Data Envelopment Analysis (DEA) – Application at NMIMS – SBM, a Leading AACSB Accredited Indian Higher Education Business School

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Abstract

This study seeks to use the concept of Data Envelopment Analysis for setting benchmarks of efficiency using two inputs and two outputs. In the process, the study highlights the inherent contradictions in the application. In case of deficient divisions, instead of increasing the inputs to better the output, the DEA analysis recommends reducing the inputs.

Design / Methodology / Approach: Cross-sectional study of data is used for analysis of the performance of the various divisions in NMIMS.

Findings: Data Envelopment Analysis (DEA) is a wonderful method for benchmarking and enhancing productivity of services. As services are entirely different from products, concepts like productivity cannot be applied without modifications. Further, services being customer-centric characterised by customer participation, simultaneity, perishability, intangibility, and hetereogeneity, the concept of an 'absolute' benchmark is also not feasible. With the input and output metrics being ill-defined,setting milestones and targets for improvement become difficult. DEA technique uses the concept of 'relative' benchmark and also provides sufficient directions for improvement.

Practical Implications: In the Indian context, these concepts become very relevent because in the present state of evolution of services, we have much to improvise. Further, India being a geographical expanse with wide variation in customer preferences, expectations and preceptions, the process of improvement of services becomes more complex. At present, the demand for services exceeds supply and hence, the need for competitiveness is not felt. In the near future when the performance metrics of services becomes an important criteria for business success, the role of DEA will be crucial for productivity improvements and in deciding the viability of service outlets.

Originality / Value: This DEA analysis in the Indian higher education context is one of the few analyses that demonstrate the utility of the DEA technique, its limitations and its role in qualitative aspects of services benchmarking. DEA analysis is applied in the context of linear relationships of inputs and outputs with the focus on controlling the inputs rather than focusing on output performance. The outputs in terms of performance are more difficult to manage whereas the inputs are comparitively easy to manage.

Keywords: *Benchmarking, Data Envelopment Analysis, Productivity, efficiency, shadow price.*

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Introduction

The Indian Prime Minister, Shri Narendra Modi, while speaking at the World Economic Forum, Davos, in January 2018, spoke about Foreign Direct Investment in India (FDI) and that every Indian sector is now open for foreign investors. He went on to say that India is not far from being a US$ One Trillion economy and the third largest economy in the world. This growth cannot be achieved only by growth in the manufacturing sector, but by an exponential growth in the services sector in India. Besides the IT service companies in India, services providers like Amazon, Wal-Mart, Alibaba, etc. are all present here. With the growth in services comes the requirement of efficiency and competitiveness for new and existing players. Services by nature are intangible and heterogeneous and thus, the concept of “good” service is mostly the perception of the consumer. The adage “Beauty lies in the eyes of the beholder” is apt for services because the concept of “good” service is very subjective. How then should a service organisation go about bettering their service offerings for their customers? How would the service organisation decide on an efficient service outlet that would be a benchmark for other service outlets to emulate? How can a service outlet identify the 'problem child' for improvements and / or decide to close down a service outlet that can never be productive? Which service outlets should be investigated for inefficiencies and what could be an improvement target?

These are some of the questions that get addressed in this paper with a case from a leading higher education AACSB accredited business school in India. We also explore whether the efficiency analysis in the Indian context needs some refinements or whether the generally accepted Data Envelopment Analysis (DEA) techniques are adequate. India, with a population of over 1 billion people, is in a seller's market, where the demand for services is higher than the services being offered. This results in everything that is offered being sold and unless the markets change to a buyer's market, the concepts of competitiveness and efficiency will not be given prominence. In its 2014 report, “Understanding India: The future of higher education and opportunities for international cooperation” the British Council identified the following four broad challenges to higher education in India:

- The supply-demand gap – low ratio of enrolment in higher education at 18% compared to 26% in China and 38% in Brazil.
- The low quality of teaching and learning – The system is beset by issues of quality in many of its institutions: a chronic shortage of faculty, poor quality teaching, outdated and rigid curricula and pedagogy, lack of accountability and quality assurance, and separation of research and teaching.
- Constraints on research capacity and innovation.
- Uneven growth and access to opportunity – access to higher education is uneven with multidimensional inequalities in enrolment across population groups and geographies.

