Faculty Recruitment in Engineering Organization Through Fuzzy Multi-Criteria Group Decision Making Methods

Ruchika Banerjee[1] and Dipendra Nath Ghosh[2]

[1]*Department of Information Technology*
Dr. B. C Roy Engineering College, Durgapur-713206, West Bengal, India
[2]*Department of Computer Science & Engineering*
Dr B. C Roy Engineering College, Durgapur-713206, West Bengal, India
rchk.banerjee@gmail.com, ghoshdipen2003@yahoo.co.in

Abstract

Faculty selection procedure in any educational organization is a multi-criteria decision making (MCDM) problem. Faculty members play an important role while judging the quality of an educational institute. Thus, educational organizations are interested to recruit the best faculty in order to provide a quality education to their students. As, this MCDM problem requires multiple criteria and a finite set of candidate alternatives, an amalgamation of various MCDM methods can be used to solve such problem. In this paper a study has been made on ranking five alternatives with the help of three step methodology combining FAHP with PROMETHEE-2 and TOPSIS, comparing the results and finally determining the rank using group decision making method. This proposed model yields the ranking of the five candidates in a faculty interview considering several experts' opinion.

Keywords: *MCDM, Fuzzy AHP, PROMETHEE-2, TOPSIS, Spearman's Rank Correlation Coefficient, Group Decision Making*

1. Introduction

Education System plays a vital role in the development of any country. As, best educational institutes are an asset for a country, in the same way best faculty members are an asset for that institute. The quality of faculty members in an educational organization determines the quality of education provided to their students. Thus choosing the best faculty staff members for their institute have become a major priority among the selectors. Similar study regarding the Faculty selection in Engineering Organization is done in [1] and it forms the basis of this paper. To improve the lack of recruitment processes as well as reduce individual senses of supervisory level by fuzzy logic and AHP methods, Pin-Chang Chen in [2] tried to identify appropriate personality traits and key professional skills through the information statistics. Kazem Oraee and *et al.*, combined AHP with TOPSIS and PROMETHEE-2 in two step methodology for selecting a tunnel system [3]. Evaluation of best technical institutions fuzzy analytic hierarchy process was developed to tolerate vagueness and uncertainty of human judgment [4].

This paper efficiently combines fuzzy analytic hierarchy process with PROMETHEE-2 and TOPSIS for ranking the interview candidates on the basis of some experts' opinion followed by the comparison between the results and final ranking by group decision analysis method. This three step proposed methodology is effectively more powerful than the traditional methods.

2. MCDM Methods

2.1. Fuzzy Sets

A fuzzy set is a class of objects with a range of grades of membership. A membership function characterizes such a set which assigns to each object a grade of membership ranging between zero and one [5]. Fuzzy logic is a powerful mathematical tool for representing uncertainty in every field. Their role is significant when applied to complex phenomena which are not easily described by traditional mathematical methods, especially when the goal is to find a good approximation solution [6]. Fuzzy sets have proven to be an eminent way for solving the decision problems where the information available is subjective and vague [7].

2.2. Linguistic Variable

A variable which can be a word or a sentence in a natural or artificial language is often referred to as linguistic variable [8]. For example, marks can be a linguistic variable if they are assumed to be the fuzzy variables labeled very good, good, bad, very bad etc rather than numbers 0,1,2,3,4… For some situations where the evaluation becomes too complex and conventional quantitative terms cannot be used, linguistic variables can provide a means of approximate characterization of the phenomena. The main applications of the linguistic approach lie especially in the fields of artificial intelligence, linguistics, human decision processes, pattern recognition, psychology, law, medical diagnosis, information retrieval, economics and related areas [8].

2.3. Fuzzy Numbers

A fuzzy number $\tilde{M}$ is a convex normalized fuzzy set $\tilde{M}$ of the real line R which exists [7] such that one $x_o \in$ R with $\mu_{\hat{M}}(x_o)=1$ (x_o is called mean value of $\tilde{M}$) and $\mu_{\hat{M}}(x_o)$ is piecewise continuous. Triangular fuzzy numbers (TFNs) are often convenient to work with because of their computational simplicity, and they are useful in representation and information processing in a fuzzy environment. In this study TFNs are adopted in the fuzzy AHP method. TFNs can be defined as a triplet (l, m, u). The parameters l, m, u indicate the smallest possible value, the most promising value, and the largest possible value that describes a fuzzy event. A triangular fuzzy number $\tilde{M}$ is shown in Figure 1:

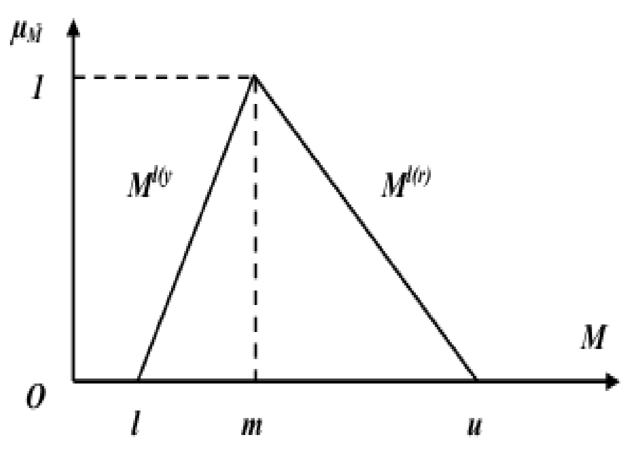

Figure 1. Triangular Fuzzy Number

2.4. Fuzzy Analytic Hierarchy Process

Fuzzy Analytic Hierarchy Process (FAHP) is an extension of Analytic Hierarchy Process (AHP) in fuzzy environment [9]. In case of AHP, elements of pair wise comparison matrix lie between 1 and 9, whereas in the case of fuzzy AHP these are fuzzy numbers. In this study the fuzzy AHP is implemented, which was originally introduced by Chang [10].

Let $X = \{x_1, x_2, x_3 ......x_n\}$ an object set and $G = \{g_1, g_2, g_3 ......g_n\}$ be a goal set. According to Chang's extent analysis each object is taken from the pair wise comparison matrix. Then, extent analysis for each goal is performed, respectively. Therefore, m extent analysis values for each object can be obtained with the following signs:

$$M_{gi}^1, M_{gi}^2, M_{gi}^3, ...M_{gi}^m \qquad i = 1,2,3,....n$$

where M_{gi}^j (j = 1,2,3…m) all are TFNs. The steps of Chang [10] extent analysis can be given as in the following:

Step 1: The value of fuzzy synthetic extent analysis is calculated as :

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \qquad (1)$$

Step 2: If M_1, M_2 be two triangular fuzzy numbers, the degree of possibility of $M_2 \geq M_1$ is $V(M_2 \geq M_1)$ defined as

$$V(M_2 \geq M_1) = \sup\left[\min(\tilde{M}_1(x), \tilde{M}_2(y))\right] \qquad (2)$$

And can be expressed as follows:

$$V(M_2 \geq M_1) = hgt\left(\tilde{M}_1 \cap \tilde{M}_2\right) = \tilde{M}_2(d) = \begin{cases} 1, & if \quad m_2 \geq m_1 \\ 0, & if \quad l_1 \geq u_2 \\ \dfrac{(l_1 - u_2)}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \qquad (3)$$

Figure 2 illustrates Eq (3) where d is the ordinate of the highest intersection point D between M_1 and M_2. To compare $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$.

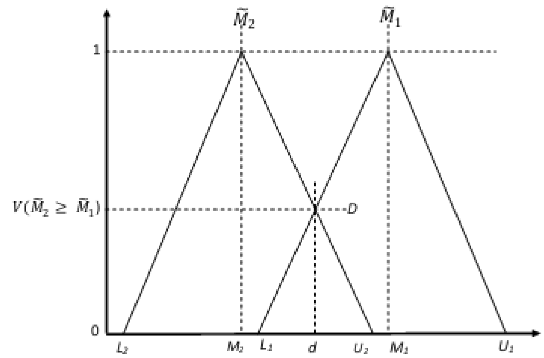

Figure 2. Degree of Possibility

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy $M_i (i = 1,2,....k)$ numbers can be defined by

$$V(M \geq M_1, M_2, ..., M_k) = \min(V(M \geq M_i), i = 1,2,3,....k \quad (5)$$

Assuming,

$$d(A_i) = \min V(S_i \geq S_k) \text{ for k = 1, 2,…n; k} \neq \text{i}$$

Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2),....., d'(A_n))^T \quad (6)$$

where $A_i (i = 1,2,3....n)$ are the n elements.

Step 4: Repeat steps 1 to 3 for all criteria under each experts individually.

Step 5: Calculate the geometric mean of each cell of each expert for each alternative and each criteria to obtain the final decision matrix.

Step 6: Obtained decision matrix is normalized using Eq. (7):

$$\frac{r_{ij}}{\sum_{j=1}^{J} w_{ij}} = w_{ij} \qquad \text{j=1,2,….,J} \qquad \text{i=1,2,...n} \quad (7)$$

where J is the no. of alternatives and n is the no. of criteria. w_{ij} is the value in each cell of the decision matrix.

