airports are initially chosen for further evaluation. The airports are designated by A1, A2 and A3. The proposed multi-criteria decision making algorithm is applied for evaluation, ranking and selection of the airport under consideration. The solution procedure of the airport selection problem is illustrated through the demonstration of the developed and proposed paradigm in the following subsection.

3.2 Calculation and Discussions

In the current decision making problem, there are three alternative airports, fifteen criteria and four decision makers. All criteria are subjective with imprecision, vagueness and ambiguity. Hence linguistic variables are used by the decision makers for estimating the associated performance rating of the alternative airports. Seven degrees of linguistic variables viz. very poor, poor, medium poor, fair, medium good, good and very good are used for estimation of performance ratings. For quantification of each linguistic variable specific fuzzy interval is used. The linguistic variables, abbreviations and corresponding fuzzy intervals for measuring performance rating are represented in Table 1.

Table1. Linguistic variable, abbreviation and interval for performance rating

Linguistic Variables	Abbreviations	Intervals
Very Poor	VP	[0,0.2]
Poor	P	[0.1, 0.3]
Medium poor	MP	[0.2,0.4]
Fair	F	[0.4, 0.6]
Medium Good	MG	[0.6,0.8]
Good	G	[0.7, 0,9]
Very Good	VG	[0.8, 1]

In ranking and selection of alternative airports, various decision criteria are given varying importance weight by the experts based on their significance as per the decision makers' experience, knowledge and perceptions. For the purpose of extracting this importance weights decision makers generally prefer linguistic terms. The present investigation advocates five degrees of linguistic terms viz. very low, low, medium, high and very high. The linguistic terms, abbreviation and associate fuzzy intervals are accommodated in Table 2.

Table 2: Linguistic variables, abbreviations and intervals for criteria weight

Linguistic Variables	Abbreviations	Intervals
Very Low	VL	(0, 0.3)
Low	L	(0, 0.5)
Medium	M	(0.3, 0.7)
High	H	(0.5, 1)
Very High	VH	(0.7, 1)

Three alternative airports are assessed by four decision makers using the prescribed seven degrees of linguistic variables which are regarded as the performance ratings of the alternatives. It is seen that decision makers D1, D2, D3 and D4 estimate alternative A1 with MG, G, G, VG with respect to criterion C1. Alternative A2 is assessed with VG, G, MG, MG. Here, VG implies very good, G means good, MG implies medium good. All the other abbreviation bears the similar meanings as described earlier. The decision matrix containing performance rating in terms of linguistic variable is presented in Table 3.

Table 3. Decision matrix in linguistic variables expressing performance ratings

	A1				A2				A3			
Ci	D1	D2	D3	D4	D1	D2	D3	D4	D1	D2	D3	D4
C1	MG	G	G	VG	VG	G	MG	MG	MG	F	MG	F
C2	MG	VG	G	MG	G	G	VG	G	G	VP	G	G
C3	VG	F	F	MG	VG	G	MG	G	VG	VP	G	G
C4	VG	G	VG	VG	F	MG	MG	MG	MG	MG	G	MG
C5	G	MG	F	G	MG	F	F	G	F	VG	G	MG
C6	VG	G	VG	VG	MG	VG	G	G	G	F	MG	G
C7	F	G	MG	G	G	MG	VG	MG	VG	MG	VG	G
C8	MG	VG	MG	G	VG	F	VG	G	G	G	VG	MG
C9	VG	G	G	VG	MG	G	G	VG	VG	G	VG	VG
C10	G	G	G	F	G	MG	G	G	G	VG	G	MG
C11	G	VG	MG	MG	VG	MG	G	MG	VG	MG	G	G
C12	G	VG	G	MG	VG	G	VG	G	G	G	VG	MG
C13	F	MG	MG	G	F	MG	F	MG	G	G	VG	VG
C14	VG	MG	MG	VG	MG	MG	G	VG	F	MG	G	MG
C15	G	VG	F	G	MG	F	VG	G	F	F	F	F