The application of DEA analysis is limited to the availability and sharing of the relevant data and any higher level DEA analysis will be subject to data adequacy. In the absence of valid data, DEA analysis can at best point out in the direction of efficient and inefficient frontiers.

In their research paper “Measuring performance of Indian banks: An application Data Envelopment Analysis” researchers *Roma Mitra Debnath* and *Ravi Shankar*, (2008) observed that identifying the input and the output variables in the Indian context is most difficult. They settled for profits and NPAs as outputs and total assets and deposits as inputs. The selection of these input and output parameters highlights the difficulty of getting reliable and valid data for the DEA analysis in the macro Indian context.

Literature review and observations

Bivraj Bhushan Parida (2013) in his research paper "Measuring moderating effects of service recovery and CRM on consumer trust, re-patronisation and advocacy with distribution variation of the same across recovery zone-of-tolerance" mentioned about the effects of service failure related to its transactions and quality perceptions. In this paper, the author mentions about the banking sector and the moderating effect of perceived service recovery and zone of tolerance of customers on some specific behavioural manifestation, again referring to inputs and outputs.

Rita Chopra (2014) in her research paper "Service Quality in Higher Education: A Comparative Study of Management and Education Institutions" identifies the gaps between perceptions and expectations of students seeking higher education in the country. The paper using SERVQUAL concluded that there is a significant dissatisfaction due to the negative gap in service quality.

Kunjal Sinha (2014) in her research paper "An Empirical Study on Employees' Perception towards Learning and Development: A Self-Learning Perspective" identifies the fact that many organisations would like to have some benchmark and correlation between learning, innovation and high-performance. This paper speaks about the qualitative aspects and the problems involved in assessing the qualitative aspects and then linking it to performance.

Mani Shreshta (2014) in his paper "Customers' Preference Towards Functional Benefits Versus Experiential Benefits from Bank Brands" speaks about the aspect of competitiveness in the banking space and the need to have a system to ensure that bank services are acceptable to the customers.

Dr. Tejinder Sharma (2015) in his paper "Faculty Perspectives of Internal Marketing Practices – An Exploratory Study in B-Schools of Punjab" speaks about the internal customer and external customer concept in education institutes again highlighting the competitive scenario in the education "services" sector.

Gordhan K. Saini, S. K. Pandey, Archana Singh, Gurumurthy Kalyanaram (2018) in their research paper "Role of Empathy and Customer Orientation in Job Satisfaction and Organisational Commitment Indian Stock Markets" explored the concept of customer orientation in the services sector. The paper speaks about the reasons for customer dissatisfaction after their interactions with the customer contact personnel. A measurement of the dissatisfaction level and a benchmark for customer contact personnel empathy is mentioned in the paper.

M Abbot & C Doucouliagos (2003) in their research paper "The efficiency of Australian Universities – A Data Envelopment Analysis" observed that Australian Universities as a whole had higher degrees of efficiency relative to each other irrespective of the output-input mix. The need for higher efficiency in the Operations of the universities across the globe was felt because of increasing numbers of students registering for participation in higher education and the finance constraints for governments in funding these universities.

Y. H. B. WONG and J. E. BEASLEY, (1990) in their research paper Restricting Weight Flexibility in Data Envelopment Analysis, studied three inputs namely number of academic staff, academic staff salaries and support staff salaries vis-a-vis three outputs which are - number of under-graduate students, number of post-graduate students and number of research papers published across all departments. The researchers describe a method to give priority or proportions of weightings to the inputs and outputs rather than deciding arbitrarily the importance of each input or output.

H David Sherman and Franklin Gold (1985) in their research paper "Bank branch operating efficiency: Evaluation with Data Envelopment Analysis" analyses efficient and inefficient bank branches using the DEA technique. They considered the services provided as outputs and resources used to provide these services as inputs. They concluded that the DEA approach is a beneficial complement to other methods measuring the banking efficiency.

Yong Joo Lee, Seong-Jong Joo, Hong Gyun Park, (2017) in their research paper "An application of data envelopment analysis for Korean banks with negative data", found out that the performance difference between special banks and regional banks is statistically significant. This is because of the national presence of these special banks and their ownership. In this paper, the authors advocate the use of Modified Slacks Based Measure of efficiency model (MSBM) over the Banker, Charles and Cooper (BCC) model as the MSBM model can handle negative data.