Step 7: Weighted normalized decision matrix is formed using Eq. 8:

$$v_{ij} = r_{ij} * w_{ij} \text{ ; j=1,2,….,J} \quad \text{i=1,2,...n} \quad (8)$$

2.5. PROMETHEE-2

PROMETHEE-2 (**P**reference **R**anking **O**rganisation **METH**od of **E**nrichment **E**valuation) is a MCDM method of outranking nature. It is one among the 5 versions of PROMETHEE, *i.e.*, 1 to 5 [12, 13]. The method is based on preference function approach [14]. Thus it considers a preference between alternatives individually. In this study, PROMETHEE-2 is used to obtain the final ranking from the weighted normalized matrix.

The steps of this method are as follows:

The input of PROMETHEE is the weighted normalized matrix which is obtained from Fuzzy-AHP.

Step 1: Normalize all the values according to any normalization method.
Determine the deviation based on pair wise comparisons of each alternative k and l, within each criteria i is calculated,

$$d_i(k,l) = r_{ki} - r_{li} \quad (9) \qquad k,l = 1,2\ldots\ldots J \text{ and } i = 1,2\ldots\ldots n$$

where, $d_i(k,l)$ denotes the difference between the evaluations of alternatives k and l on each criterion, r_{ki} denotes the normalized value of kth criteria and ith alternative.

Step 2: Calculate the threshold values of each criteria by Eq. (10) :

$$\sigma_i = \frac{\sum_{\substack{k,l=1 \\ k \neq l}}^{k,l=J} |d_i(k,l)|}{J(J-1)} \qquad i = 1,2,\ldots,n \qquad k,l = 1,2 \tag{10}$$

Step 3: Calculate the preference function using any preference function, in this paper **Gaussian function** is used as a preference function, $P_i(d)$ for each criteria i:

$$P_i(k,l) = \begin{Bmatrix} 0 & if & d_i(k,l) \leq 0 \\ 1 - \exp\left(\frac{-d_i^2}{2\sigma^2}\right) & if & d_i(k,l) > 0 \end{Bmatrix} \tag{11}$$

Step 4: Calculate the preference index and constitute the preference index matrix using Eq. (12):

$$\pi(k,l) = \sum_{i=1}^{n} w_i * P_i(k,l) \qquad k,l \in \text{J} \tag{12}$$

Thus, we will be getting an Alternative Vs Alternative matrix whose diagonal elements are 0 as the values show the preference of alternative A_k over alternative A_l. w_i is the weight of each criteria.

Step 5: Calculate the net outgoing flow, this represents the strength of an alternative over other alternatives. The outgoing flow is calculated as:

$$\phi_j^+ = \frac{1}{J-1} \sum_{\substack{k=1 \\ k \neq j}}^{J} \pi(j,k) \qquad \text{j, k=1,2,\ldots,J} \tag{13}$$

Step 6: Calculate the net entering flow, which represents the weakness of an alternative over other alternatives.

$$\phi_j^- = \frac{1}{J-1} \sum_{\substack{k=1 \\ k \neq j}}^{J} \pi(k,j) \qquad \text{j, k=1,2,\ldots,J} \tag{14}$$

Step 7: Calculate net flow ϕ_j^{net} based on the difference between outgoing and entering flows of alternative j using Eq. (15):

$$\phi_j^{net} = \phi_j^{+} - \phi_j^{-} \qquad j= 1,2,\ldots J \tag{15}$$

Ranking of the alternatives is done according to the ϕ_j^{net} values. Thus, the alternative that has the highest net flow is preferable.

