

# Academic Staff Selection using Graph Theory Matrix Approach

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## Abstract

**Background:** Qualified and competent academic staff selection is a very important task for the successful running of an academic organization. **Method:** The complexity of the selection process calls for the adaption of Multi criteria decision making method where in, the optimal decision can be taken depending on the available qualitative and quantitative data. The present study deals with the ranking and selection of academic staff for a technical institute considering nine attributes. **Findings:** The adaptability of Graph theoretic approach is presented for the first time to rank and select academic staff from among ten candidates. **Application / Improvement:** Graph theoretic approach is very much helpful in selecting the best alternative from among various alternatives.

**Keywords:** Graph Theory Matrix Approach, Permanent Function, Rank, Staff Selection

## 1. Introduction

The survival of the organization in the present competitive market is driven by the commitment of the employees to organization. Choosing of potential individual who suit the qualifications or policies to do a specified job will indeed lead to the success of an academic organization. Great amount of attention is given on personnel selection in literature. In<sup>1</sup> conducted a numerous studies on analysis of resumes, interviews, sample tests, personality tests, and knowledge tests for selection. Computer based testing telephonic interviews multi-media simulation tests have been adapted in personnel selection to save time and money<sup>2</sup>. The complexity of personnel selection requires the adaption of Multi Criteria Decision Making method (MCDM) for unbiased selection procedure.

In personnel selection<sup>3</sup> adapted a MCDM model using Fuzzy VIKOR method considering the worst case method in choosing weight criteria. The results of the fuzzy VIKOR are ranked and compared with modified fuzzy VIKOR. It was concluded that the final ranking of fuzzy VIKOR is in very close accordance with the modified

VIKOR approach. A mathematical model was proposed by<sup>4</sup> to select personnel which comprises of four stages. The uniqueness of their model is that it automates a lot of steps in selection process which reduces time and cost. In<sup>5</sup> adapted simple additive weighting method to select the best among personnel. Qualitative and positive criteria were considered in their approach rather than intuitive decisions in the tele-communications sector. A hybrid model was proposed by<sup>6</sup> using DEMATEL and TOPSIS to select the personnel based on talent management. Their model ensures the selection of personnel with right usage of talents for developing high performance on capability in the success of an organization. To perform robust personnel selection<sup>7</sup> adapted extended fuzzy MULTIMOORA approach. The qualitative characteristics of the candidates are expressed in linguistic terms to avoid the uncertainty and their model used seven point scales to express the linguistic variables into crisp scores.

In<sup>8</sup> used Grey relational analysis for the selection of personnel. In their approach, the opinion of decision makers is aggregated as the group opinion using fuzzy weighted averaging. The weights of the criteria were obtained using

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fuzzy entropy and the ranking of the personnel was done using grey relational analysis. The approach based on ANP integrated with fuzzy data envelopment was proposed by<sup>2</sup> in personnel selection for an electric company. Rather than the conventional operational research method, their proposed method deals with the selection of personnel convincingly and persuasively. For a manufacturing system, in selecting personnel<sup>10</sup> adapt an integrated ANP and TOPSIS method. The organization of the problem and criteria weights was developed using ANP and the final ranking of the personnel was done using TOPSIS method.

From the above literature review, it can be concluded that the complexity of personnel selection analysis requires the application of multi criteria decision making method for robust and unbiased recruitment.

There has been a sea change in the technical education in India as there are major issues of concern about quality of technical education offering, increasing the attractiveness of engineering education and retention of students, promoting industry – institution interaction etc., even though there is strong interest among Indian youth to study engineering, there is severe shortage of qualified and competent faculty. While there are islands of excellence, these are few in number.

The robust MCDM procedure for academic staff selection should be able to incorporate qualitative as well as quantitative data. The present study hence is aimed to rank and select academic staff for the technical institute using Graph theory matrix approach, a MCDM tool.

## 2. Problem Structure

Out of the applications received, 10 applications are short listed for interview. The bottleneck areas are identified and tabulated in Table 1.

