Service quality evaluation of technical institutions using data envelopment analysis

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Abstract: In the present emerging global economy, the focus has been shifted from manufacturing to service sector necessitating the quality assessment in service sector as an important issue. Education sector, especially Technical Education System (TES), is characterised as highly process oriented, intangibility and multistakeholder situations. Therefore, difficulty arises in evaluating quality of education being imparted aggregating the inputs and outputs of the system. This paper proposes an alternative method viz. Data Envelopment Analysis (DEA) which can aggregate the input and output components in such situations for obtaining an overall performance measure. Selected technical institutions in India are assessed for their service quality using DEA and suggestion is put forward for the non-performing institutions. The result shows significant difference between the conventional system of evaluation and DEA methods.

Keywords: decision-making units; DMUs; benchmarking; technical education system; TES; data envelopment analysis; DEA; EduQUAL.

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1 Introduction

Amongst many service sectors, Technical Education System (TES) plays a pivotal role for socio-economic development in any country since it deals with knowledge development and dissemination, technology transfer, education and collaborative works with industries. The demand and opportunities in TES resulted in mushrooming growth in number of technical institutes especially in the developing countries like India. In this context, the technical institutes in India are currently facing a stiff competition because of opening of the off-shore campus of foreign universities and diminishing public funding. Highly competitive environment makes quality as a key competitive weapon for attracting primary customers (students). Therefore, the challenges ahead of technical institutions necessitate reassessing the brand equity and market positioning through sufficient control to follow the quality standards of education (Liberatore and Nydick, 1999). The quality of education comprises various dimensions related to system level factors and improvement upon these dimensions may enable an institution to become an efficient one.

The conventional method adopted by various surveying agencies for assessing these institutes seems to be inadequate as it is based on summation of scores assigned to a limited number of factors like infrastructure, number of students recruited by the recruiting firms, management styles, etc. One of the major drawbacks of the conventional method is that it assigns equal weightage to all pertinent factors and inadequate to reflect the true picture on the quality of education being imparted by an institution. For example, an institution having high score in ‘quality infrastructure’ and low score in ‘quality faculty’ may have the same overall quality with an institution having low score in ‘quality infrastructure’ and high score in the ‘quality faculty’. Intuitionally, the later case should be treated as an efficient institution because profile of faculty plays a dominating role for imparting quality education in comparison to the adequacy of infrastructure.

Further, ranking of institutions widely differ from one surveying agency to another depending on sample size and criteria considered by them. In order to alleviate such problem, quality dimensions defined in terms of expectations and perceptions of the customers using instruments like ‘SERVQUAL’, ‘SERVPERF’, ‘EduQUAL’, etc. can be conveniently used to reveal complete picture of quality of education in an educational set-up (Cronin and Taylor, 1994; Mahapatra and Khan, 2006; Parasuraman et al., 1988). Usually, technical institutions exhibit highly process oriented and a multistakeholder situation leading to difficulty in aggregating the functional variables (inputs and outputs) for the evaluation of education quality. Therefore, it is desirable to use a tool that is capable of relating customers’ perception (input) to the desired performance (output) of the TES so that strategic decision-making can be made easier. Data Envelopment Analysis (DEA) is one such technique that aggregates the input and output components in order to obtain an overall performance measure through comparison of a group of decision units. It evaluates performance of Decision-Making Units (DMUs) by finding out the relative efficiency of the units under consideration. The DMUs can be business units (points of sales, bank branches, dealers, franchisees, etc.), government agencies, police departments, hospitals, educational institutions and even human beings on assessment of athletic, sales and student performance, etc. The major advantages of DEA may be listed as:

1. it can handle multiple input and multiple output models
2. it does not require the functional relationship between inputs and outputs
3. it identifies the possible peers as the role models (benchmarks)
4. it determines the possible sources of inefficiency
5. it is independent of units of measurement of various parameters.

In this study, an attempt has been made to assess the efficiency of the institutes using various quality dimensions of education through application of DEA. This study seeks to measure the relative efficiency of 20 top graded technical institutions in India. In doing so, it not only measures the degree of variation in efficiency across the sector as a whole but also identifies possible sources of inefficiency. The efficiency score has been calculated based on two scale of assumptions viz., Constant Return to Scale (CRS) and Variable Return to Scale (VRS). Finally, a comparison is made between the ranking of the institutions based on the efficiency scores using CRS and VRS assumptions and the ranking of a leading surveying agent.

