RESEARCH ARTICLE OPEN ACCESS

Group Decision Making Under Intuitionistic Fuzzy Environment Based On Topsis Method

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ABSTRACT:
Decision making can become more effective and purpose serving only when group of experts well acquainted with all the criteria pertaining to decision making. It is therefore the result of collective efforts. All the participants of the decision making are not equally talented. Varied weights are to be assigned to different criteria according to their contributions. This article makes a novel approach to determine the weights of criteria by using the TOPSIS (Technique for order preference similarity to Ideal solution) method and intuitionistic fuzzy setting.

KEY WORDS: Triangular intuitionistic fuzzy set, Triangular intuitionistic fuzzy numbers, Multi criteria decision making, Multiple attributes group decision making, TOPSIS method.

Date of Submission: 23-02-2021 Date of Acceptance: 07-03-2021

I. INTRODUCTION

In the dynamic world wheels of progress are rotating at sky – rocketing speed in order to make these changes favorable for bringing about the desired changes. Desired changes can be brought about by considering multi criteria over which a decision maker may not be well verse. Individual decision makers can have caliber, understanding and expertise of one or more criteria to make the decision complete effective and fruitful. The coordinated effects of multiple decision makers are essential. To make it practically understandable, different weights of criteria are decided in advance. This is because of the reason that the decision makers are usually hailing from varied fields. They may be possessing distinctive characteristics, specialized knowledge and skill sets. Each decision maker may be familiar with one or few criteria but not with all the criteria. The decision maker who is unfamiliar with criteria may not be able to assign proper evaluation values for the criteria. If each expert assigns the same or equal weights for all the criteria, unreasonable decision will result and wrong alternative mat be selected . Determining fairly reasonable weights for criteria has therefore become an important and interesting research topic. A more effective and useful method is to assign weights of criteria is by using the TOPSIS method wherein weights are computed by utilizing the distance of evaluation value from the positive ideal solution (PIS), the left negative ideal solution (NIS) and right negative ideal solution respectively. TOPSIS is extensively studied and widely applied. TOPSIS is one that is the nearest to the positive ideal alternative and at the same time it is the farthest from the negative ideal alternative.

Intuitionistic Fuzzy Set (IFS) developed by Atanassov is a powerful tool to deal with vagueness. A prominent characteristic of IFS is that it assigns to each element a membership degree and a non-membership degree and thus, the IFS constitutes an extension of Zadeh's fuzzy set, which exclusively assigns to each element a membership degree. In the last two decades many authors have paid attention to the IFS theory that has been successfully applied in different areas such as, logic programming, decision making problems, medical diagnosis etc., Recently various applications of IFS to artificial intelligence have appeared intuitionistic fuzzy expert systems, intuitionistic fuzzy neural networks, intuitionistic fuzzy decision making, intuitionistic fuzzy machine learning intuitionistic fuzzy semantic representations etc.,

II. NEWLY REVISED MAGDM ALGORITHM IN INTUITIONISTIC FUZZY SETUP

In the decision making process, Several Criteria which may emanate from various sources are taken into consideration for formulating scientific decisions. Let us assume that there is a multiple criteria decision making problem in the following manner. Let $\{C_1, C_2, C_3 .... C_t\}$ be the set of Criteria, $\{S_1, S_2, S_3 .... S_m\}$ be the set of alternative sources and $\{A_1, A_2, A_3 .... A_n\}$ be the set of attributes. The Criteria $\{C_k\}$ is used to evaluate the alternative $\{S_i\}$ with respect to the attributes to obtain the evaluate value

$$x_{ij}^{(k)} = \left(u_{ij}^{(k)}, v_{ij}^{(k)} \right) k = 1, 2, \ldots t,$$

then the decision matrix $D^{(k)}$ is as follows:

$$D^{(k)} = (x_{ij}^{(k)})_{m \times n} = \begin{bmatrix} x_{11}^{(k)} & x_{12}^{(k)} & . & . & . & x_{1n}^{(k)} \\ x_{21}^{(k)} & x_{22}^{(k)} & . & . & . & x_{2n}^{(k)} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_{m1}^{(k)} & x_{m2}^{(k)} & . & . & . & x_{mn}^{(k)} \end{bmatrix}.$$

While proceeding with decision making process, varied decision matrices should be added together in order to form a collective one.

