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Sobhan Sarkar
Indian Institute of Technology Kharagpur

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A De Novo approach for the Performance evaluation of Indian technical institutions

Sobhan Sarkar[1], Bijan Sarkar[2]

[1] *M.Tech of Production Engineering, Jadavpur University, West Bengal*
[2] *Professor of Production Engineering, Jadavpur University, West Bengal*

Abstract

Education is the prime need of every citizen. Without this no one can sustain in this competitive world. Indian technical education system is enormous and complex both in primary level and higher level. India has 82 engineering colleges (IITs -16, IIMs – 13, IISC – 1, IISERs – 5, Nits – 30, IIITs – 4, NITTRs – 4, Others (SPA, ISMU, NERIST, SLIET, NITIE & NIFFT, CIT) - 9) but Indian technical education is facing a big threat for liberalization as well as global economy. Reviews of India's college education structure are clouded by endless controversies. The demands to "liberalize" college education have leaned on the need for new investments at a critical juncture of India's growth. So, the national, International and private investment become the key source of advanced study and newer techniques. As there is limited resource, so the performance evaluation is come into picture and is followed by the ranking among the alternatives. Aiming at this noble target of prioritizing the alternatives, we propose a multiple criteria analysis based performance evaluation model. In this model, six criteria (faculty strength (C1), student Intake (C2), number of Ph.D. awarded (C3), number of patents applied for (C4), the campus areas in acres (C5) and tuition fee per semester in rupees (C6)) and seven IITs have been considered for performance evaluation in this study. They are expressed as A, B, C, D, E, F and G. Weightage value for each criterion is computed by Subjective and Objective Weight Integrated Approach (SOWIA) and ranking is done by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. Furthermore, correlation between the two methods i.e., fuzzy AHP-COPRAS and our proposed method TOPSIS has been carried out in order to explore interrelationship of the methods used.

Keywords: Indian Institute of Technologies, SOWIA, TOPSIS, Ranking, Co-relational and sensitivity analysis.

1. Introduction

Education in a college falls, roughly in either of two categories the world over. A liberal education implies training in the fine arts, the humanities, cultural patterns and behavior, and aims at developing a man's personality. Technical education, on the other hand, aims primarily at equipping a man for work in the practical sense of getting him fit for a job. With the advancement of industrialization the people of the West came to realize importance of technical education. The Industrial Revolution brought about a great change in the outlook of men regarding education. The increasing use of machinery has compelled us to feel the necessity of technical education. All the countries of the world, with no exception, have started to impart specialized training to their youths. Indian technical education system is one of the largest educational systems in the world. Quality is the prime purpose in this system that makes the stand of India in the global competitive market with skilled manpower, improved quality and productivity. Today's scenario shows us the statistics of technical Institutions in India. There are three categories of institutions in this system like, institutions funded by Central govt., institutions funded by state government and last one is self-financed institutions. In 2012-13, there are 3495 Engineering colleges and 17,61,976 seats per year in engineering in the country [1] that shows the rise in demand of technical education in country. Among the centrally funded institutions, IIT's rank top as they demand high quality world class knowledge based technical system with practical exposure. In this paper, seven IITs are selected. They are situated at kharagpur, Bombay, Madras, Kanpur, Delhi, Guwahati and Roorkee and they are coded as A,B,C,D,E,F and G. Today's competitive world demand high quality output with minimum input time and other minimum resources. So, performance evaluation is the crying need of this hour. So, in this paper, we suggest a combined methodology consisting of subjective and objective weight integrated approach (SOWIA) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). SOWIA method helps the decision maker to get the decision based on either the subjective weights or by the objective weights or both of two. TOPSIS helps the decision maker to evaluate the final rank of the IITs.

The paper comprises of the following sections: Section 2 reviews the previous literatures. Section 3 shows the procedural steps of proposed model used in this paper. Section 4 elaborates the data analysis and computations and sensitivity analysis. Section 5 presents the discussions on this topic and conclusion is given in the last section.

