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PERFORMANCE EVALUATION OF STUDENTS - A DECISION MAKING STRATEGY BASED ON FUZZY TOPSIS METHOD

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Abstract

Multi Criteria Decision Making (MCDM) has been a key field of study for many years and has generated many conceptual and applied papers and books. Many MCDM approaches deal with distinct alternatives, which are defined by a collection of parameters. The values of the criteria may be specified as cardinal or ordinal data. To define the desired alternative, assign alternatives in a limited number of categories, or rate alternatives in a specific order of choice, MCDM methods have been developed. It enables strong decision-making in domains where choosing the optimal choice is extremely difficult. Fuzzy TOPSIS is a multi-criteria decision-making approach that compares the alternatives by determining criteria weights. The performance evaluation technique is a systematic way that helps the teachers to evaluate the performance level of students in the mid semester level itself. In this paper we apply the Fuzzy (TOPSIS) approach for evaluating student performance.

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1. Introduction

Performance evaluation system is a systematic way to scrutinize how well an individual is performing in his job. This allows businesses to evaluate their personnel, as well as teachers to evaluate their students. This assists individuals in motivating themselves to do their best for themselves by identifying their flaws. A standard assessment form, standard performance metrics, instructions for providing feedback, and evaluation disciplines are all part of the performance evaluation process. After evaluation process, positive performance should be encouraged and support should be given to improve weaknesses. Here in this paper we make use of Fuzzy TOPSIS (Technique of Order of Preference by Similarity to Ideal Solution) where we compare many options against a set of criteria. The best performance value for each alternative make up a Fuzzy Positive Ideal Solution[FPIS] while the worst values make up the Fuzzy Negative Ideal Solution[FNIS]. Using this technique we can also evaluate the performance level of decision makers.

Performance evaluation of students is a fundamental step to improve the academic performance of students. The quality of an educational institution is mostly determined by the performance of its students. The evaluation helps parents or teachers to find measures to improve performance relative to the factors affecting the performance.

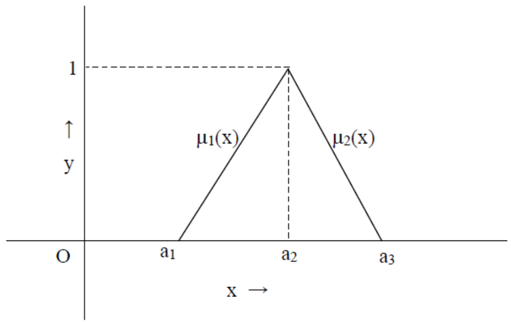
Here, the performance of students is evaluated based on certain personal level criteria, and a model based on the Fuzzy TOPSIS approach has been designed to evaluate student performance.

2. Preliminaries

2.1 Fuzzy Set (Klir and Yuan, 2001)**.** Let X be the universal set. A fuzzy set in X is a set of ordered pairs, $A = \{(x, \mu_A(x)) : x \in X\}$, where $\mu_A : X \to [0, 1]$ is called the membership function of A in x and $[0, 1]$ is called the membership set [3].

2.2 Triangular Fuzzy Number (Gani and Mohamed, 2012) [3]**.** A triangular fuzzy number A is defined as (a_1, a_2, a_3) where the membership function is given by

$$\mu_A(x) = \begin{cases} 0 & \text{if } x \le a_1 \\ \dfrac{x - a_1}{a_2 - a_1} = p_1(x) & \text{if } a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} = p_2(x) & \text{if } a_2 \le x \le a_3 \\ 0 & \text{if } x \ge a_3 \end{cases} \tag{1}$$



2.3 The distance between fuzzy triangular numbers. Let $\overline{a} = (a_1, a_2, a_3)$ and $\overline{b} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. The distance between them is given using the vertex method by

$$d(\overline{a}, \overline{b}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \tag{2}$$

2.4 Fuzzy Conversion Scale. Conversion scales are used to convert linguistic concepts into fuzzy numbers. Normally, the criteria and options are rated on a scale of 1 to 9. Here we make use of triangular fuzzy numbers to represent the five linguistic ratings that have a consistent representation from 1 to 9. [1]

2.5 Fuzzy TOPSIS Method. The following are the steps of Fuzzy TOPSIS method as described in [1]:-

Step 1. The decision makers rate the alternatives.

Step 2. The weightage of each criterion is decided by the decision maker.