In the dynamic set up, science and technology are developing fast and the problem confronted for arriving at a decision emerges as a complex and complicated one. By taking into consideration many alternatives the best and optimal one is to be selected. Over and above the criteria, human element is involved in taking into consideration of criteria and arriving at the concrete and constructive decision. The human being involved in making decisions may differ in their caliber and capabilities. If in decision making, human beings are assigned with identical weights for all the attributes, accurate and acceptable results cannot be the outcome. Each criteria has its own characteristic in contributing for the decision . If the human being involved in decision making is familiar and well verse with one or few criteria, it or they should be assigned with appropriate evaluation value . If each criteria and its attributes are analyzed for the purpose of assigning appropriate weight for the attributes, the resultant computation will become excessively large and will result in poor accuracy TOPSIS is widely used technique in the real time decision making . In TOPSIS the alternative decisions are arranged according to theie rank and the size of closeness co-efficient computed by utilizing the positive ideal solution and negative ideal solution. For the purpose of avoiding the influence of unreasonably high or low evaluation value of ranking, the evaluation value very close to the positive ideal evaluation value and faraway from negative ideal evaluation values. They should have at the same time large weight and the evaluation values in respect of other cases should have small weights. The average evaluation value can therefore be observed as an intuitionistic fuzzy positive ideal evaluation value identical to that in Yue (2011). In this manner the intuitionistic fuzzy positive ideal matrix can be depicted as

$$D^{+} = (x_{ij}^{+})_{m \times n} = \begin{bmatrix} x_{11}^{+} & x_{12}^{+} & . & . & . & x_{1n}^{+} \\ x_{21}^{+} & x_{22}^{+} & . & . & . & x_{2n}^{+} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_{m1}^{+} & x_{m2}^{+} & . & . & . & x_{mn}^{+} \end{bmatrix}$$

where $x_{ij}^{+} = \left(\sum_{k=1}^{t} x_{ij}^{(k)} \right) / t,\ i = 1, 2, \ldots, m,\ j = 1, 2, \ldots, n,\ k = 1, 2, \ldots, t,$ denote intuitionistic fuzzy positive ideal solutions (IFPIS). The intuitionistic fuzzy negative ideal solution portioned in to two parts, viz., D_{d}^{-} and D_{u}^{-} :

$$D_{d}^{-} = (x_{ij}^{d})_{m \times n} = \begin{bmatrix} x_{11}^{d} & x_{12}^{d} & . & . & . & x_{1n}^{d} \\ x_{21}^{d} & x_{22}^{d} & . & . & . & x_{2n}^{d} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_{m1}^{d} & x_{m2}^{d} & . & . & . & x_{mn}^{d} \end{bmatrix}$$

$$D_{d}^{-} = (x_{ij}^{u})_{m \times n} = \begin{bmatrix} x_{11}^{u} & x_{12}^{u} & . & . & . & x_{1n}^{u} \\ x_{21}^{u} & x_{22}^{u} & . & . & . & x_{2n}^{u} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_{m1}^{u} & x_{m2}^{u} & . & . & . & x_{mn}^{u} \end{bmatrix}$$

Wherein $x_{ij}^{d} = \min\{ x_{ij}^{(k)} \le x_{ij}^{+} \}$ and $x_{ij}^{u} = \max\{ x_{ij}^{(k)} \ge x_{ij}^{+} \}$ denote the intuitionistic fuzzy negative ideal solutions (IFNIS).

The distance between $x_{ij}^{(k)} = \left(u_{ij}^{(k)}, v_{ij}^{(k)} \right)$ and $x_{ij}^{+} = \left(u_{ij}^{(k)}, v_{ij}^{(k)} \right)$, $x_{ij}^{d} = \left(u_{ij}^{d}, v_{ij}^{d} \right)$, $x_{ij}^{u} = \left(u_{ij}^{u}, v_{ij}^{u} \right)$ can be defined, respectively, as follows:

$$d_{ij}^{+} = \frac{1}{2}\left(\left|u_{ij}^{(k)} - u_{ij}^{+}\right| + \left|v_{ij}^{(k)} - v_{ij}^{+}\right|\right)$$

$$d_{ij}^{d} = \frac{1}{2}\left(\left|u_{ij}^{(k)} - u_{ij}^{d}\right| + \left|v_{ij}^{(k)} - v_{ij}^{d}\right|\right)$$

$$d_{ij}^{u} = \frac{1}{2}\left(\left|u_{ij}^{(k)} - u_{ij}^{u}\right| + \left|v_{ij}^{(k)} - v_{ij}^{u}\right|\right)$$