2 Literature review

An organisation can become an efficient one if it sufficiently controls over the inputs with positive management commitment. However, identification of inputs and outputs in a service sector is really a challenging task as they are not well defined. In this context, Mahapatra and Khan (2007) have suggested a methodology to find out the factors responsible for quality improvement in education sector via neural network approach. Elangovan et al. (2007) have used an Executive Support System (ESS) approach for improving the quality and productivity in maintenance engineering model. However, DEA approach enables the management to frame right kind of policy for improvement of quality through identification of inefficiencies in certain dimensions in an organisation, both in manufacturing and service industries (Anatiliy, 2007; Parkan, 2006). Pacheco and Fernandes (2003) analysed efficiency of 35 Brazilian domestic airports using DEA and suggested the best quality implementation strategy. Lin et al. (2005) determined the efficiency for a shipping industry using financial indicators through DEA so that Quality Improvement Programme (QIP) can be implemented. Recent studies reveal that DEA has been successfully applied to education sector but each study differs in its scope, meaning and definition. In one such study, the policy for Italian universities has been derived based on computation of Technical Efficiency (TE) using DEA with various input and output specifications (Agasisti and Bianco, 2006). A comparative study on efficiency of private universities and public universities in the USA using DEA has been carried out by Rhodes and Southwick (1986) considering each individual university as a DMU. Tomkins and Green (1988) have used DEA to test the performance of individual departments of a university considering both teaching and research activities and compared the results with the ranking obtained by means of elemental analysis of staff/student ratio. McMullen (1997) applied DEA in order to assess the relative desirability of Association to Advance Collegiate Schools of Business (AACSB) accredited MBA programmes. Mcmillan and Datta (1998) used DEA to assess the relative efficiency of 45 Canadian universities and found that a subset of universities comprising of three categories such as comprehensive with medical school, comprehensive without medical school and primarily undergraduate universities are regularly found to be efficient. In an attempt to compare the performance of selected schools in the Netherlands, Ramanathan (2001) studied the effect of several non-discretionary input variables which are not under direct control of management on efficiency scores. Calhoun (2003) employed DEA to compare relative efficiencies of private and public Institutions of Higher Learning (IHL) using a sample of 1323 four-year old institutions and introduced a new way for clustering institutions based on revenue management. Lee (2004) had examined the relative performance or organisational effectiveness of research centres and institutes within publicly funded higher education set-ups based on the Competing Values Framework (CVF) as a theoretical foundation. The CVF encompasses four representative organisational effectiveness models viz., rational goal model, open system model, human relations model and internal process model. By employing DEA methodology, this study identified the ‘best practices’ exhibited by organisations on the efficient frontier and makes recommendations regarding how ‘best practices’ could be adopted by inefficient DMUs to become more efficient. Application of DEA in Indian educational set-up is extremely limited. However, a study focuses on integration of DEA and Knowledge Management (KM) methods for evaluating the efficiency of TES in India (Wadhwa et al., 2005).

3 Objective of the study

It is evident that quality of education plays a vital role to gain an edge over its competitors and hence, efficiency of an institution must relate its performance to quality dimensions. As quality in TES characterises multiinput and output system, its measurement through the efficiency score enables to provide not only an aggregate picture of performance of an institution in terms of quality education but also helps to reassesses its brand positioning in market-place. The relative efficiency calculated for a number of institutions helps to rank them based on their efficiency score. The inefficient institutions can pursue continuous improvement strategies by adjusting the slack and target values. To address these issues, the objectives of this study focuses on finding out bench marking institutions, ranking of technical institutions of India based on their efficiency scores, and discuss improvement areas for inefficient institutions.