Tomáš Rosenmayer, (2014) in his research paper "Using Data Envelopment Analysis: a Case of Universities" mentions that the university is a social construct and a subjective matter related to the objectives of the stakeholders and as such, inter university comparisons may not be entirely correct. As per the author, it is necessary to set an objective function that accepts the objectives of the given stakeholders and not just focus on the inputs and outputs.

Bernard Montoneri, 2014, in his research paper "Teaching Improvement Model Designed with DEA Method and Management Matrix" studied the student evaluation of teachers to design a teaching improvement matrix based on teaching efficiency and performance using the DEA analysis. Two inputs, teaching clarity and teaching enthusiasm, and two outputs, students learning interest and students satisfaction with the grades were considered, as these inputs and outputs were highly correlated.

In the context of this paper, three key concepts need to be explained:

1. Concept of Benchmarking.
2. Concept of Data Envelopment Analysis (DEA).
3. Concept of Shadow price.

Concept of Benchmarking

Benchmarking is the process of comparing one's business processes and performance metrics with the best performing organisations with a singular objective to improve upon one's performance. Some of the measures used in benchmarking could include cost per unit of measure, productivity per unit of measure, cycle time per unit of measure or defects per unit of measure. In the case of services, cost is never the focus with revenues being more important. In case of revenue, there is no universal benchmark feasible as a lot depends on many extraneous factors like location, customer profile, demographics, etc. It would be unwise to compare the performance of a bank branch located in a residential area with a branch located in a commercial district. Similarly the pizza outlets or burger outlets operating only vegetarian outlets will have different cost structure when compared with the outlets also offering non-vegetarian products. Cycle time per customer cannot be a measure because the requirements of the customers may vary and the customer profile may also vary, in which case fixing a benchmark cycle time or customer turn-around time is also not admissible. Heterogeneity of services rule out the concept of customer satisfaction as a benchmark and for similar reasons, defects per unit cannot be a measure of services benchmark. The only option for services benchmarking is therefore productivity per service centre also known as efficiency per service centre.

Concept of Data Envelopment Analysis

DEA is a non-parametric method used to compute the efficiency frontier, and measure the productive efficiency of each decision making unit. In our case of services, we can identify any number of tangible outputs and likewise any number of tangible inputs which can be measured on a common scale and use this data to identify the best performing centres. These best performing centres then become a reference point for the other centres to emulate. In the process, the best performing centres are all relative to each other and the best performing centre may or may not continue to be the best performing centre in the next round of analysis. Wherever possible, all the inputs and all the outputs must be considered and weightings for the inputs and outputs should be considered. In our research paper, for the sake of simplicity we have considered two inputs and two outputs with equal weights. Any quantifiable input and output must not be ignored in the DEA analysis.

In the words of Cook, Tone and Zhu (2014) DEA may not form a production frontier but would lead to a best practice frontier. DEA differs from the ordinary least squares (OLS) method which bases comparison relative to an average service centre with the DEA comparing everyone with the most efficient service centre amongst themselves.

In the example given in Figure1, we have six service centres having two common inputs but different values and presuming the same output for all outlets we have identified the best service centres. The service centres A (2, 200), B (4, 150), C (4, 100), D (6, 100), E (8, 80) and F (10, 50) are plotted and it is observed that centre A, C & F are efficient centres. Centres B, D & E are inefficient at present and can be efficient only when their coordinates are those at the intersection of dotted line from origin and the efficient boundary or envelope.