The closeness coefficient of $x_{ij}^{(k)}$ is determined by

$$c_{ij}^{(k)} = \frac{d_{ij}^{u} + d_{ij}^{d}}{d_{ij}^{u} + d_{ij}^{d} + d_{ij}^{+}}, \; i = 1,2,\ldots\ldots m, \quad j = 1,2,\ldots\ldots n, \; k = 1,2,3\ldots.., \; t,$$

and the weight of decision maker C_k for the alternative S_i and with respect to the attribute A_j can be determined as :

$$w_{ij}^{(k)} = \frac{c_{ij}^{(k)}}{\sum_{k=1}^{t} c_{ij}^{(k)}}, \; i = 1,2,\ldots\ldots m, \; j = 1,2,\ldots\ldots n, \; k = 1,2,3\ldots.., \; t,$$

wherein $w_{ij}^{(k)} \geq 0, \; \sum_{k=1}^{t} w_{ij}^{(k)} = 1$. The new weights are large if the evaluation value is nearer to the IFPIS. It is small if the evaluation value is nearer to the IFNIS.

After assigning the new weights we can add up the intuitionistic fuzzy evaluation value $x_{ij}^{(k)} \; (k = 1,2,\ldots\ldots t)$ computed by various decision makers $C_k \; (k = 1,2,\ldots\ldots t)$ into a collective one x_{ij} , by using the intuitionistic fuzzy weighted averaging (IFWA) operator:

$$x_{ij} = w_{ij}^{(1)} x_{ij}^{(1)} + w_{ij}^{(2)} x_{ij}^{(2)} + \ldots\ldots + w_{ij}^{(t)} x_{ij}^{(t)} .$$

We can therefore get the intuitionistic fuzzy collective decision matrix D as given below

$$D = (x_{ij}^{+})_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & . & . & . & x_{1n} \\ x_{21} & x_{22} & . & . & . & x_{2n} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_{m1} & x_{m2} & . & . & . & x_{mn} \end{bmatrix} .$$

With the help of the above fuzzy collective decision matrix D we can evolve a new MAGDM algorithm with the view to make it suitable to varied situations about the attribute weight information. If the criteria weight vectors are exactly known, the TOPSIS approach in the intuitionistic fuzzy setting can be utilized for ranking alternatives directly. The attribute weight must be computed firstly if it is partly known or completely unknown in the decision making process situation wherein the attribute weight information is not known accurately, but only a part can be obtained. The partly known attribute weight information can be elucidated as some subset of the following types which show the relationship as follows:

1) A weak ranking: $\{w_i \geq w_j\},\ i \neq j;$

2) A Strict ranking: $\{w_i - w_j \geq \varepsilon(>0)\},\ i \neq j;$

3) A ranking with multiples: $\{w_i \geq x_i w_j\}, 0 \leq x_i \leq 1, i \neq j;$

4) An interval form: $\{\beta_j \leq w_j \leq \beta_j + \varepsilon_j\}, 0 \leq \beta_j \leq \beta_j + \varepsilon_j \leq 1;$

5) A ranking of differences: $\{w_i - w_j \geq w_k - w_l\}$, for $i \neq j \neq k \neq 1$

The attribute weight information set can be denoted by H. As per the information theory the evaluation values of the attributes are nearer to positive ideal evaluation value and are at a considerable distance from the negative evaluation value. They should at the same time have large weight. Based on this principle, we can compute the closeness coefficient C_{ij} of each of the x_{ij} collective evaluation value in accordance with its distances to positive ideal value $x_j^+ = (1,0)$ and the negative ideal value $x_j^- = (0,1)$ is given below

$$C_{ij} = \frac{d\left(x_{ij}, x_j^-\right)}{d\left(x_{ij}, x_j^+\right) + d\left(x_{ij}, x_j^-\right)}, i = 1,2,\ldots.m,\ j = 1,2\ldots\ldots.n$$