The decision maker gives priority to quality of teaching, capability of handling subjects, number of research papers published, communication skills, technical aptitude and experience on the other hand, gives least importance to salary. On the other side, the applicant's aspirations are other way true. The quality of teaching, technical aptitude and communication skills are not measurable quantities so, a suitable scale is proposed to convert them into ratings in the range of 1 to 10 as shown in Table 2.

The table for evaluation of academic staff constituting attributes and relative values of attributes is shown in Table 3.

**Table 1.** Attributes for ranking of academic staff.

Sl. No	Criteria / Name	Quali-fication	Quality of teaching	Research papers published	Expe-rience	Tech-nical Apti-tude	Ability to handle different subjects	Faculty reten-tion in years	Exp-ected salary	Com-muni-cation skills
1	A 1	PG	Average	3	3	Average	4	2	40000	Above average
2	A 2	PG	Above average	1	1	Average	2	4	30000	Good
3	A 3	PG + Pursuing PhD	Good	4	4	Good	6	3	55000	Above average
4	A 4	PG	Average	3	2	Above average	4	2	32000	Below average
5	A 5	PG	Below average	2	3	Average	4	3	38000	Average
6	A 6	PG	Good	5	2	Good	5	4	28000	Above average
7	A 7	PG + Pursuing PhD	Excellent	6	2	Good	6	4	30000	Good
8	A 8	PG	Good	6	4	Good	6	3	50000	Average
9	A 9	PG + Pursuing PhD	Good	8	5	Good	6	3	60000	Good
10	A 10	PG	Average	4	3	Average	4	2	42000	Above average

**Table 2.** Judgment for non-measurable quantities.

Attribute	Below average	Average	Above average	Good	Excellent
Quality of teaching	6	7	8	9	10
Technical Aptitude	6	7	8	9	10
Communication skills	6	7	8	9	10

**Table 3.** Attributes and relative values.

Sl. No	Cri-teria / Name	Quali-fica-tion	Quality of teach-ing	Re-search papers pub-lished	Experi-ence	Techni-cal Apti-tude	Ability to handle differ-ent sub-jects	Faculty retention (No. of years)	Expec-ted salary	Communi-cation skills
1	A 1	7	7	3	3	7	4	2	40000	8
2	A 2	7	8	1	1	7	2	4	30000	9
3	A 3	8	9	4	4	9	6	3	55000	8
4	A 4	7	7	3	2	8	4	2	32000	6
5	A 5	7	6	2	3	7	4	3	38000	7
6	A 6	7	9	5	2	9	5	4	28000	8
7	A 7	8	10	6	2	9	6	4	30000	9
8	A 8	7	10	6	4	9	6	3	50000	7
9	A 9	8	10	8	5	9	6	3	60000	9
10	A 10	7	7	4	3	7	4	2	42000	8

### 3. Graph Theory Matrix Approach

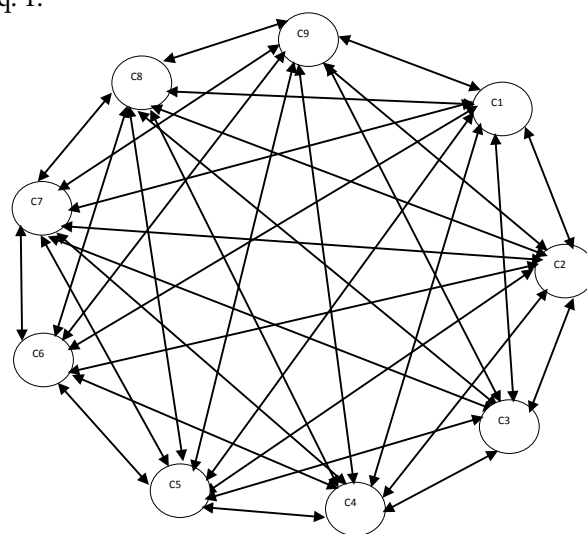
#### 3.1 Structure Graph

Graph theoretic models have the capability to model the characteristics of attributes and their interdependencies<sup>11</sup>. The attributes Qualification (C1), Quality of teaching (C2), Research papers published (C3), Experience (C4), Technical aptitude (C5), Ability to handle different subjects (C6), faculty retention (C7), expected salary (C8) and Communication skills (C9) are denoted as nodes while inter-connection among the attributes is represented as edges. The influence of one attribute on the other attribute is shown in Figure 1.