Step 3. Apply fuzzy numbers to alternative ratings as well as criteria weightage according to fuzzy ratings for linguistic variables.

Step 4. An aggregated alternative and criteria fuzzy decision matrix has to be constructed.

Step 5. At first, create a matrix representation of the provided fuzzy multi-criteria group decision-making problem. Then, along with the matrix for criteria weightage, normalize the fuzzy decision matrix for alternative.

Step 6. Compute FPIS and FNIS for alternatives.

Step 7. Find FPIS and FNIS for each criteria.

Step 8. Calculate the distance of each criteria from FPIS and FNIS for both alternatives.

Step 9. Calculate the distance of each weighted alternative

$$d_i^+ = \sum_{j=1}^{n} d(\overline{p}_{ij},\ p_j^+)$$

$$d_i^- = \sum_{j=1}^{n} d(\overline{p}_{ij},\ p_j^-).$$

Step 10. Find the closeness coefficient of each alternative

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+},\ i = 1, 2, \ldots, m.$$

Step 11. Rank the alternatives in descending order based on CC_i values.

3. Performance Evaluation of students using Fuzzy TOPSIS Method

In this paper, we propose a decision-making model for the Fuzzy TOPSIS approach for assessing student's performance based on certain factors. These factors are the input variable and performance level is the output variable.

The personal level factors such as Personal Caliber, Financial support, Motivation, Communication skill are considered. Let it be the criteria C_1, C_2, C_3 and C_4 respectively.

Consider two students (i.e. the alternatives A_1 and A_2). Suppose we need to rank these students based on the above criteria.

Scaling of linguistics variables is done by Triangular fuzzy conversion as follows. Usually apply a scale of 1 to 9.

Table 1. Fuzzy Ratings for Linguistic Variables (as in [1]).

Fuzzy number	Alternative Assessment	QA weights
(1,1,3)	Very Poor (VP)	Very Low (VL)
(1,3,5)	Poor (P)	Low (L)
(3,5,7)	Fair (F)	Medium (M)
(5,7,9)	Good (G)	High (H)
(7,9,9)	Very Good (VG)	Very High (VH)

Step 1. Alternative ratings by Decision makers

Consider the following two options: A_1 and A_2 (students) for comparison with four criteria: $C_1, C_2, C_3,$ and C_4. Assume there are two decision makers, DM1 and DM2.

Table 2. Alternative Rating By Decision makers [as in [1]].

	A_1		A_2	
Criteria	DM_1	DM_2	DM_1	DM_2
C_1	F	F	G	G
C_2	VG	VG	G	VG
C_3	P	F	P	P
C_4	F	F	P	P

Step 2. Decision makers give weightage to criteria (as in [1]).

Table 3. Criteria weightage.

Criteria	DM_1	DM_2
C_1	H	M
C_2	VH	H
C_3	VH	H
C_4	M	L

Step 3. Apply Fuzzy numbers to both alternatives and criteria (Refer Table No.1).

Table 4. Fuzzy Numbers for alternative Rating.

	A_1		A_2	
Criteria	DM_1	DM_2	DM_1	DM_2
C_1	F(3,5,7)	F(3,5,7)	G(5,7,9)	G(5,7,9)
C_2	VG(7,9,9)	VG(7,9,9)	G(5,7,9)	VG(7,9,9)
C_3	VG(7,9,9)	VG(7,9,9)	G(5,7,9)	VG(7,9,9)
C_4	F(3,5,7)	F(3,5,7)	P(1,3,5)	P(1,3,5)

Table 5. Fuzzy Numbers for criteria weightage.

Criteria	DM_1	DM_2
C_1	H(5,7,9)	M(3,5,7)
C_2	VH(7,9,9)	H(5,7,9)
C_3	VH(7,9,9)	H(5,7,9)
C_4	M(3,5,7)	L(1,3,5)

Step 4. Construct alternative Fuzzy decision matrix along with criteria weightage Fuzzy decision matrix using the following equations.

$$\bar{x}_{ij}^{k} = (a_{ij}^{k}, b_{ij}^{k}, c_{ij}^{k})$$

$$w_{ij}^{k} = (w_{j1}^{k}, w_{j2}^{k}, w_{j3}^{k})$$

where $$a_{ij} = \min_{k} \{a_{ij}^{k}\},\ b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^{k},\ c_{ij} = \max_{k} \{c_{ij}^{k}\} \tag{3}$$

$$\omega_{j1} = \min_{k} \{\omega_{ij}^{k}\},\ \omega_{j2} = \frac{1}{K}\sum_{k=1}^{K} \omega_{j2}^{k},\ \omega_{j3} = \max_{k} \{\omega_{j3}^{k}\} \tag{4}$$

Table 6. Aggregated Fuzzy Decision matrix for Alternative [as in 1].