2. Review of the past researchers

Abbott and Doucouliagos (2002) [2] used DEA technique to derive estimates of the technical and scale efficiency of Victorian Technical and Further Education Institutes. Agha et al. (2011) evaluated the relative technical efficiencies of academic departments at the Islamic University in Gaza [3]. Operating expenses, credit hours and training resources were the inputs, while number of graduates, promotions and public service activities were considered as the outputs. Das et al., [4] have used fuzzy AHP method for performance evaluation of six institutions. Das et al., [5] present a comparative evaluation of seven Indian institutes of technology (IITs) using fuzzy AHP and COPRAS method. Das et al., [6] present a combined SOWIA-MOORA approach to evaluate the performances of the Indian technical institutions. Kounetas et al. (2011) applied DEA technique with six model variants to assess the research performance of academic departments in a Greek university [7]. A Tobit model was also considered to study the impact of environmental effects on departmental efficiencies. Kuah and Wong (2011) [8] presented a DEA model for jointly evaluating the relative teaching and research efficiencies of 30 universities. McMillan and Datta (1998) assessed the relative efficiency of 45 Canadian universities employing DEA technique [9]. Tyagi et al. (2009) [10] evaluated performance efficiencies of 19 academic departments of IIT Roorkee (India) using DEA technique. The use of league table [11, 12, and 13] is found to rank academic institutions in UK. League tables are generally used to compare academic performance of various institutions by considering a set of well-defined criteria such as- student satisfaction, research assessment/quality, entry standards, student-staff ratio, academic services spend, and facilities spend, good honours, graduate prospects and completion rate. A statistical technique known as Z-transformation is applied to each criterion to create a score for that criterion. Weighted Z-scores on each criterion help to determine the final rank of the institution. Wahab and Abdul Rahman [14] measured the efficiency of zakat institutions in Malaysia during the period of 2003 to 2007, and showed that zakat institutions had mean technical efficiency of 80.6%.

3. Steps of the proposed model

In practice, there are lots of factors, criteria to be considered by the decision maker to evaluate the performance score of the technical institutions which is really difficult. Among these criteria, we select the criteria of the published paper [15] and solve their example by our proposed methodology. The evaluation criteria are: i) Faculty strength (C1), ii) Student intake (C2), iii) Number of PhD awarded (C3), iv) Number of patents applied for (C4), v) The campus area in acres (C5), and vi) Tuition fee per semester in rupees (C6). All are beneficial criteria except the tuition fee which is non-beneficial criteria i.e., lower the better.

3.1 The methods used: There are a lot of multi-criteria decision making processes like- AHP [16], ELECTRE [17], DEA [18], PROMETHEE [19], MOORA [20], VIKOR etc. available to rank the alternatives using weight value. In this paper, we use SOWIA [21] method to determine the weights of the criteria and using these weights we use TOPSIS method to get the final rank of the alternatives. In SOWIA method, we use Shannon's entropy method [22] to calculate the objective weights and we get the subjective weights from the published paper by Das. et al., [15].

At first, we start with the definition of decision matrix having four components, namely: i) alternatives, ii) criteria, iii) subjective weights and iv) measure of performance of the alternatives with respect to criteria. The decision matrix can be expressed in Eq 1.

Here, A_i represents the alternatives, i = 1,2,…m; C_j is the j-th criterion, j = 1,2,…n. W_j is the weight of the j-th criterion and x_{ij} indicates the performance value of each alternative A_i with respect to each criterion C_j.

Step 1. Firstly, we prepare the decision matrix (DM) = $\lfloor x_{ij} \rfloor$.

$$DM = [x_{ij}] = \begin{array}{c|cccccc}
 & C_1 & C_2 & .. & C_j & .. & C_n \\
 & W_1 & W_2 & .. & W_j & .. & W_n \\
\hline
A_1 & x_{11} & x_{12} & .. & x_{1j} & .. & x_{1n} \\
A_2 & x_{21} & x_{22} & .. & x_{2j} & .. & x_{2n} \\
.. & .. & .. & .. & .. & .. & .. \\
A_i & x_{i1} & x_{i2} & .. & x_{ij} & .. & x_{in} \\
.. & .. & .. & .. & .. & .. & .. \\
A_m & x_{m1} & x_{m2} & .. & x_{m3} & .. & x_{mn}
\end{array} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Step 2. Then, the decision matrix is normalized by the following equation.

$$x^*_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} ; \ \ldots\ldots\ldots \qquad \ldots\ldots \text{(2)}$$

Where x^*_{ij} is the normalized value of x_{ij} and $\sum_{i=1}^{m} x_{ij}$ is the total value of the j-th criterion for m number of alternatives.

Step 3.

Step 3.1. Subjective weight (S_j) of the importance of criteria:

Here, we use the same weights determined by Das et al. [15] by fuzzy AHP process.