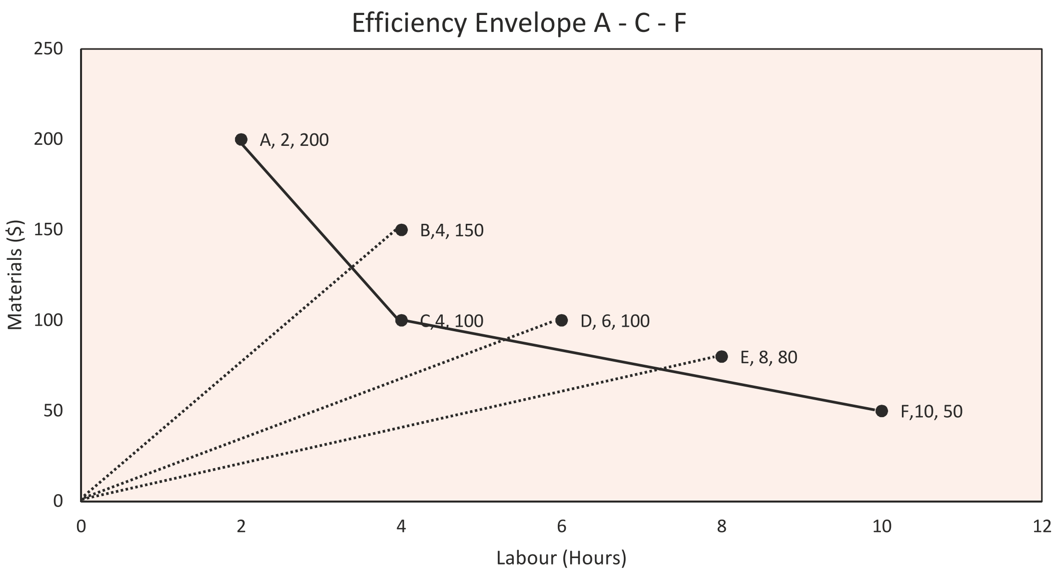

Figure 1: DEA efficiency frontier

Since DEA identifies a frontier characterised by extreme points method, it forms an envelope with the best service centres lying on this frontier and the inefficient centres lying inside the envelope. As per Berg (2010), the most efficient producers form a composite producer or service benchmark centre, allowing the computation of an efficient solution for every level of input or output. Although theoretically we can increase the output of a service centre to better its efficiency, we prefer to reduce the inputs of a service centre in order to increase the centre efficiency. This is for the obvious fact that we can better control and manage the inputs and not the outputs due to external factors.

DEA is not without its disadvantages; a comprehensive selection of all inputs and outputs is not always possible. Moreover with an increase in the inputs and outputs, the number of efficient firms increases, which can make benchmarking complicated. We can come across situations where some firms are efficient on parameters A & B, whereas some other firms are efficient on parameters B & C. One method to overcome this is by of assigning weights to the input parameters, besides just identifying them. We then use the cross-efficiency ranking method of assigning weights to each of the input and output parameters to reduce some of these disadvantages of multiple inputs and outputs. In this paper, we have used the basic DEA model to explain the advantages and disadvantages of the method.

Concept of Shadow Price

In the case of fully utilised constraints, the shadow price reflects the change in the optimal value of the objective function per infinitesimal change in the unit of the constraint. The constraints that are fully utilised are therefore called binding constraints. In the case of DEA, for improving the efficiency of the inefficient units, we use shadow prices of the binding constraints for further analysis. Mathematically the shadow price is the value of the Lagrange multiplier[1] at the optimal solution, which is the infinitesimal change in the objective function arising from an infinitesimal change in the constraint. This is because the gradient of the objective function at optimality is a linear combination of the constraint function gradients, with the weights given by Lagrange multipliers. Not all constraints have a shadow price and in such cases, the value is 0. This means that the objective function is constrained by those constraints with shadow price and not by the constraints, which have shadow price zero. These binding constraints and their shadow are then used for setting efficiency targets for the inefficient units.

Case Example: (Figures are to be considered representative for discussion purposes only) NMIMS University School of Business Management (SBM), Mumbai campus has 10 Divisions in its flagship MBA program. Amongst the two outputs of performance measure, the first output is students securing A grade and the second output is the students securing good placements. Two inputs were considered, the first being direct teaching hours and the second being non-teaching campus hours, which includes group working, workshops, guest lectures, simulation workshops and time spent in Bloomberg lab besides other co-curricular activities. The objective is to identify which amongst the Divisions is efficient and what should the inefficient Divisions do more to be as efficient. It can be seen that we cannot set improvement targets for the output parameters due to externalities, but the input control for improving the efficiency of the Divisions is possible.

1 - https://en.wikipedia.org/wiki/Lagrange_multiplier

The input and output data is provided in table 2.