The following steps of Promethee-2 can be implemented in C-Code as follows:

```
/* PROMETHEE-2 */
#include<stdio.h>
#include<math.h>
#include<stdlib.h>
int main(){
 float DecMat[10][10], Dev[30][10], Thres[10], Pref[30][10], PI[10][10], Netflow[10],
wei[10], RowSum[10];
  int i,j,alt,cri;
  printf("Enter no. of criteria");
    scanf("%d",&cri);
  printf("\nEnter no. of alternative");
    scanf("%d",&alt);
  printf("\nEnter the weighted normalized matrix(row wise)\n");
  for(i=0;i<alt;i++){
    for(j=0;j<cri;j++)
      scanf("%f",&DecMat[j][i]);
    }
 printf("\nThe given matrix is:\n");
 for(i=0;i<alt;i++){
   for(j=0;j<cri;j++)
     printf(" %f",DecMat[i][j]);            //The weighted normalized matrix in transposed form
   printf("\n");
 }
 float sum=0.0;                              //Normalizing the weighted normalized matrix
 for(i=0;i<cri;i++){
    for(j=0;j<alt;j++){
     sum=sum+DecMat[i][j];
    }
    RowSum[i]=sum;                           //Calculating Sum of each row before normalization
    sum=0.0;
 }
 printf("\nThe row summation is\n");
 for(i=0;i<cri;i++)
    printf(" %f",RowSum[i]);
 for(i=0;i<cri;i++){
      for(j=0;j<alt;j++)
         DecMat[i][j]=(DecMat[i][j]/RowSum[i]);                  //Normalization method
 }
```

```
 printf("\nThe normalized matrix of the weighted normalized matirx\n\n");
for(i=0;i<cri;i++){
  for(j=0;j<alt;j++)
    printf(" %f",DecMat[i][j]);
  printf("\n"); }
printf("\nEnter the weights of the criteria\n");     //Weights of the criteria calculated by FAHP
for(i=0;i<cri;i++)
  scanf("%f",&wei[i]);
int m=0,k=0;
for(k=0;k<cri;k++){                                          //The Deviation amplitude matrix
  for(i=0;i<alt;i++){
    for(j=0;j<alt;j++){
      if(i==j)
        continue;
      else{
        Dev[m][k]=(DecMat[k][i]-DecMat[k][j]);
//Calculating Deviation
        m=m+1;
      }
    }
  }
  m=0;
}
m=alt*(alt-1);
printf("\nThe Deviation Matrix is \n");
for(j=0;j<m;j++){
  for(i=0;i<cri;i++)
    printf(" %f",Dev[j][i]);
  printf("\n");
}
sum=0.0;
for(i=0;i<cri;i++){                              //Calculating Threshold Values of each criteria
  for(j=0;j<m;j++){
    sum=sum+fabs(Dev[j][i]);
    Thres[i]=sum/((float)(cri*(cri-1)));
  }
  sum=0.0;
}
printf("\nThe Threshold values are \n");
for(i=0;i<cri;i++)
  printf("\n%f",Thres[i]);
for(i=0;i<cri;i++){
//Preference Function matrix
  for(j=0;j<m;j++){
    if(Dev[j][i]<=0)
      Pref[j][i]=0;
    else
```

```
      Pref[j][i]=(1-exp((-(Dev[j][i]*Dev[j][i]))/(2*(Thres[i]*Thres[i])))); //Gaussian Preference
Function
  }
}
printf("\nThe Preference Function is \n");
for(i=0;i<m;i++){
  for(j=0;j<cri;j++)
    printf(" %f",Pref[i][j]);
  printf("\n");
}
int p;
p=k=0;
sum=0.0;
for(i=0;i<m;i++){
//Preference Index Matrix
  for(j=0;j<cri;j++){
    if(p==k){
      PI[p][k]=0.0;                    //Diagonal elements of Prefence Index Matrix is 0
      k=k+1;
    }
    sum=sum+(Pref[i][j]*wei[j]);
  }
  PI[p][k]=sum;
  k=k+1;
  sum=0.0;
  if(k==alt){
    p=p+1;
    k=0;
}
PI[alt-1][alt-1]=0.0;
printf("\nPreference Matrix is\n");
for(i=0;i<alt;i++){              //Preference Index is Alternative Vs Alternative Matrix
  for(j=0;j<alt;j++)
    printf(" %f",PI[i][j]);
  printf("\n");
}
float inflow=0.0,outflow=0.0;
for(i=0;i<alt;i++){
  for(j=0;j<alt;j++){
    outflow=outflow+PI[i][j];
    inflow=inflow+PI[j][i];
  }
  outflow=outflow/4;                                    // Outgoing flow
  inflow=inflow/4;                                      // Incoming flow
  Netflow[i]= outflow-inflow;          //NetFlow = Outgoing flow - Incoming flow
  outflow=inflow=0.0;
}
printf("\nThe Netflow is \n");
```

```
for(i=0;i<alt;i++)
  printf("\nS%d -  %f\n",i,Netflow[i]);
return(0);
}
```

2.6. TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is one of the useful Multi Attribute Decision Making techniques that are very simple and easy to implement. Unlike AHP the user need not to have a detailed knowledge about the criteria in the decision hierarchy to make informed decisions [15]. TOPSIS method was firstly proposed by Hwang and Yoon [16]. According to this technique, the best alternative would be the one that is nearest to the positive ideal solution and farthest from the negative ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes the cost criteria, whereas a negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [17]. In this study, TOPSIS method is used to determine the final ranking. The steps of this method are as follows:

The input of TOPSIS is the weighted normalized matrix which is obtained from Fuzzy-AHP.

Step 1: Determine the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) as for each criteria:

$$A^* = \{v_1^*, v_2^*, \ldots\ldots, v_n^*\} \quad (16)$$

Where v_n^* gives the maximum value of nth criteria.

$$A^- = \{v_1^-, v_2^-, \ldots\ldots\ldots v_n^-\} \quad (17)$$

Where v_n^- gives the minimum value of nth criteria.