4 Methodology

Several techniques like SERVQUAL, Regression analysis, Control chart, etc. have been used for assessment of performance of a service organisation in quality dimension. However, they have several serious limitations. Regression analysis is very useful in discriminating more important quality dimensions from the less important ones but fails to answer any straightforward methodology for adjusting the resources among these dimensions to increase service quality. Further, existing techniques compares service quality of an organisation with the average performance of a set of organisations under consideration. In doing so, a firm sets average performance of the group as its benchmark which is undesirable. DEA can overcome some of the major limitations of the existing technique as it sets best in the group as the benchmarking unit and suggest the slacks for each of the quality dimension for improvement. Since slacks are quantified, it helps the managers to try out methods, procedures and techniques to achieve the optimal level of service quality.

4.1 Data envelopment analysis

DEA is a linear programming based tool for measuring the relative productive efficiency of each unit in a set of comparable organisational units using theoretical optimal performance for each organisation. Usually the investigated DMUs are characterised by a vector of multiple inputs and multiple outputs making it difficult to directly compare them. In order to aggregate information about input and output quantities, DEA makes use of Fractional Programming Problem (FPP) and corresponding Linear Programming Problem (LPP) together with their duals to measure the relative performance of DMUs (Charnes et al., 1978; Charnes et al., 1994; Cooper et al., 2000; Farrell, 1957; Norman and Stoker, 1991; Seiford, 1996; Seiford and Thrall, 1990).

The Charnes Cooper and Rhodes (CCR) model is a FPP model which measures the relative TE of a DMU by calculating the ratio of weighted sum of its outputs to the weighted sum of its inputs. The fractional programme is run for each DMU to determine the set of input-output weights that maximises the efficiency of that DMU subject to the condition that no DMU can have a relative efficiency score greater than unity for that set of weights. Thus, the DEA model calculates a unique set of factor weights for each DMU. The set of weights has the following characteristics:

- it maximises the efficiency of the DMU for which it is calculated
- it is feasible for all DMU
- since DEA does not incorporate price information in the efficiency measure, it is appropriate for non-profit organisations where price information is not available.

Since the efficiency of each DMU is calculated in relation to all other DMUs using actual input-output values, the efficiency calculated in DEA is called relative efficiency. In addition to calculating the efficiency scores, DEA also determines the level and amount of inefficiency for each of the inputs and outputs. The magnitude of inefficiency of the DMUs is determined by measuring the radial distance from the inefficient unit to the frontier.

The basic DEA model for ‘n’ DMUs with ‘m’ inputs and ‘s’ outputs proposed by CCR, the relative efficiency score of pth DMUs is given by

$$\begin{aligned} &\text{Max } Z_p = \frac{\sum_{k=1}^{s} v_k y_{kp}}{\sum_{j=1}^{m} u_j x_{jp}} \\ &\text{s.t.} \quad \frac{\sum_{k=1}^{s} v_k y_{ki}}{\sum_{j=1}^{m} u_j x_{ji}} \leq 1 \forall i \\ &v_k, u_j \geq 0 \forall k, j \end{aligned} \tag{1}$$

where $k = 1$ to s (no. of outputs); $j = 1$ to m (no. of inputs); $i = 1$ to n (no.of DMUs); y_{ki} = amount of output k produced by DMU i; x_{ji} = amount of input j utilised by DMU i; v_k = weight given to output k and u_j = weight given to input j.

The fractional programme shown in Equation (1) can be reduced to LPP as follows:

$$\begin{aligned} &\text{Max } Z_p = \sum_{k=1}^{s} v_k y_{kp} \\ &\text{s.t.} \quad \sum_{j=1}^{m} u_j x_{jp} = 1 \\ &\sum_{k=1}^{s} v_k y_{ki} - \sum_{j=1}^{m} u_j x_{ji} \leq 0 \forall i \\ &v_k, u_j \geq 0 \forall k, j \end{aligned} \tag{2}$$

This model is called CCR output oriented maximisation DEA model. The efficiency score of ‘n’ DMUs is obtained by running the above LPP ‘n’ times.

4.2 Selection of DMUs

In order to identify DMUs, 20 Indian institutions offering technical education in undergraduate, postgraduate and research level have been considered. They happen to be top ranked institutions as per a survey conducted by a leading weekly magazine in association with a professional surveying agency. The ranking is based on total score summed over perceptual score and factual score obtained from each DMU. The perpetual score considers seven parameters such as reputation of the institute, curriculum, quality of academic input, student-care, admission procedure, infrastructure and job prospects whereas factual score is collected on three parameters like infrastructure, placements and faculty. In order to calculate the total score of an institute, 70% weightage is assigned to perceptual score whereas factual score carries 30% weightage.