The linguistic terms expressing performance ratings are converted into fuzzy interval as per prescribed conversion scale. Each fuzzy interval has two value viz. lower value and upper value. Application of fuzzy interval value is recommended for simplicity in calculation and having capability of conveying information. Geometric mean of the performance rating is determined using the Eq.(6). The fuzzy intervals of the alternative A1 with respect to criterion C1 assessed by the four decision makers D1, D2, D3 and D4 are [0.6, 0.8], [0.7, 0.9], [0.7, 0.9] and [0.8, 1] respectively. Therefore, the geometric mean of the performance rating in fuzzy interval is calculated as $(0.6\times0.7\times0.70.8)^{1/4}=(0.4141,\ 0.5045)$. The other mean performance ratings in fuzzy intervals are similarly calculated and accommodated in Table 4.

Table 4. Mean performance ratings in fuzzy intervals

	Alternative Airports			
Criteria	A1	A2	A3	A4
C1	(0.4141, 0.5045)	(0.6447, 0.8459)	(0.6447, 0.8459)	(0.4899, 0.6928)
C2	(0.6701, 0.8239)	(0.7238, 0.9240)	(0.7238, 0.9240)	(0.7238, 0.9240)
C3	(0.4757, 0.6447)	(0.6964, 0.8972)	(0.6964, 0.8972)	(0.7483, 0.9487)
C4	(0.8181, 0.9740)	(0.5422, 0.7445)	(0.5422, 0.7445)	(0.6236, 0.8239)
C5	(0.6236, 0.7896)	(0.5091, 0.6447)	(0.5091, 0.6447)	(0.6055, 0.8107)
C6	(0.8181, 0.9740)	(0.6964, 0.8426)	(0.6964, 0.8426)	(0.5856, 0.7896)
C7	(0.6236, 0.7896)	(0.6701, 0.8239)	(0.6701, 0.8239)	(0.7200, 0.5180)
C8	(0.7135, 0.8712)	(0.6506, 0.8107)	(0.6506, 0.8107)	(0.6964, 0.8972)
C9	(0.7913, 0.9487)	(0.6964, 0.8426)	(0.6964, 0.8426)	(0.7737, 0.974)
C10	(0.6735, 0.8132)	(0.6735, 0.8207)	(0.6735, 0.8207)	(0.6964, 0.8972)
C11	(0.7200, 0.8712)	(0.6701, 0.8181)	(0.6701, 0.8181)	(0.6964, 0.8972)
C12	(0.7483, 0.8972)	(0.7483, 0.8972)	(0.7483, 0.8972)	(0.6964, 0.8972)

Table 4. Mean performance ratings in fuzzy intervals

	Alternative Airports			
Criteria	A1	A2	A3	A4
C13	(0.6000, 0.7667)	(0.4899, 0.6260)	(0.4899, 0.6260)	(0.7483, 0.9487)
C14	(0.6928, 0.8459)	(0.6701, 0.8181)	(0.6701, 0.8181)	(0.5635, 0.7667)
C15	(0.6701, 0.8349)	(0.6055, 0.7667)	(0.6055, 0.7667)	(0.4000, 0.6000)

Mean performance rating in crisp numbers is calculated by using Eq. (7a) in the manner $\sqrt{0.4141 \times 0.5045} = 0.4571$ for the alternative A1 under criterion C1. The remaining values are similarly calculated and have been put in Table 5.

Table 5. Mean performance rating in crisp numbers

	Alternative Airports			
Ci	A1	A2	A3	A4
C1	0.4571	0.7385	0.7385	0.5826
C2	0.7430	0.8178	0.8178	0.8178
C3	0.5538	0.7905	0.7905	0.8426
C4	0.8927	0.6353	0.6353	0.7168
C5	0.7017	0.5729	0.5729	0.7006
C6	0.8927	0.7660	0.7660	0.6800
C7	0.7017	0.7430	0.7430	0.6107
C8	0.7884	0.7263	0.7263	0.7905
C9	0.8664	0.7660	0.7660	0.8681
C10	0.7401	0.7435	0.7435	0.7905
C11	0.7920	0.7404	0.7404	0.7905
C12	0.8194	0.8194	0.8194	0.7905
C13	0.6783	0.5538	0.5538	0.8426
C14	0.7655	0.7404	0.7404	0.6573
C15	0.7480	0.6814	0.6814	0.4899

Linguistic weights of criteria assessed by the decision makers using their own experience as well as knowledge ate presented in Table 6.