#### 3.2 Matrix Representation of Structure Graph

The structure graph gives the visual inspection of attributes and inter-connections. However, matrices render a

convenient way for mathematical calculations. Structure matrix is an analogous to characteristic matrix in the graph theory<sup>12</sup>. Structure matrix of Figure 1 is shown in eq. 1.



**Figure 1.** Structure graph.

$$[N] = \begin{bmatrix} N_1 & n_{12} & n_{13} & n_{14} & n_{15} & n_{16} & n_{17} & n_{18} & n_{19} \\ n_{21} & N_2 & n_{23} & n_{24} & n_{25} & n_{26} & n_{27} & n_{28} & n_{29} \\ n_{31} & n_{32} & N_3 & n_{34} & n_{35} & n_{36} & n_{37} & n_{38} & n_{39} \\ n_{41} & n_{42} & n_{43} & N_4 & n_{45} & n_{46} & n_{47} & n_{48} & n_{49} \\ n_{51} & n_{52} & n_{53} & n_{54} & N_5 & n_{56} & n_{57} & n_{58} & n_{59} \\ n_{61} & n_{62} & n_{63} & n_{64} & n_{65} & N_6 & n_{67} & n_{68} & n_{69} \\ n_{71} & n_{72} & n_{73} & n_{74} & n_{75} & n_{76} & N_7 & n_{78} & n_{79} \\ n_{81} & n_{82} & n_{83} & n_{84} & n_{85} & n_{86} & n_{87} & N_8 & n_{89} \\ n_{91} & n_{92} & n_{93} & n_{93} & n_{95} & n_{96} & n_{97} & n_{98} & N_9 \end{bmatrix} \quad (1)$$

The values of  $N_i$  and  $n_{ij}$  or  $n_{ji}$  are taken both from Table 4 and 3.

**Table 4.** Values of attributes<sup>13</sup>.

Sl. No.	Subjective measure of attributes	Assigned value
1	Exceptionally low	0.0
2	Extremely low	0.1
3	Very low	0.2
4	Low	0.3
5	Below average	0.4
6	Average	0.5
7	Above average	0.6
8	High	0.7
9	Very high	0.8
10	Extremely high	0.9
11	Exceptionally high	1.0

The values of Table 3 are subjective and objective. The objective values will have different units. The values of  $N_i$  are desired to be subjective. In the present study, except expected salary, all other attributes are beneficial attributes. As the normalized values of attributes does not contain zero, no information will be lost. The normalized value of the attributes is shown in Table 5.

The values of the off-diagonal elements  $n_{ij}$ , where  $i$ ,  $j^{\text{th}}$  attribute is dependent on  $j^{\text{th}}$  attribute as well as  $j^{\text{th}}$  attribute is also dependent on  $i^{\text{th}}$  attribute and are shown in Table 6.

**Table 6.** Values of relative importance.

Sl. No.	Class description	Relative importance	
		$a_{ij}$	$a_{ji} = 1 - a_{ij}$
1	Two attributes are equally important	0.5	0.5
2	One attribute (i) is slightly more important over the other (j)	0.6	0.4
3	One attribute (i) is strongly important over the other (j)	0.7	0.3
4	One attribute (i) is very strongly important over the other (j)	0.8	0.2
5	One attribute (i) is extremely important over the other (j)	0.9	0.1
6	One attribute (i) is exceptionally more important over the other (j)	1.0	0.0