Next to this the weighted closeness co-efficient is computed in the following manner.

$$C_i = \sum_{j=1}^{m} c_{ij} w_j,\ i = 1,2,\ldots\ldots\ m$$

An acceptable weight vector $w = (w_1, w_2, \ldots\ldots\ldots\ ..w_n)$ should produce the closeness co-efficient as large as possible. By doing so we formulate the below mentioned multiple objective programming model

$$\max \left\{ \sum_{j=1}^{m} c_{1j} w_j, \ldots\ldots\ldots .., \sum_{j=1}^{n} c_{mj} w_j \right\} \quad such \quad that \quad W \in H$$

$$w_j \geq 0,\ j = 1,2,\ldots\ldots n$$

$$w_1 + w_2 + \ldots\ldots\ldots + w_n = 1$$

As all the possible objective are equally important we can transform them into the following single objective by the equally weight summation method. (French at al.1983)

$$\max \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} w_j \quad such \quad that \quad W \in H$$

$$w_j \geq 0,\ j = 1,2,\ldots\ldots\ n$$

$$w_1 + w_2 + \ldots\ldots\ldots + w_n = 1$$

In the model furnished above, the attribute weight $w_j\ (j = 1,\ldots\ldots\ n)$ remains unknown. Therefore it becomes the linear programming problem which could be solved many algorithms like interior point algorithm, a simplex method etc…..

In certain cases, the attribute weight information remains completely unknowns. In such situation we can assign large weights in accordance with the principles that the attributes collective evaluation. Values are remaining either or closer to the intuitionistic fuzzy positive value or far away from the intuitionistic fuzzy negative ideal value. The attribute weight can be found out by

$$w_j = \frac{c_j}{\sum_{j=1}^{n} c_j} = \frac{\sum_{i=1}^{m} c_{ij}}{\sum_{j=1}^{n}\sum_{i=1}^{m} c_{ij}}, \; j = 1,2,\ldots\ldots.. n$$

where c_{ij} is decided by

$$c_{ij} = \frac{d(x_{ij}, x_j^-)}{d(x_{ij}, x_j^+) + d(x_{ij}, x_j^-)} \; i = 1\ldots\ldots.. m, \quad j = 1,2,\ldots\ldots\ldots \ldots\ldots n$$

and $w_j \geq 0, \sum_{j=1}^{n} w_j = 1.$

III. ALGORITHMIC APPROACH OF THE TOPSIS METHOD

Step: 1 Constitute a committee of decision makers for the purpose of identifying evaluation criteria.

Step: 2 Select the suitable linguistic variable and find out the important weight of the criteria and the Linguistic rating assigned to the alternatives with respect to criteria.

Step: 3 The aggregate of the assigned weight of criteria to find out the total fuzzy weight w_j and put together the decision makers options for the purpose of getting the total fuzzy ratings $\tilde{x}_{ij}$ of the alternative A_i under criterion C_j.

Step: 4 Build up the Fuzzy decision matrix and the normalized fuzzy decision matrix.

Step: 5 Build up the weight of Fuzzy Decision matrix.

Step: 6 Build up Fuzzy positive ideal solution and Fuzzy negative ideal solution .

Step: 7 Compute and find out the distance of each alternative Fuzzy positive ideal solution respectively.

Step: 8 In accordance with the closeness coefficients, the ranking order of all the selected alternatives can be decided.

IV. NUMERICAL EXAMPLE

The investment decision making criteria in IT companies are evaluated on the basis of five variables. These variables are extended by A_1, A_2 and A_3 the committee of three investors D_1, D_2 and D_3 has been formed to proceed with an evaluation to find out the appropriate.