Table 6. Linguistic weights of criteria assessed by the decision makers

Ci	D1	D2	D3	D4
C1	Medium	Very High	Medium	High
C2	High	High	Medium	Very High
C3	Medium	Medium	High	Medium
C4	Low	Medium	Very High	Medium
C5	Very High	Very High	Very High	Very High
C6	Very High	High	Very High	Very High
C7	High	Very High	Medium	High
C8	Medium	High	Very High	Medium
C9	Medium	Medium	High	Medium
C10	Low	Medium	High	Very High

Table 6. Linguistic weights of criteria assessed by the decision makers

Ci	D1	D2	D3	D4
C11	Very High	High	Very High	Medium
C12	High	High	Medium	Low
C13	High	Medium	High	High
C14	Medium	High	Medium	High
C15	High	Very High	High	Very High

The linguistic variables expressing weights of criteria are required to transform into corresponding fuzzy interval to initiate the process towards quantification of weights of criteria. The weights in fuzzy intervals are inserted in Table 7.

Table 7. Weights of criteria in fuzzy intervals

Ci	D1	D2	D3	D4
C1	(0.3, 0.7)	(0.7, 1)	(0.3, 0.7)	(0.3, 0.7)
C2	(0.5, 1.0)	(0.3, 0.7)	(0.3, 0.7)	(0.7, 1)
C3	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)
C4	(0.0 0.5)	(0.3, 0.7)	(0.7, 1)	(0.3, 0.7)
C5	(0.7, 1.0)	(0.7, 1)	(0.7, 1)	(0.7, 1)
C6	(0.7, 1.0)	(0.3, 0.7)	(0.7, 1)	(0.7, 1)
C7	(0.3, 0.7)	(0.7, 1)	(0.3, 0.7)	(0.3, 0.7)
C8	(0.3, 0.7)	(0.3, 0.7)	(0.7, 1)	(0.3, 0.7)
C9	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)
C10	(0.0, 0.5)	(0.3, 0.7)	(0.3, 0.7)	(0.7, 1)
C11	(0.7, 1.0)	(0.3, 0.7)	(0.7, 1)	(0.3, 0.7)
C12	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)	(0, 0.5)
C13	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)
C14	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)	(0.3, 0.7)
C15	(0.3, 0.7)	(0.7, 1)	(0.3, 0.7)	(0.7, 1)

Mean (arithmetic) weights of criteria in fuzzy interval is calculated by using Eq. (10) and the conversion of crisp weights is accomplished by using Eq. (11). Mean fuzzy weights and normalized crisp weight are presented in Table 8.

Table 8. Mean weights in interval and in crisp numbers.

Criteria	Weight in interval	GM	Weights in crisp
C1	(0.4, 0.775)	0.5568	0.0679
C2	(0.45, 0.85)	0.6185	0.0754
C3	(0.3, 0.7)	0.4583	0.0558
C4	(0.325, 0.725)	0.4854	0.0592
C5	(0.6, 0.775)	0.6819	0.0831
C6	(0.6, 0.925)	0.7450	0.0908
C7	(0.4, 0.775)	0.5568	0.0679
C8	(0.4, 0.775)	0.5568	0.0679
C9	(0.3, 0.7)	0.4583	0.0558
C10	(0.325, 0.725)	0.4854	0.0592

Table 8. Mean weights in interval and in crisp numbers.