4.3 Questionnaire survey

SERVQUAL is the most widely applied instrument for measuring service quality due to easiness to use, simple structure and adaptability to generalisation. As the quality of service largely depends on the human behaviour, the number of quality dimensions and items under each dimension of a measuring instrument usually vary with service settings leading to difficulty in defining the quality of service precisely (Saleh and Ryan, 1991; Weitzel et al., 1989). Service sector, in general, depict persistence of intangibility and lack of physical evidence making perceptions of service quality and its analysis a difficult proposition. Further, TES is characterised with multiple stakeholders having different backgrounds and varied behavioural patterns.

Since EduQUAL has been successfully implemented in Indian context in order to evaluate the quality at aggregate level fitting to most of the important stakeholders, it is used to collect data for already identified 20 technical institutions (Mahapatra and Khan, 2006).The responses of the stakeholders such as students, alumni, parents and recruiters for their perceptions and expectations under each item are collected through a structured questionnaire survey (Appendix). Each respondent is asked to rate his/her opinion in a Likert type scale 1 to 7 (1 being strongly disagree and 7 being strongly agree). The survey is administered to the respondents via e-mail, postal mode and personal contacts. Further, additional data are collected from the experts such as head of institutions, head of departments/centres and deans of 20 DMUs through e-mail. The survey was conducted during June–August 2006. Responses from own institution are excluded from the data to minimise bias. Finally 512 responses are taken into consideration for further analysis after screening the responses for correctness and rationality in judgemental scores.

The responses for each institute on every service items are aggregated to get a single value both for expectations and perceptions. The expectations of the stakeholders and experts have been considered as the inputs and perception scores are taken as the outputs for Data Envelopment Analysis. Thus, we have 28 inputs, 28 outputs and 20 DMUs. The list of DMUs is shown in Table 1.

Table 1 Selected technical institutions in India (DMUs)

DMUs	*Name of the institute*
DMU_1	Birla Institute of Technology, Ranchi
DMU_2	College of Engineering, Guindy
DMU_3	Delhi College of Engineering, Delhi
DMU_4	Dr. B.R. Ambedkar NIT, Jalandhar
DMU_5	Guru Nanak Dev College, Ludhiana
DMU_6	Indian Institute of Technology, Chennai
DMU_7	Indian Institute of Technology, Delhi
DMU_8	Indian Institute of Technology, Kanpur
DMU_9	Indian Institute of Technology, Kharagpur
DMU_{10}	Indian Institute of Technology, Mumbai

Table 1 Selected technical institutions in India (DMUs) (continued)

DMUs	*Name of the institute*
DMU_{11}	Indian Institute of Technology, Roorkee
DMU_{12}	Indian Institute of Technology, Guwahati
DMU_{13}	Institute of Technology, BHU
DMU_{14}	Motilal Nehru NIT, Allahabad
DMU_{15}	National Institute of Technology, Karnataka, Surathkal
DMU_{16}	National Institute of Technology, Thiruchirapally
DMU_{17}	National Institute of Technology, Warangal
DMU_{18}	PIET's College of Engineering, Pune
DMU_{19}	Thapar Institute of Engineering and Technology, Patiala
DMU_{20}	University Visvesvaraya College of Engineering, Bangalore

5 DEA application

5.1 DEA with CRS scale assumption

The objective function for DEA has been fixed as the ratio of weighted sum of perceptions to the weighted sum of expectations assuming that perception of a stakeholder seldom touches the expectation. Hence, a DMU becomes a benchmark unit when the objective function becomes unity. In other words, perceptions equals to expectations. The general output oriented maximisation CCR–DEA model is used to obtain efficiency score. Data Envelopment Analysis Programme (DEAP version 2.1) has been used to solve the model. The results of DEA are shown in Table 2.