Step 2: Calculate the distance of each alternative from PIS and NIS as:

$$d_i^* = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^*\right)^2} \quad i = 1,2,3,\ldots,J \quad (18)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2} \quad i = 1,2,3,\ldots,J \quad (19)$$

where there are J alternatives and n criteria.

Step 3: The closeness coefficient of each alternative is:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad i=1,2,3,\ldots, J \quad (20)$$

Step 4: Rank the alternatives according to the decreasing order of the CC_i values. The best alternative is the one with the greatest closeness to ideal solution.

The above steps of Topsis can be implemented in C- Code as follows :

```
/*TOPSIS*/
#include<stdio.h>
```

```
#include<math.h>
float MAXI(float DecMat[10][10],int alt, int pos){          //Calculates Positive Ideal Solution
  int i; float max;
  max=DecMat[pos][0];
  for(i=1;i<alt;i++){
    if(DecMat[pos][i]>max)
      max=DecMat[pos][i];
  }
   return(max);
}
float MINI(float DecMat[10][10],int alt, int pos){          //Calculates Negative Ideal Solution
  int i; float min;
  min=DecMat[pos][0];
  for(i=1;i<alt;i++){
    if(DecMat[pos][i]<min)
      min=DecMat[pos][i];
  }
   return(min);
}

int main(){
  float DecMat[10][10],MaxArr[10],MinArr[10],Maxdist[10],Mindist[10],CC[10];
  int i,j,alt,cri;
  printf("Enter no. of criteria");
    scanf("%d",&cri);
  printf("\nEnter no. of alternative");
   scanf("%d",&alt);
  printf("\nEnter the weighted normalized matrix(row wise)");
  for(i=0;i<alt;i++){
    for(j=0;j<cri;j++)
      scanf("%f",&DecMat[j][i]);
  }
  for(i=0;i<cri;i++){
    MaxArr[i]=MAXI(DecMat,alt,i);                //Positive Ideal Solution for each criteria
  }
  for(i=0;i<cri;i++){
    MinArr[i]=MINI(DecMat,alt,i);                //Negative Ideal Solution for each criteria
  }
  printf("\nThe positive and negative ideal solutions are\n");
  printf("\tPIS\t\t\tNIS\n");
  for(i=0;i<cri;i++)
    printf("    %f\t\t    %f\n",MaxArr[i],MinArr[i]);
    float sum=0;
    for(i=0;i<alt;i++){
      for(j=0;j<cri;j++){
        sum=sum+pow((DecMat[j][i]-MaxArr[j]),2);      //Distance from positive ideal solution
        Maxdist[i]=sqrt(sum);
      }
```

```
    sum=0;
  }
  for(i=0;i<alt;i++){
    for(j=0;j<cri;j++){
      sum=sum+pow((DecMat[j][i]-MinArr[j]),2);          //Distance from negative ideal solution
      Mindist[i]=sqrt(sum);
    }
    sum=0;
  }
  for(i=0;i<alt;i++){
    CC[i]=(Mindist[i]/(Maxdist[i]+Mindist[i]));          //Relative Closeness of each alternative
   }
   printf("\nThe relative closeness of each alternative is\n");
   for(i=0;i<alt;i++){
     printf("S%d - %f",i,CC[i]);
   printf("\n");
   }
   return(0);
}
```

2.7. Correlation Coefficients

Assessing the correlation/consistency between different ranking patterns obtained by different MCDM methods and/or different decision makers and/or different scenarios for a given set of alternatives forms a major part in their comparative study. Correlation coefficients measure the extent to which the ranks are correlated which can be used in this regard. These values vary from +1.00 (perfect positive relation) to -1.00 (perfect negative relationship) and value of zero indicates no relationship.

A non parametric rank correlation method namely, Spearman which is used to compute correlation coefficient values is explained as follows:

2.7.1. Spearman Rank Correlation Method

Spearman rank correlation coefficient ρ is useful to determine the measure of association/correlation (including positive or negative direction of a relationship) between ranks achieved by different MCDM methods and/or different decision-makers and/or different scenarios for a given set of alternatives. If Ua and Va denote the ranks achieved by above situation(s) for the same alternative a, then R is defined as [18] :

$$R = 1 - \frac{6\sum_{a=1}^{n} d_a^2}{n^3 - n}$$

,where d^a = difference between ranks U_a and V_a achieved by the same alternative a
n = number of alternatives and $-1 \le R \le 1$.

Various critical values for Spearman rank correlation coefficient for various significance levels is provided in [19]. Numerous case studies have used the Spearman rank correlation method for computation of correlation coefficient values [20].