Criteria	Weight in interval	GM	Weights in crisp
C11	(0.5, 0.85)	0.6519	0.0794
C12	(0.225, 0.65)	0.3824	0.0466
C13	(0.3, 0.7)	0.4583	0.0558
C14	(0.3, 0.7)	0.4583	0.0558
C15	(0.5, 0.85)	0.6519	0.0794

Table 9. Weighted individual contribution

Ci	A1	A2	A3	A4
C1	0.1016	0.1549	0.1266	0.1266
C2	0.1921	0.2071	0.0000	0.0000
C3	0.0936	0.1108	0.0000	0.0000
C4	0.1362	0.1038	0.1149	0.1149
C5	0.2228	0.1871	0.2225	0.2225
C6	0.3207	0.2855	0.2590	0.2590
C7	0.1485	0.1557	0.1320	0.1320
C8	0.1632	0.1528	0.1635	0.1635
C9	0.1188	0.1081	0.1190	0.1190
C10	0.1180	0.1184	0.1243	0.1243
C11	0.2245	0.2128	0.2242	0.2242
C12	0.0793	0.0793	0.0772	0.0772
C13	0.0978	0.0820	0.1164	0.1164
C14	0.1080	0.1052	0.0952	0.0952
C15	0.2145	0.1987	0.1484	0.1484

Normalized crisp weights and normalized fuzzy performance ratings are integrated together to compute contribution by individual criterion using Eq. (13) and the calculated weighted individual contribution are depicted in Table 9. Aggregate Performance Score (APS) of the airports are determined from the algebraic summing up of the individual contributions for each alternative airport. APS for each alternative is presented in Table 10.

Table 10. Aggregate Performance Score (APS) of the airports

	A1	A2	A3
APS	2.3396	2.2621	1.9230
Rank	1	2	3

The APS for the alternatives A1, A2 and A3 in decreasing order are 2.3396, 2.2621 and 1.9230 respectively. Therefore the ranking orders of the airports A1, A2, A3 are 1, 2 and 3 respectively. A1 is selected as the best airport and A3 as the worst airport. The result is compared with the results obtained by two well-known and well established existing techniques viz. TOPSIS and SAW. PIS, NIS, Closeness coefficients and ranks of the airports by TOPSIS method are represented in Table 11.

Table 11. PIS, NIS, Closeness coefficient and rank of the airports by TOPSIS

Ci	A1	A2	A3	PIS	NIS
C1	0.0310	0.0501	0.0395	0.0501	0.0310
C2	0.0560	0.0616	0.0000	0.0616	0.0000
C3	0.0360	0.0441	0.0000	0.0441	0.0000
C4	0.0528	0.0376	0.0424	0.0528	0.0376
C5	0.0583	0.0476	0.0582	0.0583	0.0476
C6	0.0810	0.0695	0.0617	0.0810	0.0617
C7	0.0476	0.0504	0.0414	0.0504	0.0414
C8	0.0535	0.0493	0.0536	0.0536	0.0493
C9	0.0484	0.0428	0.0485	0.0485	0.0428
C10	0.0438	0.0440	0.0468	0.0468	0.0438
C11	0.0629	0.0588	0.0628	0.0629	0.0588
C12	0.0382	0.0382	0.0368	0.0382	0.0368
C13	0.0379	0.0309	0.0471	0.0471	0.0309
C14	0.0428	0.0413	0.0367	0.0428	0.0367
C15	0.0594	0.0541	0.0389	0.0594	0.0389
S+	0.0238	0.0411	0.1585	---	---
S-	0.155	0.131813	0.021726	---	---
CC	0.867	0.762292	0.12056	---	---
Rank	1	2	3	---	---

The same problem is solved by SAW method. Calculated composite scores and ranking orders of the alternative airports obtained by applied SAW method are decorated in Table 12. It is seen that the composite scores of the airports A1, A2, A3 are 0.750, 0.720 and 0.615 reactively. Since, the higher composite score is better, airport A1 is ranked 1, A2 is ranked 2 and A3 is ranked is 3.