Table 2 Results of DEA (CRS model)

DMUs (Technical institutions)	*Efficiency*	*Ranking by surveying agency (a)*	*Ranking by DEA (b)*	*Difference (a–b)*	*Referring institutes*	*Peer weights*	*Peer count*
DMU_1	0.900	17	8	9	6	0.669	0
					12	0.222	
DMU_2	0.913	12	6	6	7	0.462	0
					6	0.467	
DMU_3	0.951	7	3	4	13	0.263	0
					19	0.676	
DMU_4	0.811	18	12	6	7	0.245	0
					9	0.537	
					12	0.137	
					6	0.027	
DMU_5	0.759	19	13	6	7	1.138	0
DMU_6	1.000	5	1	4	6	1.000	7

Table 2 Results of DEA (CRS model) (continued)

DMUs (Technical institutions)	*Efficiency*	*Ranking by surveying agency (a)*	*Ranking by DEA (b)*	*Difference (a–b)*	*Referring institutes*	*Peer weights*	*Peer count*
DMU_7	1.000	1	1	0	7	1.000	7
DMU_8	1.000	2	1	1	8	1.000	3
DMU_9	1.000	4	1	3	9	1.000	7
DMU_{10}	1.000	3	1	2	12	1.000	0
DMU_{11}	1.000	6	1	5	18	1.000	0
DMU_{12}	1.000	11	1	10	12	1.000	7
DMU_{13}	1.000	9	1	8	13	1.000	4
DMU_{14}	0.889	20	9	11	8	0.229	0
					9	0.409	
					12	0.308	
DMU_{15}	0.954	8	2	6	6	0.027	0
					7	0.476	
					12	0.393	
DMU_{16}	0.904	13	7	6	6	0.030	0
					7	0.519	
					9	0.012	
					12	0.345	
DMU_{17}	0.939	10	4	6	6	0.418	0
					13	0.399	
					12	0.099	
DMU_{18}	0.851	15	11	4	7	0.516	0
					9	0.203	
					8	0.239	
					13	0.043	
DMU_{19}	0.923	14	5	9	7	0.566	0
					8	0.164	
					9	0.163	
DMU_{20}	0.883	16	10	6	9	0.050	0
					12	0.042	
					6	0.360	
					13	0.521	
Mean efficiency = 0.934							

The first column of the table represents the selected technical institutions (DMUs) arranged serially in alphabetical order. The second column specifies the efficiency score of the corresponding DMUs. The third column stands for the ranking by the surveying agency. Based on the efficiency score, DMUs are ranked as shown in the fourth column. The fifth column indicates the difference between the rank assigned by the surveying agency and the rank obtained through DEA. The sixth column shows the peers or the benchmarking units for the corresponding DMU. The seventh column indicates the weightage of each of the peers or the benchmarking unit. The last column shows the peer count of the DMUs, that is, the number of times a particular DMU is being referred by other DMUs for improvements.

DEA efficiency ranking finds that eight DMUs out of 20 DMUs have emerged as benchmarking units for the other 12 DMUs. The benchmarking units are listed as DMU_6–DMU_{13} as shown in Table 2. The efficiency score for these DMUs approaches unity while that of DEA-inefficient DMUs is less than unity. The inefficient units can refer the units given in column 6 with the corresponding weightage given in column 7 for improvement in education quality. For example, DMU_1 having efficiency score of 0.900 can refer DMU_6 and DMU_{12}. DMU_1 can assign a weightage of 0.669 to DMU_6 and 0.222 to DMU_{12} to become a benchmark unit. As shown in column 6, there are four DMUs (DMU_4, DMU_{16}, DMU_{18} and DMU_{20}) which can refer different DEA-efficient (benchmark) units with varying degree of weightages. DMU_{14}, DMU_{15}, DMU_{17} and DMU_{19} consult three benchmarking units whereas DMU_1–DMU_3 cite only two efficient institutes with the corresponding weightages. It is interesting to note that DMU_5 has only one reference institute (DMU_7) with a weightage of 1.138. Four DMUs (e.g. DMU_6, DMU_7, DMU_9 and DMU_{12}) have become the peer units seven times while DMU_8 and DMU_{13} becomes the referring institute for three and four times, respectively. Six institutes ranked as 1 to 6 by surveying agency have become efficient units in DEA also. DMU_{12} and DMU_{13} have been ranked at 11th and 9th position, respectively, by the surveying agency but DEA treats them as efficient peer institutes. DMU_7 and DMU_8 are ranked as 1 and 2 position, respectively by surveying agency and DEA treats them as the most efficient units because these units are referred most frequently by the inefficient units. It can be observed from column 5 of Table 2 that major gainers in upgrading ranking position are DMU_{14}, DMU_{12} and DMU_1 whereas the major losers in respect to sliding of their position are DMU_3 and DMU_{18}. However, there is a scope for improvement of the technical institutions in India because mean efficiency score for all DMUs shows 0.934.