Characteristics of R can be explained in Table 1 as:

Table 1. Characteristics of Co-efficient R

Correlation	Nature of correlation	Remark
0.9 - 1.0	Very High	Very Strong relationship
0.7 – 0.9	High	Marked relationship
0.4 – 0.7	Moderate	Substantial relationship
0.2 – 0.4	Low	Definite relationship
< 0.2	Slight	Small relationship

2.8. Group Decision Making

The real life decisions are particularly complex in nature, with personal interests and conflicting preferences among a good number of decision-makers involved, which may lead to an unsatisfactory conclusion and sometimes may be even erroneous. In this regard, effective group decision-making can be viewed as a process in which individual interests are reduced and integrated so as to form a single group preference or consensus [21]. An integrated approach can be used where rank coefficient values can be used as a benchmark to ascertain the conflicting nature of decision makers and their strength. The two main group decision making methods are as follows [22]:

2.8.1. Additive Ranking Rule

The Additive Ranking rule is applied to integrate the rankings of a group of decision makers or different MCDM methods into a consensus. A group evaluation of an alternative a in additive ranking rule is the arithmetic mean of the rankings made by G MCDM methods/decision makers, i.e.,

$$r_a^G = \frac{\sum_{DM=1}^{G} w_{DM} r_{a.DM}}{G}$$

where G = Number of methods; w_{DM} = Relative influence of each decision method DM on expected outcome; $r_{a.DM}$ = Rank obtained for each alternative a by decision method DM; raG = Rank obtained for each alternative a by the group of G decision methods.

2.8.2. Multiplicative Ranking Rule

A group evaluation of an alternative a in multiplicative ranking rule is the product of the rankings made by G decision makers or different MCDM methods raised to the power 1/G.

$$r_a^G = \left[\prod_{DM=1}^{G} w_{DM} r_{a.DM} \right]^{1/G}$$

where G = Number of methods; w_{DM} = Relative influence of each decision method DM on expected outcome; $r_{a.DM}$ = Rank obtained for each alternative a by decision method DM; raG = Rank obtained for each alternative a by the group of G decision methods.

3. Case Study

In this section, the above explained methodologies are applied to a case study, in order to prove its applicability and validity. The study is based on a faculty interview in an engineering college. A triplet of decision makers (Expert 1, Expert 2, Expert 3) were asked to evaluate the set of five candidates (S1, S2, S3, S4, S5). The experts mark the alternatives using linguistic variables (E, VG, G, A, B) which are later converted to triangular fuzzy numbers. This evaluation was done on the basis of five attributes, Academic Qualification (AQ), Knowledge (K), Teaching Ability (TA), Research (R) and Presentation (P). According to the requirement of the college the candidates were evaluated. The panelists marked the candidates using linguistic variables. The table containing the remarks for each candidate is shown in the Table 2.

Table 2. Candidates Mark using Linguistic Variables

	Academic Qualification			Knowledge (K)			Teaching Ability (TA)			Research (R)			Presentation (P)		
Candidate	**Ex-1**	**Ex -2**	**Ex -3**	**Ex -1**	**Ex -2**	**Ex -3**	**Ex -1**	**Ex -2**	**Ex -3**	**Ex -1**	**Ex -2**	**Ex -3**	**Ex -1**	**Ex -2**	**Ex -3**
S1	E	V	E	V	G	G	G	G	G	E	V	V	V	G	G
S2	VG	G	G	E	V	V	V	G	V	G	G	A	E	V	V
S3	E	E	E	V	G	E	G	A	A	V	V	E	V	V	G
S4	E	V	V	G	A	G	A	B	G	V	G	A	A	A	B
S5	G	A	G	G	G	V	V	G	V	A	B	G	G	A	A

3.1. Application with Fuzzy AHP Method:

Experts use the linguistic variables, to evaluate the ratings of alternatives with respect to each criterion and then each variable is converted into triangular fuzzy numbers. The fuzzy numbers are defined in Table 3:

Table 3. Linguistic Variable and Triangular Fuzzy Numbers

Criteria	**AQ**	**K**	**TA**	**R**	**P**	**---**
Linguistic Variables	Strong	Very Strong	Absolute	Weak	Average	Equal
Fuzzy Numbers	4,6,7	5,7,9	7,8,9	2,3,4	3,5,7	1,1,1
Grades	G	VG	E	B	A	---

According to the markings of the experts, the linguistic variables are converted into triangular fuzzy numbers and a pair wise comparison matrix is given in Table 4:

Table 4. Pair Wise Comparison Matrix

Criteria	**Academic Qualification**	**Knowledge**	**Teaching Ability**	**Research**	**Presentation**
Academic Qualification	1,1,1	0.457,0.857,1.25	0.567,0.75,0.967	1.2,2,2.4	1,1.2,1.5
Knowledge	0.795,1.167,2.18	1,1,1	0.6,0.875,1.078	1.433,2.333,2.93	1,1.4,2
Teaching Ability	1.034,1.333,1.76	0.928,1.149,1.66	1,1,1	2.4,2.667,3.1	1.5,1.6,1.9
Research	0.416,0.5,0.833	0.341,0.428,0.69	0.323,0.374,0.41	1,1,1	0.3,0.6,1.2
Presentation	0.667,0.833,1	0.5,0.714,1	0.526,0.625,0.66	0.833,1.667,3.33	1,1,1

Following all above mentioned steps from 1 to 7 of Fuzzy Analytic Hierarchy Process, the individual weights of each criteria and weighted normalized matrix is calculated and given in Table 5:

Table 5. Weighted Normalized Matrix

Weight	**0.197460966**	**0.255012403**	**0.291842988**	**0.088486794**	**0.167196848**
Candidate	**Academic Qualification**	**Knowledge**	**Teaching Ability**	**Research**	**Presentation**
S1	0.207868425	0.141985995	0.190900948	0.277981878	0.171561269
S2	0.13391749	0.229873928	0.264506429	0.097644208	0.29949027
S3	0.232906151	0.178280943	0.113804966	0.274378751	0.188175683
S4	0.204980087	0.098380755	0.02002437	0.107789208	0.023749001
S5	0.099143279	0.155196772	0.264506429	0.00736647	0.077250077

3.2. Application with PROMETHEE -2 and TOPSIS Method:

In this section, the above mentioned steps of PROMETHEE 2 and TOPSIS are applied to the weighted normalized matrix found in Table 4 and individual ranks of each alternative by both the methods is given in Table 6:

Table 6. Ranking of Candidates according PROMETHEE-2 and TOPSIS

Candidate	**Rank**	
	PROMETHEE-2	**TOPSIS**
S1	3	1
S2	1	2
S3	2	3
S4	5	5
S5	4	4

3.3 Correlation Coefficients

The ranks determined by Promethee-2 and Topsis differ from each other as given in Table 7. Thus, to determine the measure of association between the ranks achieved by these two methods, the Spearman Rank Correlation Method as mentioned in Section 2.7.1 is used to find the correlation coefficient ρ .

Table 7. Difference between PROMETHEE-2 and TOPSIS

Candidate	**Rank**		**Difference in ranks**	d_a^2
	PROMETHEE-2	**TOPSIS**		
S1	3	1	2	4
S2	1	2	-1	1
S3	2	3	-1	1
S4	5	5	0	0
S5	4	4	0	0

From Table-7, $R = 0.7$ establishes a **Marked Relationship** between Promethee-2 &Topsis.

3.4. Group Decision Making

Table 8 presents the group decision making analysis following the rules given in Section 2.8.

Table 8. Additive and Multiplicative Ranking

Alternatives	Rank		Additive Ranking	Inferred Group Ranking	Multiplicative Ranking	Inferred Group Ranking
	Promethee-2	Topsis				
S1	3	1	2.00	2	1.732	2
S2	1	2	1.50	1	1.414	1
S3	2	3	2.50	3	2.449	3
S4	5	5	5.00	5	5.000	5
S5	4	4	4.00	4	4.000	4

From Table-8, the final ranking can be given as:

Table 9. Final Ranking of the Candidates

Alternatives	Rank
S1	2
S2	1
S3	3
S4	5
S5	4

4. Conclusion

In this case study of the faculty selection interview in an Engineering Organization the uncertainty and vagueness of the experts' marks have been effectively represented and resolved to a more effective decision using the Fuzzy AHP MCDM method. For a comparative study the result of Fuzzy AHP was separately used as an input to PROMETHEE-2 and TOPSIS. Since, the final ranking of these two methods slightly differs from each other; a group decision making method is implemented to get a single ranking structure. There is no doubt for the 4th and 5th positions taken by S5 and S4 respectively but S1, S2 and S3 all are strong contenders for the best position. S1 and S3, despite having a very strong Academic Qualification and Research work are not chosen as the best choice as they are significantly weak in skill of Teaching Ability (TA) than S2. In comparison to this, S2 which although has comparatively not so strong Academic Qualification and Research work but is very strong in depth of Knowledge and Teaching Ability, which are more important criteria in an Engineering institute than others. Hence, S2 is the best choice for a faculty member in this Engineering Organization.