Table 12. Composite score and ranking by SAW method

Airports	A1	A2	A3
Composite score	0.750	0.720	0.615
Rank	1	2	3

Table 13. Comparison of ranking order

Methods	A1	A2	A3
Rank by proposed Method	1	2	3
Rank by TOPSIS Method	1	2	3
Ranking by SAW method	1	2	3

Comparison of ranking orders obtained by the proposed method with TOPSIS and SAW are shown in Table 13. Aggregate performance score of the airports are graphically represented in Figure 1. for better visibility and demonstration.

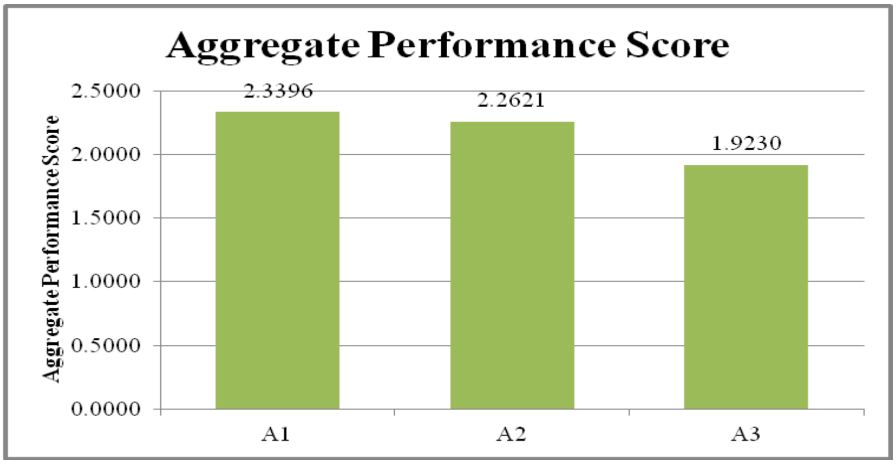

Figure 1. Aggregate performance score of the airports

The ranking orders of the airports is depicted in Figure 2. It is observed that airport A1is ranked 1, airport A2 is ranked 3 and airport A3 is ranked 3. Therefore the preferene order is A1>A2>A3.

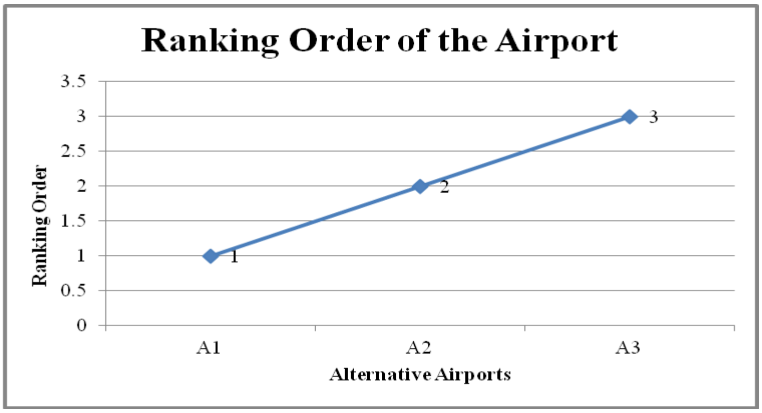

Figure 2. Ranking orders of the airports

4. Conclusion

This research work aims to develop and implement a new framework for evaluating, ranking and selecting the best airports considering multiple conflicting criteria incorporating group homogeneous decision makers' experience, opinion, knowledge and perception. The proposed method has been demonstrated through the illustration of a airport selection problem containing three feasible airports, fifteen subjective criteria and four rational decision makers. The result clearly indicates the best airport ensuring the better applicability of the method. The same problem on airport selection is also solved and the result is compared with that of the proposed approach. It is found that the result obtained by the proposed method completely matches with those of the existing approaches. The proposed Interval based Multi-criteria homogeneous Group Decision making technique (IMGD) can also be applied for solving similar decision making problem under FMCDM. The approach may be useful FMCDM tool for individual as well as managerial decision makers. Heterogeneous group decision making by considering interdependent multiple conflicting criteria may be the direction of future research.

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