5.2 *DEA with VRS scale assumption*

In a multistakeholder situation like TES, significant variation is observed in expectations and perceptions of the stakeholders when they attempt to assess the quality. Unlike CRS model, variation in inputs may not lead to the same level of variation in the output in such situations. In order to address this issue, an extension of CRS model, popularly known as VRS model is used and compared with CRS model (Banker et al., 1984).

The result of VRS-DEA model is compared with the ranking of DMUs proposed by surveying agency as shown in Table 3. In contrast to CRS model, only two DMUs viz., DMU_5 and DMU_{18} with efficiency score 0.790 and 0.851, respectively are found to be the DEA-inefficient units using VRS model. The inefficient units can make adjustments in their inputs/outputs looking into their peer groups to become efficient unit. These units may adopt either input-oriented strategy or output-oriented strategy to become efficient. The input-oriented strategy emphasises on achieving current level of output using less inputs than the current level whereas output-oriented strategy rests on achieving higher level of output by same level of inputs. The latter strategy is not only preferred but also suitable for service sectors such as education.

It is clear from Table 3 that DMU_5 should refer to the benchmarked units such as DMU_7, DMU_8, DMU_{13} and DMU_{10} in pursuit of improving quality of education with corresponding weightages of 0.220, 0.072, 0.094 and 0.614. Similarly, DMU_{18} should refer to DMU_9, DMU_8, DMU_{13} and DMU_7 with peer weights of 0.205, 0.241, 0.039 and 0.518, respectively to become a 100% efficient unit. The last column of the table indicates that DMU_7, DMU_8 and DMU_{13} become the peer units for two times and DMU_9 and DMU_{10} turns out a single referring institute for the inefficient institutes. The mean efficiency for the 20 DMUs considering Variable Rating Scale (VRS) is 0.982 which happen to be more than that of Constant Rating Scale (CRS). It is interesting to note that only four DMUs qualify as benchmarking units out of 18 efficient units.

Table 3 Results of DEA (VRS model)

DMUs (Technical institutions)	*Efficiency*	*Ranking by surveying agency (a)*	*Ranking by DEA (b)*	*Difference (a–b)*	*Referring institutes*	*Peer weights*	*Peer count*
DMU_1	1.000	17	1	16	1	1.000	0
DMU_2	1.000	12	1	11	2	1.000	0
DMU_3	1.000	7	1	6	3	1.000	0
DMU_4	1.000	18	1	17	4	1.000	0
DMU_5	0.790	19	2	17	7	0.220	0
					8	0.072	
					13	0.094	
					10	0.614	
DMU_6	1.000	5	1	4	6	1.000	0
DMU_7	1.000	1	1	0	7	1.000	2
DMU_8	1.000	2	1	1	8	1.000	2
DMU_9	1.000	4	1	3	9	1.000	1
DMU_{10}	1.000	3	1	2	10	1.000	1
DMU_{11}	1.000	6	1	5	11	1.000	0
DMU_{12}	1.000	11	1	10	12	1.000	0
DMU_{13}	1.000	9	1	8	13	1.000	2
DMU_{14}	1.000	20	1	19	14	1.000	0
DMU_{15}	1.000	8	1	7	15	1.000	0
DMU_{16}	1.000	13	1	12	16	1.000	0
DMU_{17}	1.000	10	1	9	17	1.000	0
DMU_{18}	0.851	15	3	12	9	0.205	0
					8	0.241	
					13	0.039	
					7	0.515	
DMU_{19}	1.000	14	1	13	19	1.000	0
DMU_{20}	1.000	16	1	15	20	1.000	0
Mean efficiency = 0.982							

5.3 Comparisons between various rankings

The results from the two models and the surveying agency are shown in Table 4. The surveying agency ranks the 20 technical institutions from 1 to 20 using perpetual and factual scores. Based on the efficiency scores obtained from CRS and VRS model, the institutes are also ranked. It is interesting to note that DMU_5 and DMU_{18} show the lowest TE in both CRS and VRS model. The DMUs with efficiency score of unity is assigned a rank of one and the inefficient units are ranked in descending order of their TE score.