(1) Equity Capital (C_1)

(2) Earnings per share (C_2)

(3) Price to book value (C_3)

(4) Net Profit Margin (C_4)

(5) Dividend payout (C_5)

The three decision makers use the seven point scale linguistic variables whose values are given as triangular fuzzy numbers to express the importance weight /priority to five criteria given by

Table 1: Linguistic variable of triangular intuitionistic fuzzy number for criteria

Very Low (VL)	(0,0,1; 0.5,0,1.5)
Low(L)	(0,1,3 ; 0.5,1,3.5)
Medium Low (ML)	(1,3,5; 1.5,3,5.5)
Medium(M)	(3,5,7; 2.5, 5,7.5)
Medium High(MH)	(5,7,9 ; 4.5,7,9.5)
High(H)	(7,9,10 ; 6.5,9,10.5)
Very High (VH)	(9,10,10; 8.5,10,10.5)

Table 2: The importance weight of the criteria

	D_1	D_2	D_3
C_1	H	VH	VH
C_2	H	H	H
C_3	MH	H	MH
C_4	MH	MH	MH
C_5	H	H	H

Based on table 1 and table 2, the fuzzy weight of each criterion is found as

Table 3: Fuzzy weight of each criteria

$\tilde{w}$	**Fuzzy weight**
w_1	(8.33,9.67,10.5 ; 7.83,9.67,10.5)
w_2	(7,9,10 ; 6.5,9,10.5)
w_3	(5.67,7.67,9.33 ; 5.17,7.67,9.83)
w_4	(5,7,9 ; 4.5,7,9.5)
w_5	(7,9,10 ; 6.5,9,10.5)

The three candidates are assessed by the three decision makers on a seven point linguistic scale whose values are given as

Table 4: Linguistic scale of triangular intuitionistic fuzzy number of alternatives

Very Low (VL)	(0, 0, 0.1 ; 0.05, 0, 0.15)
Low(L)	(0, 0.1, 0.3 ; 0.05, 0.1, 0.35)
Medium Low (ML)	(0.1, 0.3, 0.5 ; 0.15, 0.3 ,0.55)
Medium(M)	(0.3 , 0.5 , 0.7 ; 0.25, 0.5, 0.75)
Medium High(MH)	(0.5, 0.7, 0.9 ; 0.45, 0.7, 0.95)
High(H)	(0.7 , 0.9, 1 ; 0.65, 0.9, 1.05)
Very High (VH)	(0.9, 1, 1 ; 0.85, 1, 1.05)

By the evaluation of the three candidates by the three decision makers under the five criteria and combining the opinion of all the three decision makers for each criterion, the fuzzy decision matrix $\tilde{F} = \left(\tilde{X}_{ij}\right)$, where $i = 1, 2, 3$ and $j = 1, 2, 3, 4, 5$ is given by the following table.

Table 5: Fuzzy Decision matrix

		C_1	C_2	C_3	C_4	C_5
$\tilde{D} =$	X_1	(7,7,7; 7,7,7)	(0.7,0.9,1 ; 0.65,0.9,0.95)	(0.56,0.76,0.9 ; 0.57,0.77,0.95)	(0.8,0.9,1 ; 0.7,0.9,1.05)	(0.3,0.5,0.7 ; 0.25,0.5,0.75)
	X_2	(5,5,5 ;5,5,5)	(0.9,1,1 ; 0.85,1,1.05)	(0.7,0.9,1 ; 0.65,0.9,1.05)	(0.7,0.9,1 ; 0.65,0.9,1.05)	(0.6,0.8,0.9; 0.5,0.8,0.95)
	X_3	(4,4,4; 4,4,4)	(0.7,0.86,0.96 ; 0.65,0.87,1.02)	(0.7,0.87,0.97; 0.7,0.87,1.02)	(0.8,1,1; 0.8,1,1.05)	(0.7,0.9,1; 0.65,0.9,1.05)

Then calculated the normalized decision matrix $\tilde{R} = (r_{ij})$ for each criterion is given below in the following table.