Division	Students with Grade A	Good Placements	Teaching Time (Hours per week)	Non-teaching Time (Hours per week)
A	30	25	40	35
B	28	26	38	33
C	27	29	36	37
D	31	20	37	32
E	30	27	35	35
F	32	22	38	33
G	29	28	31	34
H	27	30	32	30
I	26	31	38	32
J	31	28	36	33

Table 2: NMIMS SBM data

Variables

Output Variable – Students with grade A (u_1) and good placements (u_2)

Input Variables – Teaching hours (v_1) and non-teaching hours (v_2)

Objective Function Formulation (For Division A)

Max $Z = 30u_1 + 25u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \leq 0$	Division A constraint
$28u_1 + 26u_2 - (38v_1 + 33v_2) \leq 0$	Division B constraint
$27u_1 + 29u_2 - (36v_1 + 37v_2) \leq 0$	Division C constraint
$31u_1 + 20u_2 - (37v_1 + 32v_2) \leq 0$	Division D constraint
$30u_1 + 27u_2 - (35v_1 + 35v_2) \leq 0$	Division E constraint
$32u_1 + 22u_2 - (38v_1 + 33v_2) \leq 0$	Division F constraint
$29u_1 + 28u_2 - (31v_1 + 34v_2) \leq 0$	Division G constraint
$27u_1 + 30u_2 - (32v_1 + 30v_2) \leq 0$	Division H constraint
$26u_1 + 31u_2 - (38v_1 + 32v_2) \leq 0$	Division I constraint
$31u_1 + 28u_2 - (36v_1 + 33v_2) \leq 0$	Division J constraint
$(40v_1 + 35v_2) = 1$	Division A unique constraint
$u_1, u_2, v_1, v_2 \geq 0$	non-negativity constraint

Objective Function Formulation: (For Division B)

Max $Z = 28u_1 + 26u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \leq 0$	Division A constraint
$28u_1 + 26u_2 - (38v_1 + 33v_2) \leq 0$	Division B constraint
$27u_1 + 29u_2 - (36v_1 + 37v_2) \leq 0$	Division C constraint
$31u_1 + 20u_2 - (37v_1 + 32v_2) \leq 0$	Division D constraint
$30u_1 + 27u_2 - (35v_1 + 35v_2) \leq 0$	Division E constraint
$32u_1 + 22u_2 - (38v_1 + 33v_2) \leq 0$	Division F constraint
$29u_1 + 28u_2 - (31v_1 + 34v_2) \leq 0$	Division G constraint
$27u_1 + 30u_2 - (32v_1 + 30v_2) \leq 0$	Division H constraint
$26u_1 + 31u_2 - (38v_1 + 32v_2) \leq 0$	Division I constraint
$31u_1 + 28u_2 - (36v_1 + 33v_2) \leq 0$	Division J constraint
$(38v_1 + 33v_2) = 1$	Division B unique constraint
$u_1, u_2, v_1, v_2 \geq 0$	non-negativity constraint

Objective Function Formulation: (For Division C)

Max $Z = 27u_1 + 29u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$ Division A constraint

$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$ Division B constraint

$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$ Division C constraint

$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$ Division D constraint

$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$ Division E constraint

$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$ Division F constraint

$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$ Division G constraint

$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$ Division H constraint

$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$ Division I constraint

$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$ Division J constraint

$(36v_1 + 37v_2) = 1$ Division C unique constraint

$u_1, u_2, v_1, v_2 \ge 0$ non-negativity constraint

Objective Function Formulation: (For Division D)

Max $Z = 31u_1 + 20u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$ Division A constraint

$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$ Division B constraint

$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$ Division C constraint

$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$ Division D constraint

$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$ Division E constraint

$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$ Division F constraint

$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$ Division G constraint

$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$ Division H constraint

$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$ Division I constraint

$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$ Division J constraint

$(37v_1 + 32v_2) = 1$ Division D unique constraint

$u_1, u_2, v_1, v_2 \ge 0$ non-negativity constraint

Objective Function Formulation: (For Division E)

Max $Z = 30u_1 + 27u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$ Division A constraint

$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$ Division B constraint

$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$ Division C constraint

$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$ Division D constraint

$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$ Division E constraint

$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$ Division F constraint

$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$ Division G constraint

$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$ Division H constraint

$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$ Division I constraint

$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$ Division J constraint

$(35v_1 + 35v_2) = 1$ Division E unique constraint

$u_1, u_2, v_1, v_2 \ge 0$ non-negativity constraint

Objective Function Formulation: (For Division F)