Criteria	A_1	A_2
C_1	(3,5,7)	(5,7,9)
C_2	(7,9,9)	(5,8,9)
C_3	(1,4,7)	(1,3,5)
C_4	(3,5,7)	(1,3,5)

Illustration

C_1A_1 from Table 4

Using the third equation,

1. $a_{ij} = \min_k \{a_{ij}^k\} =$ minimum value of first place

$$(3,\ 5,\ 7) \text{ and } (3,\ 5,\ 7) = 3$$

2. $b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k =$ average of values at middle place of $(3,\ 5,\ 7)$ and $(3,\ 5,\ 7) = (5+5)/2 = 5$

3. $c_{ij} = \max_k \{c_{ij}^k\} =$ maximum of $(3,\ 5,\ 7)$ and $(3,\ 5,\ 7) = 7$.

Table 7. Aggregated Fuzzy Decision matrix for criteria weightage (as in [1]).

Criteria	Agg. Weightage
C_1	(3,6,9)
C_2	(3,6,9)
C_3	(5,8,9)
C_4	(1,4,7)

Illustration.

From Table 5 C1DM1 and C1DM2 are $(5, 7, 9)$ and $(3, 5, 7)$ respectively.

Let $\omega_j^k = (\omega_{j1}^k, \omega_{j2}^k, \omega_{j3}^k)$

Using equation (4),

ω_{j1} = minimum value of first place of $(5, 7, 9)$ and $(3, 5, 7) = 3$

ω_{j2} = average values at middle place of $(5, 7, 9)$ and $(3, 5, 7) = \frac{7+5}{2} = 6$

ω_{j3} = maximum values of last place of $(5, 7, 9)$ and $(3, 5, 7) = 9$

$\therefore \omega_j = (3, 6, 9)$.

Step 5. Compute the normalized fuzzy decision matrix as follows:-

At first identify beneficial and non-beneficial criteria (cost criteria).

For beneficial criteria, maximum value is desired and minimum value for cost criteria.

In this study, the criteria C_1 (Personal Caliber) is a non-beneficial criteria.

Normalizing, using equations as in reference [1]

$$\overline{R} = [\bar{r}_{ij}]_{m \times n},\ i = 1, 2, \ldots, m,\ j = 1, 2, \ldots, n \tag{5}$$

$\bar{r}_{ij} = (a_{ij}/c_j^*, b_{ij}/c_j^*, c_{ij}/c_j^*)$ where

$$c_j^* = \max_i c_{ij} \text{ benefit criteria} \tag{6}$$

$\bar{r}_{ij} = (\bar{a}_j/c_{ij}, \bar{a}_j/b_{ij}, \bar{a}_j/a_{ij})$ where

$$\bar{a}_j = \min_i a_{ij} \text{ (cost criteria)} \tag{7}$$

Table 8. Normalized Aggregated Fuzzy Decision matrix for alternative.

Criteria	A_1	A_2
C_1	(.429, .6, 1)	(.333, .429, .6)
C_2	(.778, 1,1)	(.556, .889, 1)
C_3	(.143,.571,1)	(.143, .429, .714)
C_4	(.429, .714,1)	(.143, .429, .714)

Illustration.

From table 6, consider $C_1A_1(3, 5, 7)$ and $C_1A_2(5, 7, 9)$ where C_1 is the cost criteria.

Since C_1 is the cost criteria, use equation (7) for normalization

$\bar{a}_j = \min_i a_{ij} =$ minimum value of first place $(3, 5, 7)$ and $(5, 7, 9) = 3$.

Now $\bar{r}_{ij} = (\bar{a}_j \mid c_{ij}, \bar{a}_j \mid b_{ij}, \bar{a}_j \mid a_{ij})$ Equations as in [1]

Now $(a_{ij}, b_{ij}, c_{ij}) = (3, 5, 7)$

$\therefore \bar{r}_{ij} = (3/7, 3/5, 3/3) = (.429, .6, 1)$

Similarly for $(5, 7, 9)$ take the same value $\bar{a}_{ij} = 3$.