Table 4 Comparison between various rankings

DMUs (Technical institutions)	*Ranking by surveying agency*	*Ranking by DEA (CRS)*	*Ranking by DEA (VRS)*	*Referring institutes (CRS)*	*Referring institutes (VRS)*	*Peer weights (CRS)*	*Peer weights (VRS)*
DMU_1	17	8	1	6	1	0.669	1.000
				12		0.222	
DMU_2	12	6	1	7	2	0.462	1.000
				6		0.467	
DMU_3	7	3	1	13	3	0.263	1.000
				19		0.676	
DMU_4	18	12	1	7	4	0.245	1.000
				9		0.537	
				12		0.137	
				6		0.027	
DMU_5	*19*	*13*	*2*	*7*	*7*	*1.138*	*0.220*
					8		*0.072*
					13		*0.094*
					10		*0.614*
DMU_6	5	1	1	6	6	1.000	1.000
DMU_7	1	1	1	7	7	1.000	1.000
DMU_8	2	1	1	8	8	1.000	1.000
DMU_9	4	1	1	9	9	1.000	1.000
DMU_{10}	3	1	1	12	10	1.000	1.000
DMU_{11}	6	1	1	18	11	1.000	1.000
DMU_{12}	11	1	1	12	12	1.000	1.000
DMU_{13}	9	1	1	13	13	1.000	1.000
DMU_{14}	20	9	1	8	14	0.229	1.000
				9		0.409	
				12		0.308	
DMU_{15}	8	2	1	6	15	0.027	1.000
				7		0.476	
				12		0.393	

Table 4 Comparison between various rankings (continued)

DMUs (Technical institutions)	*Ranking by surveying agency*	*Ranking by DEA (CRS)*	*Ranking by DEA (VRS)*	*Referring institutes (CRS)*	*Referring institutes (VRS)*	*Peer weights (CRS)*	*Peer weights (VRS)*
DMU_{16}	13	7	1	6	16	0.030	1.000
				7		0.519	
				9		0.012	
				12		0.345	
DMU_{17}	10	4	1	6	17	0.418	1.000
				13		0.399	
				12		0.099	
DMU_{18}	*15*	*11*	*3*	*7*	*9*	*0.516*	*0.205*
				9	*8*	*0.203*	*0.241*
				8	*13*	*0.239*	*0.039*
				13	*7*	*0.043*	*0.515*
DMU_{19}	14	5	1	7	19	0.566	1.000
				8		0.164	
				9		0.163	
DMU_{20}	16	10	1	9	20	0.050	1.000
				12		0.042	
				6		0.36	
				13		0.521	

The average TE score of the DMUs calculated using output oriented CRS model is 0.934 indicates plenty of scope exists for improvements in Indian technical institutions. The average TE of DMUs calculated using output oriented VRS model is 0.982. It is worthwhile to interpret the correlation between the various rankings to know the degree of association between various methods. The correlation is calculated using the Spearman's rank correlation coefficient (r_s) as follows:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}(X_i - Y_i)^2}{n(n^2 - 1)} \tag{3}$$

where X_i is the rank of the ith observation of variable X; Y_i is the rank of the ith observation of variable Y; 'n' is the number of pairs of observations.

High degree of correlation ($r_s = 0.888$, $p = 0.000$) between the ranks assigned by the surveying agency and DEA ranking using CRS model has been observed. Similarly, the correlation coefficient between rankings of the surveying agency and DEA ranking using VRS model is 0.318 ($p = 0.172$) which indicates a very weak relationship between the two rankings. But, an average degree of correlation is found between the ranks assigned by DEA rankings using CRS and VRS model ($r_s = 0.512$, $p = 0.021$).

In order to check for existence of significant difference between TE scores calculated using the two models that is, CRS and VRS, a paired two sample t-test for means is carried out (Bain and Engelhardt, 1992).