Max $Z = 32u_1 + 22u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$ Division A constraint

$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$ Division B constraint

$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$ Division C constraint

$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$ Division D constraint

$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$ Division E constraint

$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$ Division F constraint

$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$ Division G constraint

$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$ Division H constraint

$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$ Division I constraint

$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$ Division J constraint

$(38v_1 + 33v_2) = 1$ Division F unique constraint

$u_1, u_2, v_1, v_2 \ge 0$ non-negativity constraint

Objective Function Formulation: (For Division G)

Max $Z = 29u_1 + 28u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$ Division A constraint

$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$ Division B constraint

$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$ Division C constraint

$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$ Division D constraint

$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$ Division E constraint

$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$ Division F constraint

$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$ Division G constraint

$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$	Division H constraint
$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$	Division I constraint
$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$	Division J constraint
$(31v_1 + 34v_2) = 1$	Division G unique constraint
$u_1, u_2, v_1, v_2 \ge 0$	non-negativity constraint

Objective Function Formulation: (For Division H)

Max $Z = 27u_1 + 30u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$	Division A constraint
$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$	Division B constraint
$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$	Division C constraint
$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$	Division D constraint
$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$	Division E constraint
$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$	Division F constraint
$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$	Division G constraint
$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$	Division H constraint
$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$	Division I constraint
$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$	Division J constraint
$(32v_1 + 30v_2) = 1$	Division H unique constraint
$u_1, u_2, v_1, v_2 \ge 0$	non-negativity constraint

Objective Function Formulation: (For Division I)

Max $Z = 26u_1 + 31u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$	Division A constraint
$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$	Division B constraint
$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$	Division C constraint
$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$	Division D constraint
$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$	Division E constraint
$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$	Division F constraint
$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$	Division G constraint
$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$	Division H constraint
$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$	Division I constraint
$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$	Division J constraint
$(38v_1 + 32v_2) = 1$	Division I unique constraint
$u_1, u_2, v_1, v_2 \ge 0$	non-negativity constraint

Objective Function Formulation: (For Division J)

Max $Z = 31u_1 + 28u_2$

Subject to

$30u_1 + 25u_2 - (40v_1 + 35v_2) \le 0$	Division A constraint
$28u_1 + 26u_2 - (38v_1 + 33v_2) \le 0$	Division B constraint
$27u_1 + 29u_2 - (36v_1 + 37v_2) \le 0$	Division C constraint
$31u_1 + 20u_2 - (37v_1 + 32v_2) \le 0$	Division D constraint
$30u_1 + 27u_2 - (35v_1 + 35v_2) \le 0$	Division E constraint
$32u_1 + 22u_2 - (38v_1 + 33v_2) \le 0$	Division F constraint
$29u_1 + 28u_2 - (31v_1 + 34v_2) \le 0$	Division G constraint
$27u_1 + 30u_2 - (32v_1 + 30v_2) \le 0$	Division H constraint
$26u_1 + 31u_2 - (38v_1 + 32v_2) \le 0$	Division I constraint
$31u_1 + 28u_2 - (36v_1 + 33v_2) \le 0$	Division J constraint
$(36v_1 + 33v_2) = 1$	Division J unique constraint
$u_1, u_2, v_1, v_2 \ge 0$	non-negativity constraint

The Excel solver solution for Division A is as given in table 3

	Division	A					
	u_1	u_2	v_1	v_2			
	30	25	0	0			
Changing Cells	0.026435	0.004406	0	0.028571	Efficiency	0.903204	
Constraints							
Division A	30	25	-40	-35	-0.0968	<=	0
Division B	28	26	-38	-33	-0.08812	<=	0
Division C	27	29	-36	-37	-0.21562	<=	0
Division D	31	20	-37	-32	-0.00668	<=	0
Division E	30	27	-35	-35	-0.08798	<=	0
Division F	32	22	-38	-33	1.98E-13	<=	0
Division G	29	28	-31	-34	-0.08144	<=	0
Division H	27	30	-32	-30	-0.01121	<=	0
Division I	26	31	-38	-32	-0.09039	<=	0
Division J	31	28	-36	-33	7.32E-14	<=	0
			40	35	1	=	1