For beneficial criteria $C_2A_1(7, 9, 9)$ and $C_2A_2(5, 8, 9)$. From equation (6),

$$c_j^* = \max_i c_{ij} = 9$$

$\bar{r}_{ij} = (a_{ij} \mid c_j^*, b_{ij} \mid c_j^*, c_{ij} \mid c_j^*)$ Equation as in [1]

Take $(a_{ij}, b_{ij}, c_{ij}) = (7, 9, 9)$

Then $\bar{r}_{ij} = (7/9, 9/9, 9/9) = (.778, 1, 1)$

Similarly for $(5, 8, 9)$.

Weighted Normalized Fuzzy Decision Matrix,

$$\overline{p} = [\overline{p}_{ij}] \text{ where } \overline{p}_{ij} = \overline{r}_{ij} \times \overline{w}_j \tag{8}$$

Table 9. Weighted Normalized Fuzzy Decision Matrix (Table as in [1]).

Criteria	A_1	A_2
C_1	(1.287,3.6, 9)	(.999, 2.574,5.4)
C_2	(3.890,8,9)	(2.78,7.112,9)
C_3	(.715,4.568,9)	(.715,3.432,6.426)
C_4	(.429,2.856,7)	(.143,1.716,4.998)

Illustration.

To get $C_1A_1(1.287, 3.6, 9)$ in table 9, multiply $C_1A_1(.429, .6, 1)$ in table – 8 by criteria weight $C_1(3, 6, 9)$ in table 7. Likewise proceed the same method for the remaining elements.

Step 6. Fuzzy Positive and Negative Ideal Solutions (FPIS and FNIS) for alternatives are computed as follows:

Let $A^+ = \{p_1^+, p_2^+, p_3^+, p_4^+\}$

where $p_j^+ = \max_i \{p_{ij3}\}, i = 1, 2, ; j = 1, 2, 3, 4$ (9)

$A^- = \{p_1^-, p_2^-, p_3^-, p_4^-\}$ where

$$p_j^- = \max_i \{p_{ij1}\}, i = 1, 2, ; j = 1, 2, 3, 4. \tag{10}$$

Select the maximum value from each row as p^+ and select the minimum value from each row as p^-.

Illustration.

From table 9, C_1A_1 is (1.287, 3.6, 9) and C_1A_2 is (.999, 2.574, 5.4)

$A^+ = \{p_1^+, p_2^+, p_3^+, p_4^+\}$

Using equation (9), for $i = 1, 2, ; j = 1, 2, 3, 4.$

For $j = 1$, $p_1^+ = \max\{p_{113}, p_{213}\} =$ max of fuzzy third component of (1.287, 3.6, 9) and (.999, 2.574, 5.4) = 9

For $j = 2$, $p_2^+ = \max\{p_{123}, p_{223}\} =$ max of fuzzy third component of (3.890, 8, 9) and (2.78, 7.112, 9) = 9

In the same way, we can compute p_3^+ and p_4^+. So that we obtain

$$A^+ = \{p_1^+(9, 9, 9), p_2^+(9, 9, 9), p_3^+(9, 9, 9), p_4^+(7, 7, 7)\} \tag{11}$$

To compute $A^- = \{p_1^-, p_2^-, p_3^-, p_4^-\}$

Using equation (10),

For $j = 1$, $p_1^- = \min\{p_{111}, p_{211}\} =$ minimum of fuzzy first component of (1.287, 3.6, 9) and (.999, 2.574, 5.4)

$= \min\{1.287, 999\} = .999$

Similarly for $j = 2, 3, 4$.

$$\therefore A^- = \{p_1^-(.999, .999, .999), p_2^-(2.78, 2.78, 2.78), p_3^-(.715, .715, .715),$$

$$p_4^-(.143, .143, .143)\} \tag{12}$$

Step 7. For both alternatives calculate the distance of each criteria from FPIS and FNIS.

FPIS $(A_1) = d(p_{ij}, p_1^+)$ and

FNIS $(A_1) = d(p_{ij}, p_1^-)$ [as in [1]]

Illustration.

To compute FPIS (A_1)

For $i = 1$, $j = 1, 2, 3, 4$.

$d(p_{ij}, p_1^+) = d[(1.287, 3.6, 9), (9, 9, 9)]$

By equation (2),

$$= \sqrt{\frac{1}{3}\left[(1.287-9)^2+(3.6-9)^2+(9-9)^2\right]}$$

$$= \sqrt{\frac{1}{3}\left[59.49+29.16\right]} = 5.436$$

Similarly, compute distance for the remaining criteria.