Step 3.2. Objective weight (O_j) of the importance of criteria:

Here, to get the objective weight of the criteria, we use Shannon's entropy method [22]. Entropy algorithm is a useful tool to acquire weights of criteria. Consider x_{ij} in decision matrix for alternatives evaluation. If there are n alternatives and k criteria then the element of the matrix for j-th criterion is as below:

$$x_{ij} = \frac{f_j(a_i)}{\sum_{i=1}^{n} f_j(a_i)} ; \text{ Where, j = 1, 2… k. } \forall j \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots.. \text{(3)}$$

Entropy is then calculated as below:

$$E_j = -M \sum_{i=1}^{n} P_{ij} \ln P_{ij} ; \ldots\ldots\ldots\ldots\ldots\ldots \qquad \ldots \text{(4)}$$

Here E_j lies in between 0 and 1 and $\forall j$

Then, M is calculated as a constant value as follows:

$$M = \frac{1}{\ln(n)}. \quad \ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Then, we have to calculate the deviation degree (d_i). It can show that to what extent j-th criterion has useful information for decision maker. If there is little difference between one criterion value, it means that alternatives are indifferent according to this criterion so its effect should be diminished. Deviation degree is calculated as follows:

$$d_i = 1 - E_i \; ; \; \forall j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad . \; (6)$$

The final step is to obtain objective weights based on the following equation:

$$O_j = d_j \Big/ \sum_{j=1}^{k} d_j \quad ; \quad \forall j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \ldots.. (7)$$

Step 3.3. The Integrated weights ($W^{\text{int}}{}_j$) of attributes: The decision maker can use the following formula to get the final integrated weight where α is known as objective factor decision weight [23 and 25]. Here, α lies in between 0 and 1. O_j and S_j are the objective and subjective weights respectively. The following equation is flexible as the value of α is changed as per the decision maker.

$$W^{\text{int}}{}_j = \alpha * O_j + (1-\alpha) * S_j \quad \ldots\ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots (8)$$

3.1.2 The TOPSIS method: TOPSIS is a multi criteria decision making process which determines solution alternatives from a finite set in the basis of maximizing the distance from the negative ideal point and minimizing the distance from the positive ideal point. The model algorithm steps of TOPSIS [24].

Step 1: For n criteria performance data of m alternatives are collected. Raw data (x_{ij}) are then normalized (r_{ij}).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2{}_{ij}}} \text{; where i = 1,2,…,m; j = 1,2,…,n} \quad \ldots\ldots \quad \ldots\ldots\ldots(9)$$

Step 2: The weight value (w_j) for each criterion is calculated. Any technique can be used for determining the weights. By the help of the weights of criteria, weighted normalized values are calculated.

$$v_{ij} = w_j * x_{ij} \text{; i = 1,2,…,m; j = 1,2,…,n.} \quad \ldots\ldots\ldots\ldots\ldots(10)$$

The weighted normalized values are calculated by formula (9) and (10) and criteria weights are calculated by SOWIA method.

Step 3: For every criterion ideal alternative with best performance (s+) and worst performance (s-) are calculated. If j is the benefit criteria;

$$s^+ = \{v_{1j}, v_{2j}, \ldots, v_{mj}\} = \{\max v_{ij} \;\; for \, \forall \; j \in n\}\ldots \quad (11)$$

If j is the cost criteria;

$$s^+ = \{v_{1j}, v_{2j}, \ldots, v_{mj}\} = \{\min v_{ij} \;\; for \, \forall \; j \in n\}\ldots\ldots\ldots\ldots\ldots \quad .. (12)$$

s^- values are calculated as benefit criteria by selecting the minimum value and as a cost criteria by selecting the maximum value.

Step 4: The distance of each alternative from the best alternative (D_i^+) and worst alternative (D_i^-) for all criteria are calculated.

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - s_j^+)^2} \text{ ; for } i = 1,2,\ldots,m; \ldots\ldots\ldots \qquad \ldots\ldots\ldots.. (13)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - s_j^-)^2} \text{ ; for } i = 1,2,\ldots,m; \ldots\ldots\ldots \qquad \ldots\ldots\ldots.. (14)$$

Step 5: C_i is determined for each alternative by dividing distance to the negative solution by the sum of distance to the positive and negative solution. According to the magnitude of Closeness ratio, C_i, alternatives are arranged. The largest C_i value is selected.

$$C_i = \frac{D_i^-}{D_i^- + D_i^+} \text{ ; Where, } i = 1,2,\ldots,m \text{ and } 0 \le C_i \le 1\ldots\ldots\ldots \qquad \ldots\ldots. (15)$$

4. Data Analysis

In this paper, we have used the same quantitative data as used by Das et al., [15] and apply our proposed methods. The data are shown in Table 1.

4.1 Calculation of the priority weights of criteria by SOWIA method: In this case, we derive the normalized decision matrix from the original decision matrix in Eq. 1 by Eq.2. The normalized DM is shown below in table 1.1. The priority weights of the criteria are calculated SOWIA method which uses Shannon's Entropy method for objective weights and subjective weights are taken from the published paper Das et al. [15]. The final integrated weights are shown in table 2.