Table 6: The normalized decision matrix

	C_1	C_2	C_3	C_4	C_5
X_1	(0.6,0.6,0.6; 0.6,0.6,0.6	(0.7,0.9,1; 0.6,0.9,0.9)	(0.5,0.7,0.9; 0.5,0.7,0.9)	(0.8,0.9,1; 0.7,0.9,1)	(0.3,0.5,0.7; 0.2,0.5,0.7)
X_2	(0.8,0.8,0.8; 0.8,0.8,0.8	(0.9,1,1; 0.8,1,1)	(0.7,0.9,1; 0.6,0.9,1)	(0.7,0.9,1; 0.6,0.9,1)	(0.6,0.8,0.9; 0.5,0.8,1)
X_3	(1,1,1; 1,1,1)	(0.7,0.8,0.9; 0.6,0.8,0.9)	(0.7,0.8,0.9; 0.7,0.8,1)	(0.8,1,1; 0.8,1,1)	(0.7,0.9,1; 0.6,0.85,1)

Now, calculated the normalized decision matrix $\tilde{V} = \left(\tilde{v}_{ij}\right)$ for each criterion and reducing to three terms we get,

Table 7: weighted normalized decision matrix

		C_1	C_2	C_3	C_4	C_5
$\tilde{V} = (v_{ij}) =$	X_1	(4.998,5.802,6.3)	(4.9,9,10)	(2.835,5.369,8.3)	(4,6.3,9)	(2.1,4.5,7)
	X_2	(6.664,7.736,8.4)	(6.3,9,10)	(3.969,6.903,9.33)	(4.5,6.3,9)	(4.2,7.2,9)
	X_3	(8.33,9.67,10.05)	(4.9,7.2,9)	(3.969,6.136,8.397)	(5,7,9)	(4,9,8.1)

Take the fuzzy positive and fuzzy negative ideal solutions to be $P^* = (\tilde{V}_1^*, \tilde{V}_2^*, \tilde{V}_3^*, \tilde{V}_4^*, \tilde{V}_5^*)$ and $\approx{N} = (\approx{V}_1, \approx{V}_2, \approx{V}_3, \approx{V}_4, \approx{V}_5)$ respectively such that $\tilde{V}_j^* = (1,1,1)$ and $\approx{V}_j = (0,0,0)$.

Now the distance of each alternative X_i from the positive solution is $d_i^+ = \sum_{j=1}^{n} d(\tilde{V}_{ij}, \tilde{V}_j^*)$ where $i = 1,2,3$

and the distance of each alternative X_i from the negative solution is $d_i^- = \sum_{j=1}^{n} d(\tilde{V}_{ij}, \approx{V}_j)$ where $i = 1,2,3$.

Therefore, the separation measures from the positive and negative solutions are calculated

Table: 8 Separation Measures

Alternatives	d_i^+	d_i^-
X_1	30.6881	31.6795
X_2	32.3656	37.2288
X_3	31.2674	37.4759

The closeness coefficient $CC_i = \dfrac{d_i^-}{d_i^+ + d_i^-}$

$$CC_1 = 0.508 \ , CC_2 = 0.535 \ , CC_3 = 0.5452 \ .$$

V. RESULT

According to the closeness co-efficient, the ranking order of the three alternatives is $X_3 > X_2 > X_1$. Therefore the last alternative is the company X_3.

VI. CONCLUSION

In this section the new algorithm using the TOPSIS method in intuitionistic fuzzy environment has been evolved. The weights of the values of evaluation assigned by various decision makers are calculated by using the TOPSIS technique. This technique is advantageous in the sense that the evaluation value nearer to the ideal mean value assumes the largest weight and the evaluation value far away from ideal mean value has the smallest weight. The new weight assigned can minimize the influence of unduly high or low values of evaluation. In the ranking result varied situations pertaining to criteria weight information are taken into consideration. In case criteria weights are not completely known, a linear programming model is built up to find out criteria weight by maximizing the criteria relative closeness co-efficient. The weight can be calculated in accordance with the principle that the evaluation value of the criteria is close to the positive ideal evaluation and far away from the negative ideal evaluation values. On the basis of evaluating value and weight the associated algorithm has been formulated according to different criteria weight situation. A real time example has been given to elucidate the efficacy and practical benefits of the new algorithm. The collective values of evaluation computed by the proposed algorithm are different from the weight of values of evaluation computed beforehand and different decision makers different weights computed by TOPSIS can help avoiding the influence of un-reasonable value of evaluation to the ranking results. As a result the result become more acceptable than those computed by existing methods.

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M.Annakkodi, et. al. "Group Decision Making Under Intuitionistic Fuzzy Environment Based On Topsis Method." *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (3), 2021, pp 01-10.