Continue the same steps to find the FPIS of A_2 also.

To compute FNIS (A_1)

For $i = 1,\ j = 1, 2, 3, 4.$

$d(p_{11},\ p_1^-) = d[(1.287,\ 3.6,\ 9), (.999,\ .999,\ .999)]$

$$= \sqrt{\frac{1}{3}\left[(1.287-.999)^2+(3.6-.999)^2+(9-.999)^2\right]}$$

$$= \sqrt{\frac{1}{3}(.083+6.765+64.02)} = 4.860$$

Similarly for $j = 2, 3, 4$

Repeat the same step to find the FNIS of A_2.

Table 10. (Data as in [1]) Distance of criteria of each alternative from FPIS and FNIS.

Criteria	FPIS (A_1)	FPIS (A_2)	FNIS (A_1)	FNIS (A_2)
C_1	5.436	6.279	4.860	2.698
C_2	3.006	3.753	4.732	4.376
C_3	5.425	5.952	5.275	3.651
C_4	4.485	5.129	4.261	2.946

Step 8. The distance of each weighted alternative is determined next

$$d_i^+ = \sum_{j=1}^{n} d(\overline{p}_{ij},\ p_j^+) \text{ for } i = 1, 2, j = 1, 2, 3, 4.$$

$$\text{and } d_i^- = \sum_{j=1}^{n} d(\overline{p}_{ij}, p_j^-)$$

Illustration.

For $i = 1$, $d_1^+ = d(p_{11}, p_1^+) + d(p_{12}, p_2^+) + d(p_{13}, p_3^+) + d(p_{14}, p_4^+)$

= Sum of FPIS (A_1) in Table – 10.

$= 5.436 + 3.006 + 5.425 + 4.485$

$= 18.352$.

Similarly compute d_2^+ for $1 = 2 \cdot d_2^+ = 21.113$.

Now, to compute d_i^-

Set $i = 1$

$d_1^- = d(p_{11}, p_1^-) + d(p_{12}, p_2^-) + d(p_{13}, p_3^-) + d(p_{14}, p_4^-)$

$= 4.860 + 4.732 + 5.275 + 4.261$

$= 19.128$.

Similarly for $i = 2$, $d_2^- = 13.671$.

Step 9. Finally for each weighted alternative compute the Closeness coefficient as follows:-

$$CC_i = d_i^- \mid (d_i^- + d_i^+),\ i = 1, 2, \ldots, m. \tag{13}$$

(as in [1])

Illustration.

From equation (13)

$$CC_i = d_i^- \mid (d_i^- + d_i^+),\ i = 1, 2. [1]$$

For $i = 1$

$$CC_1 = d_1^- \mid (d_1^- + d_1^+)$$

$$= 19.128 \mid (18.352 + 19.12) = 0.510.$$

For $i = 2$

$$CC_2 = d_2^- \mid (d_2^- + d_2^+)$$

$$= 13.671 \mid (13.671 + 21.113) = 0.393.$$

Step 10. Based on the closeness coefficient rank the alternatives.

Here, the two alternatives A_1 and A_2 (i.e. students) have closeness coefficients CC_i of 0.510 and 0.393, respectively.

Hence, we may conclude that the ranking order of student $A_1 >$ student A_2.

So based on the above criteria A_1 is the best choice.

4. Results

There are several Multi criteria decision making methods such as TOPSIS, Analytical Hierarchy Process (AHP), Fuzzy AHP, Value Based Ranking Method etc. which were utilized in performance appraisal. Every method has its own pros and cons. As we compare Fuzzy TOPSIS with any other method mentioned above it is easy to use and takes into account all types of criteria (both subjective and objective). Also the computational processes are straight forward.

5. Conclusion

The proposed model based on Fuzzy TOPSIS method for performance evaluation helps decision makers to rank their choices from multiple students and select a student that is best with respect to performance. Fuzzy TOPSIS is an excellent method since it eliminates the possibility of errors caused by mathematical computations.

In future, we can extend this method to evaluate the performance of any number of students. Also Best worst Method (BWM) can be used for calculating the criteria weight. Thus BWM and Fuzzy TOPSIS might be used in the same context. Moreover, by using a software like MATLAB we may create a model for fuzzy TOPSIS of performance evaluation.

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