**Table 5.** Normalized value of attributes.

Sl. No	Crite-ria / Name	Quali-fication	Quality of teaching	Research papers published	Expe-rience	Tech-nical Aptitude	Ability to handle different subjects	Faculty retention (No. of years)	Expected salary	Commu-nication skills
1	A 1	0.875	0.700	0.375	0.600	0.778	0.667	0.500	0.700	0.889
2	A 2	0.875	0.800	0.125	0.200	0.778	0.333	1.000	0.933	1.000
3	A 3	1.000	0.900	0.500	0.800	1.000	1.000	0.750	0.509	0.889
4	A 4	0.875	0.700	0.375	0.400	0.889	0.667	0.500	0.875	0.667
5	A 5	0.875	0.600	0.250	0.600	0.778	0.667	0.750	0.737	0.778
6	A 6	0.875	0.900	0.625	0.400	1.000	0.833	1.000	1.000	0.889
7	A 7	1.000	1.000	0.750	0.400	1.000	1.000	1.000	0.933	1.000
8	A 8	0.875	1.000	0.750	0.800	1.000	1.000	0.750	0.560	0.778
9	A 9	1.000	1.000	1.000	1.000	1.000	1.000	0.750	0.467	1.000
10	A 10	0.875	0.700	0.500	0.600	0.778	0.667	0.500	0.667	0.889

**Table 7.** Weights of criteria.

Criteria	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9
C 1	1	3	4	3	3	4	4	5	6
C 2	0.333	1	2	3	3	2	3	6	3
C 3	0.25	0.500	1	2	2	2	2	4	3
C 4	0.333	0.333	0.500	1	2	3	2	5	4
C 5	0.333	0.333	0.5	0.5	1	2	2	4	3
C 6	0.250	0.5	0.500	0.333	0.5	1	1	3	3
C 7	0.25	0.333	0.5	0.5	0.5	1	1	3	2
C 8	0.20	0.167	0.25	0.200	0.25	0.333	0.333	1	2
C 9	0.17	0.333	0.333	0.25	0.333	0.333	0.5	0.500	1
<b>Total</b>	<b>3.117</b>	<b>6.500</b>	<b>9.583</b>	<b>10.783</b>	<b>12.583</b>	<b>15.667</b>	<b>15.833</b>	<b>31.500</b>	<b>27.000</b>

**Table 8.** Consistency measures.

Criteria	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	Total	Average	Consistency Measure
C 1	0.321	0.462	0.417	0.278	0.238	0.255	0.253	0.159	0.222	2.605	0.289	9.809
C 2	0.107	0.154	0.209	0.278	0.238	0.128	0.189	0.190	0.111	1.605	0.178	9.994
C 3	0.080	0.077	0.104	0.185	0.159	0.128	0.126	0.127	0.111	1.098	0.122	9.869
C 4	0.107	0.051	0.052	0.093	0.159	0.191	0.126	0.159	0.148	1.087	0.121	9.533
C 5	0.107	0.051	0.052	0.046	0.079	0.128	0.126	0.127	0.111	0.828	0.092	9.390
C 6	0.080	0.077	0.052	0.031	0.040	0.064	0.063	0.095	0.111	0.613	0.068	9.377
C 7	0.080	0.051	0.052	0.046	0.040	0.064	0.063	0.095	0.074	0.566	0.063	9.486
C 8	0.064	0.026	0.026	0.019	0.020	0.021	0.021	0.032	0.074	0.302	0.034	9.168
C 9	0.053	0.051	0.035	0.023	0.026	0.021	0.032	0.016	0.037	0.295	0.033	9.549
											Consistency Index	0.072
											Random Index	1.46
											Consistency Ratio	0.049

The consistency of the structure matrix is checked using the standard procedure<sup>5,13</sup>. The weight of criteria is shown in Table 7 and the consistency measures are shown in Table 8. If consistency ratio is less than 0.10, then only it will be acceptable. In the present study, the consistency ratio obtained is 0.049.