Analyzing the importance of each criterion in Engineering Institutes and comparing the ranking pattern of individual MCDM methods with the final ranking it can be concluded that TOPSIS and PROMETHEE- 2 share a marked relationship between them as established by Spearman Rank Correlation Method and the difference between them exists as TOPSIS compares the alternatives on the overall marking of the experts for each criterion and PROMETHEE-2 compares the alternatives on the basis of the priority of the criteria.

References

[1] P. Kumar Dey, S. Chattaraj and D. Nath Ghosh, "Faculty Selection in Engineering Organization using AHP & TOPSIS", International Journal of Information and Computing Science (IJICS) 06/2012, vol. 15, no. 1, **(2012)**.
[2] P.-C. Chen, "A Fuzzy Multiple Criteria Decision Making Model in Employment Recruitment", IJCSNS International Journal of Computer Science and Network Security, vol. 9, no. 7, **(2009)** July, pp. 113-117.
[3] K. Oraee and E. Bakhtavar, "Selection of Tunnel Support System by Using Multi Criteria Decision-Making Tools", 29th International Conference on Ground Control in Mining.
[4] D. Chatterjee and B. Mukherjee, "Study of Fuzzy-AHP Model To Search The Criterion in the Evaluation of the Best Technical Institutions: A Case Study", International Journal of Engineering Science and Technology, vol. 2, no. 7, **(2010)**, pp. 2499-2510.
[5] L. Z. Zadeh, "Fuzzy sets", Inf. Control., vol. 8, **(1965)**, pp. 338-353.
[6] G. Bojadziev and M. Bojadziev, "Fuzzy sets and fuzzy logic applications", World Scientific, Singapore, **(1998)**.
[7] H. J. Zimmermann, "Fuzzy set theory and its applications", Kluwer, Boston, **(1992)**.
[8] L. A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning-I", Inf. Science, **(1975)**, pp. 199-249.
[9] T. L. Saaty, "How to Make a Decision: The Analytic Hierarchy Process", European Journal of Operational Research, vol. 48, **(1990)**, pp. 9-26.
[10] D. Y. Chang, "Applications of the Extent Analysis Method on Fuzzy AHP", European Journal of Operational Research, vol. 95, **(1996)**, pp. 649-655.
[11] C. Kahraman, U. Cebeci and D. Ruan, "Multi-Attribute Comparison of Catering Service Companies Using Fuzzy AHP: The case of Turkey", International Journal of Production Economics, vol. 87, no. 2, **(2004)**, pp. 171-184.
[12] M. F. A. Taleb and B. Mareschal, "Water Resources Planning in the Middle East: Application of the PROMETHEE V Multicriteria Method", European Journal of Operational Research, vol. 81, **(1995)**, pp. 500-511.
[13] J. C. Pomerol and S. B. Romero, "Multicriterion Decision in Management: Principles and Practice", Kluwer Academic, Netherlands, **(2000)**.
[14] J. P. Brans, P. Vincke and B. Mareschal, "How to Select and How to Rank Projects: The PROMETHEE method", European Journal of Operational Research, vol. 24, **(1986)**, pp. 228-238.
[15] D. Nath Ghosh, "Analytic Hierarchy Process and TOPSIS Method to Evaluate Faculty Performance in Engineering Education", UNIASCIT, vol. 1, no. 2, **(2011)**, pp. 63-70.
[16] C. L. Hwang and K. Yoon, "Multiple Attribute Decision Making Methods and Applications", Springer, Berlin Heidelberg, **(1981)**.
[17] Y. J. Wang and H. S. Lee, "Generalizing TOPSIS for fuzzy multiple-criteria group decision making", Computers and Mathematics with Applications, vol. 53, no. 11, **(2007)**, pp. 1762-1772.
[18] C. Spearman, "The Proof and Management of Association between Two Things", American Journal of Psychology, vol. 15, **(1904)**, pp. 72-101.
[19] G. Woodbury, "Introduction to Statistics", Thomson Learning, USA, **(2002)**.
[20] K. S. Raju and D. Nagesh Kumar, "Multi-criterion Decision-Making in Irrigation Planning, Agricultural Systems", vol. 62, no. 2, **(1999)**, pp. 117- 129.
[21] P. H. Liu and C. C. Wei, "A Group Decision-Making Method for Appraising the Performance of Organizations", International Journal of the Computer, the Internet and Management, vol. 8, no. 2, **(2000)**, pp. 39-49.
[22] T. X. Bui, "Coop: A Group Decision Support System for Cooperative Multiple Criteria Group Decision-making", Springer-Verlag, Berlin, **(1987)**.
[23] K. S. Raju and D. Nagesh Kumar, "Multicriterion Analysis in Engineering and Management", PHI Learning Pvt. Ltd., **(2010)**.