The hypotheses set being:

$$H_0: \text{TE from DEA} - \text{CRS} = \text{TE from DEA} - \text{VRS}$$
$$H_1: \text{TE from DEA} - \text{CRS} \neq \text{TE from DEA} - \text{VRS}$$

The *t*-test is applied using SYSTAT VERSION 7.0. The result shows the *p*–value of 0.001 allowing us to reject the null hypothesis with an α (probability of type I error) value as low as 0.01. This allows us to accept the alternative hypothesis that there is a significant difference between the efficiency scores obtained through CRS and VRS models.

6 Conclusions

In this paper, a methodology based on DEA is discussed to rank the Indian Technical Institutions using their TE scores. The methodology facilitates to identify the benchmarking institutions which can be referred by inefficient institutes to become efficient units. Two approaches of DEA viz. CRS and VRS are considered to obtain efficiency of DMUs. Eight institutions are found to be most efficient in CRS model whereas 18 institutes out of 20 are found to be the most efficient institutes in VRS models. The rankings determined by a leading surveying agency, CRS model and VRS model have been compared to acquire a richer knowledge about the relationships between them. The correlation coefficient between the ranking of the surveying agency and DEA–CRS ranking shows a high degree of association whereas rankings of the surveying agency and DEA ranking using VRS model exhibit low degree of association. It indicates that conventional ranking method adopted by surveying agencies is not adequate enough. Similarly, the correlation coefficient between the two DEA rankings using CRS and VRS models shows an average degree of association indicating reasonable degree of association. The paired two sample *t*-test indicates that there is a significant difference between the efficiency scores obtained through CRS and VRS models.

The eight benchmarked institutions resulted through DEA-CRS model happen to be premier technical institutions of India. All these institutions possess few specific characteristics favourable for imparting quality education. Being established in 1960s, they have developed sufficient expertise and competence through experience, experimentation and feedback from the market. Importantly, superior level of inputs is admitted in such institutions through an entrance examination considered as the top class entrance examination in India. Over the years, they have developed best infrastructure facilities for teaching, research and development. Dedicated, highly qualified, knowledgeable and experienced faculties characterise excellent faculty profile that enables to address the academic and learning outcome dimensions of ‘EduQUAL’. Enormous public funding, generation of funds through higher degree of consultancy and industry collaboration activities, continuing education and financial assistance by alumni help to develop best infrastructure facilities, modern and sophisticated instruments, IT facilities and library upgradation leading to facilitate improving infrastructure and personality development dimensions of ‘EduQUAL’. In case of DEA-VRS model, 90% of the selected DMUs are DEA-efficient. However, DMU_5 and DMU_{18} are found to be non-performing DMUs both in CRS and VRS model.

In this study, only the quality items that are relevant for improving the technical education quality have been considered. Other pertinent factors like quality of inputs (students), investment pattern in the institution, funds generation by the institution, research and development activities, etc. could have been incorporated in the model for ranking of the technical institutions effectively. Discrimination of efficient institutes is carried out based on the number of times they are being referred by inefficient units. A broad-based methodology is required to improve the discriminating power.

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Appendix

Items and dimensions of EduQUAL

'EduQUAL' dimensions	*Items of 'EduQUAL'*
Learning outcomes	1. Training on state-of-the art technology
	2. Practical orientation in education
	3. Adaptability to modern techniques
	4. Design of course structure based on job requirements
	5. Problem solving skills
	6. Sense of social obligation
Responsiveness	7. Prompt service at service departments
	8. Courteousness and willing to help
	9. Cleanliness, orderliness, systematic and methodical
	10. Transparency of official procedure, norms and rules
	11. Adequate facilities/infrastructure to render service
Physical facilities	12. Well equipped laboratories with modern facilities
	13. Comprehensive learning resources
	14. Academic, residential and recreational facilities
	15. Aesthetic views of facilities
	16. Training in a well equipped communication laboratory
	17. Opportunities for campus training and placement
	18. Effective classroom management
Personality development	19. Encouragement for sports, games and cultural activities
	20. Enhancement of knowledge
	21. Adherence to schedule
	22. Extra academic activities
	23. Recognition of the students
Academics	24. Adequacy of subject teachers
	25. Available regularly for students' consultation
	26. Close supervision of students work
	27. Expertise in subjects and well organised lectures
	28. Good communication skill of academic staff