Table 1: Quantitative data for performance evaluation of alternatives

Criteria → Alternatives ↓	C1 (Max)	C2 (Max)	C3 (Max)	C4 (Max)	C5 (Max)	C6 (Min)
A	519	1901	167	13	2100	22596
B	433	1550	152	10	548.2	22601
C	392	967	125	13	622.9	20400
D	311	914	86	24	1046.5	25542
E	419	1550	145	14	320	22305
F	193	796	16	5	710.1	22800
G	367	1467	107	0	360	26820

Table 1.1: Normalized decision matrix

Alternatives	FS	SI	PHD	PATENT	CA	TF
A	0.505	0.528	0.511	0.370	0.798	0.365
B	0.422	0.430	0.465	0.285	0.208	0.365
C	0.382	0.268	0.383	0.370	0.237	0.330
D	0.303	0.254	0.263	0.683	0.398	0.413
E	0.408	0.430	0.444	0.398	0.122	0.361
F	0.188	0.221	0.049	0.142	0.270	0.369
G	0.357	0.407	0.328	0.000	0.137	0.434

Table 2: The final integrated weight of the criteria by the Eq. 8

Attributes	**C1 (Max)**	**C2 (Max)**	**C3 (Max)**	**C4 (Max)**	**C5 (Max)**	**C6 (Min)**
O_j	.0535	0.0679	0.1767	0.3813	0.3167	0.0039
S_j	0.342	0.162	0.238	0.154	0.043	0.06
$W^{int}{}_j$ (when $\alpha = 0.5$)	**0.198**	**0.115**	**0.207**	**0.268**	**0.18**	**0.032**

4.2 Calculation of the Closeness Ratio from TOPSIS method: Here, the result of TOPSIS method is shown with different α values in table 3 after using Eq. 9 - 15. From this table, it is clear that with α = 0.5 the final ranking of the IIT's are (arranged in descending order): A (.702)> D (.658) > E (.495) > C (.480) > B (.456) > G (.238) > F (.181). Here, IIT with its corresponding Closeness Ratio is given within bracket. The result is quite similar with the result of the published paper of Das et al. [15] except B and C position. But, according to our proposed method, we get the best IIT i.e., A and worst IIT i.e., F. So, B, G and F institutions should improve in their academic performance to get better rank. Fig. A shows the Parato analysis graph of performance scores of the institutions where A can be set as the benchmark of quality for other institutions.

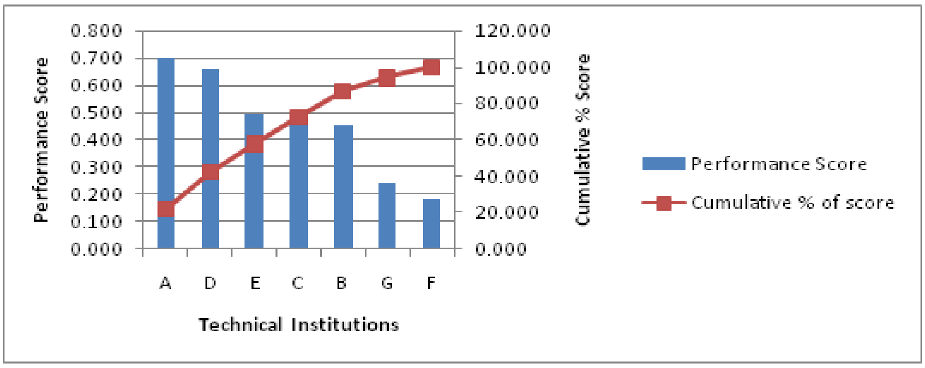

Fig. A – Parato analysis for the performance scores of the Institutions

4.3 Sensitivity Analysis: The importance of 'objective factor decision weight (α)' is perceived by decision maker when α value changes from 0 to 1. That's why sensitivity analysis is important to show that how much the closeness ratio is changed after changing the α value in this 0-1 range. This is tabulated in table 3 and shown in Fig. B. Here, from the sensitivity graph, we observe that the curve of A is not at all cut by any other curve i.e., A has the highest performance score for any α value (between 0 to 1 range). So, A has got the highest rank. The rest of the curve has at least one intersection point and based on this point α value is selected. If the α value is changed then final ranking of the institutions is also changed. So, it is much more sensitive case to select proper α value to get appropriate ranking.