**Table 9.** Structure index and rank for applicants.

Sl. No.	Criteria / Name	Structure Index	Rank
1	A1	496724	6
2	A2	495207	8
3	A3	546881	5
4	A4	490361	10

5	A5	496240	7
6	A6	579204	3
7	A7	613196	1
8	A8	577309	4
9	A9	607255	2
10	A10	492789	9

### 3.3 Structure Index

The permanent function used in combinatorial mathematics characterizes the configuration of a system<sup>14</sup>. The permanent function for the matrix is shown in eq. 2.

$$\begin{aligned}
 Per(A) = & \prod_{i=1}^M N_i + \sum_{i=1}^{M-1} \sum_{j=i+1}^M \dots \sum_{M=i+1}^M (n_{ij}n_j) N_k N_l N_m N_n \dots N_r N_s \\
 & + \sum_{i=1}^{M-2} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^M \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{ki} + n_{ik}n_{kj}n_{ji}) N_l N_m N_n N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-3} \sum_{j=i+1}^{M-2} \sum_{k=j+1}^{M-1} \sum_{l=i+2}^M \dots \sum_{M=i+1}^M (n_{ij}n_j)(n_{kl}n_{lk}) N_m N_n N_o \dots N_r N_s + \\
 & \sum_{i=1}^{M-3} \sum_{j=i+1}^{M-2} \sum_{k=i+1}^{M-1} \sum_{l=j+1}^M \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl}n_{li} + n_{ij}n_{kl}n_{li}n_{jk}) N_m N_n N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-2} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^M \sum_{l=i+1}^{M-1} \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl} + n_{ik}n_{kj}n_{jl}) (n_{lm}n_{ml}) N_n N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-2} \sum_{j=i+1}^{M-1} \sum_{k=i+1}^{M-2} \sum_{l=j+1}^M \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl}n_{lm}n_{ml} + n_{im}n_{ml}n_{lj}n_{ji}) N_n N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-3} \sum_{j=i+1}^{M-2} \sum_{k=j+1}^{M-1} \sum_{l=i+1}^M \sum_{m=i+1}^M \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl}n_{lm} + n_{il}n_{lk}n_{kj}n_{ji}) (n_{mn}n_{nm}) N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-5} \sum_{j=i+1}^{M-4} \sum_{k=j+1}^{M-3} \sum_{l=i+1}^{M-2} \sum_{m=i+1}^{M-1} \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl} + n_{ik}n_{kj}n_{jl}) (n_{lm}n_{mn}n_{ni} + n_{in}n_{nm}n_{ml}) N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-5} \sum_{j=i+1}^{M-4} \sum_{k=i+1}^{M-3} \sum_{l=j+1}^M \sum_{m=i+1}^{M-2} \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl} + n_{ik}n_{kj}n_{jl}) (n_{lm}n_{mn}n_{ni} + n_{in}n_{nm}n_{ml}) N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-5} \sum_{j=i+1}^{M-4} \sum_{k=j+1}^{M-3} \sum_{l=i+2}^M \sum_{m=k+1}^{M-1} \sum_{n=k+2}^M \dots \sum_{M=i+1}^M (n_{ij}n_j)(n_{kl}n_{lk}) (n_{mn}n_{nm}) N_o \dots N_r N_s \\
 & + \sum_{i=1}^{M-5} \sum_{j=i+1}^{M-4} \sum_{k=i+1}^{M-3} \sum_{l=j+1}^M \sum_{m=k+1}^{M-2} \sum_{n=j+1}^M \dots \sum_{M=i+1}^M (n_{ij}n_{jk}n_{kl}n_{lm}n_{ml}n_{ni} + n_{ij}n_{lm}n_{mn}n_{kj}n_{ji}) N_o \dots N_r N_s \\
 & + \dots \dots \dots
 \end{aligned} \tag{2}$$

The values of  $N_i$  and  $n_{ij}$  are substituted in eq. 2, a computer program is designed to calculate Structure index and to rank for all the applicants.

### 3.4 Selection of Academic Staff

Finally the structure index for the entire applicant is evaluated and shown in Table 9. The best personnel as per the Table 9 is A7 and then A, A6, A8, A3, A1, A5, A2, A10 and A4 respectively.

## 4. Conclusion

This study presented a MCDM method for academic staff selection using Graph theoretic approach. In the evaluation process, Graph theory matrix approach provides means to consider both qualitative and quantitative data. Above all, GTMA does not require cumbersome calculations. Further, the GTMA methodology can be applicable to broader area and any number of attributes may be considered. The future work for this study is to adopt fuzzy set theory to imprecise judgments in problems like personnel selection.

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