Table 3: Final table of the Closeness ratio of the alternatives with different 'α' values

	TOPSIS Rank						
Institutions	α = 0.0	α = 0.2	α = 0.4	α = 0.5	α = 0.6	α = 0.8	α = 1.0
A	1	1	1	1	1	1	1
B	3	4	5	5	5	5	5
C	4	5	4	4	4	3	3
D	5	2	2	2	2	2	2
E	2	3	3	3	3	4	4
F	7	7	7	7	7	6	6
G	6	6	6	6	6	7	7

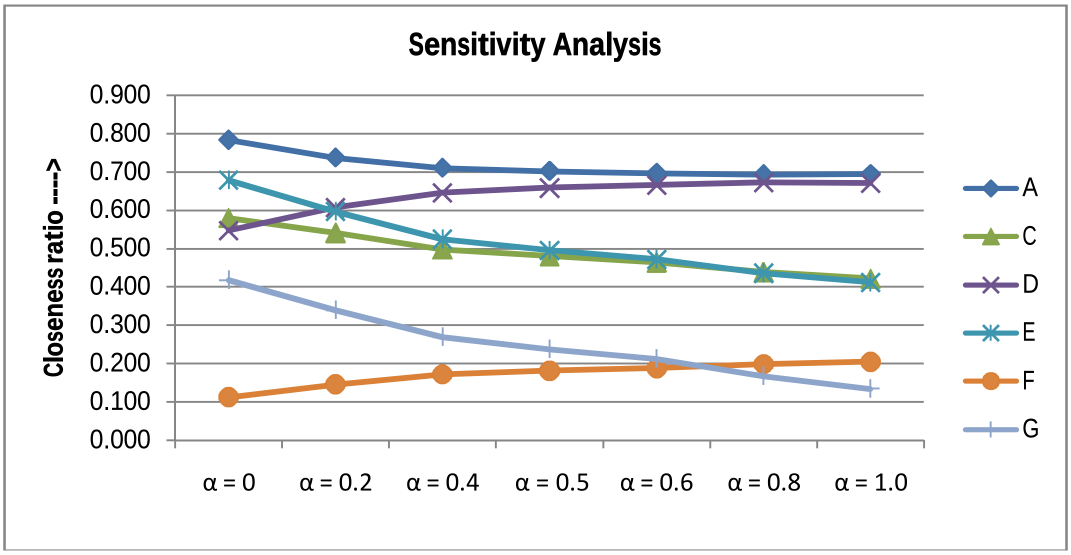

Fig. B – Sensitivity Analysis of the technical institutions

5. Discussion

Our proposed SOWIA-TOPSIS method is easier method than fuzzy AHP-COPRAS method and produces the nearly same result as the later had done so. But, little difference is that the later has more arithmetical computations and criteria weights are purely subjective whereas in our proposed method has simpler calculations and integrates both subjective and objective weights to get criteria weights. From the table 3 it is seen that performance score of A is very high as compared to other institutions. Similar results were observed in fuzzy AHP-COPRAS approach in the paper of Das et al. [15]. The results of the fuzzy AHP-COPRAS and our proposed method are given in the table 4. The Spearman correlation co-efficient (r_s) between fuzzy AHP-COPRAS and SOWIA-TOPSIS are 0.8214. This implies that there exists a strong relationship between the ranks of the two methods.

This comparative study reveals that A is the best performer and the performance of F and G are not satisfactory. From Table 1, it's clear that patents and PhD of these institutions are very less as compared to A as A is set as benchmark. To get better rank for the F and G, up gradation and a competitive environment are required with proper channel of motivation and updated research facility. In this way, the result of our proposed model can help the policy maker to point out the problematic criteria and can solve with newer technology to increase the overall performance of the IITs.

6. Conclusion

It has been the main issue now-a-days to improve the quality of the technical institutions in all respects. The government has already issued various agenda and proposals to upgrade the technical section and introduced modern research facilities to nurture the research culture in most of the technical institutions so that these can produce manpower of high level of creativity and innovations. Due to the generic nature, our proposed SOWIA-TOPSIS method can be used to evaluate performance of any type of institution. Apart from IITs, NITs, state funded institutions can be evaluated by this method discussed in this paper that paves the way of future research work.

Table 4: Comparative study of the results between fuzzy AHP-COPRAS and SOWIA-TOPSIS

Institutions → Method result ↓	A	B	C	D	E	F	G
AHP-COPRAS result	100 (1)	80.41(3)	72.24(5)	72.25(4)	81.61(2)	33.68(7)	57.62(6)
SOWIA-TOPSIS result	.702(1)	.456(5)	.480(4)	.658(2)	.495(3)	.181(7)	.238(6)

Note: *In this table 4, rank within the bracket is given with performance score.*

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