Table3: Excel solver solution for Division A

Division	Efficiency
A	0.903
B	0.908
C	0.867
D	0.999
E	0.957
F	1
G	1
H	1
I	0.969
J	1

Table 4: Efficiency summary for each Division

Table 4 gives the efficiency summary for all the Divisions. From this we can observe that Divisions D, F, G, H & J are highly efficient with their efficiencies being the maximum, i.e. 1, and the other Divisions, namely A, B, C, E &I have to catch up. Let us next consider Division A for improvements. We cannot as mentioned earlier increase the output, but can manage the inputs for better efficiency. For this we need the shadow values (prices) in regards to Division A and the same is as shown in table 5.

Name	Shadow Price
Division A Efficiency	0
Division B Efficiency	0
Division C Efficiency	0
Division D Efficiency	0
Division E Efficiency	0
Division F Efficiency	0.303738318
Division G Efficiency	0
Division H Efficiency	0
Division I Efficiency	0
Division J Efficiency	0.654205607
Unique Efficiency	0.903204272

Table 5: Sensitivity Analysis for Division A

The shadow values indicate that Division A can consider the input parameters of Division F in proportion 0.3037& of Division J in proportion 0.6543 for setting a benchmark. Thus, the teaching hours and non-teaching hours for Division A would be,

0.3037 x 38 + 0.6542 x 36 = 35.1 hours (presently 40)

0.3037 x 33 + 0.6542 x 33 = 31.62 hours (presently 35)

If we change the input parameters as derived above, we get the efficiency as 0.9997 or approximately 1, which is shown in table 6.

	Division	A					
	u_1	u_2	v_1	v_2			
	30	25	0	0			
Changing Cells	0.033173	0.000184	0.016034	0.013826	Efficiency	0.999787	
Constraints							
Division A	30	25	-35.1	-31.62	-0.00021	<=	0
Division B	28	26	-38	-33	-0.13196	<=	0
Division C	27	29	-36	-37	-0.18781	<=	0
Division D	31	20	-37	-32	-0.00368	<=	0
Division E	30	27	-35	-35	-0.04498	<=	0
Division F	32	22	-38	-33	9.45E-14	<=	0
Division G	29	28	-31	-34	2.49E-13	<=	0
Division H	27	30	-32	-30	-0.02671	<=	0
Division I	26	31	-38	-32	-0.18355	<=	0
Division J	31	28	-36	-33	1.6E-13	<=	0
Unique			35.1	31.62	1	=	1

Table 6: Revised Efficiency for Division A using benchmark input targets

Table7 gives the improvement targets for the inefficient Divisions. If we use the benchmark targets as inputs for Divisions B, C, E & I, their efficiency expectedly becomes 1.

Division	Teaching Hours Existing	Teaching Hours Target	Non-teaching Hours Existing	Non-teaching Hours Target
B	38	= 0.126 x 32 + 0.793 x 36 = 32.58	33	0.126 x 30 + 0.793 x 33 = 29.95
C	36	= 0.237 x 31 + 0.746 x 32 = 31.22	37	= 0.237 x 34 + 0.746 x 30 = 30.44
E	35	= 0.158 x 38 + 0.552 x 31 + 0.288 x 36 = 33.45	35	= 0.158 x 33 + 0.552 x 34 + 0.288 x 33 = 33.49
I	38	= 1.033 x 32 = 33.06	32	= 1.033 x 30 = 31

Table 7: Efficiency Frontier for remaining inefficient Divisions

Observations

It can be seen that the teaching hours and non-teaching hours are reduced for the inefficient Divisions, contrary to expectations that for improving their performance, more inputs should have been given. DEA computes the efficiency in terms of inputs and outputs and concludes that for the given inputs, the outputs are not commensurate. DEA analysis points out that the resources consumed are not giving equal outputs as other better service units. The institute might then investigate the reasons for this anomaly and consider ways for increasing the value of inputs in all these inefficient Divisions. Few of the possible reasons could be new faculties assigned to the inefficient Divisions or that the non-teaching hours schedule was not effectively used by the inefficient Divisions. DEA thus is insightful for comparative analysis of service unit efficiency.

Limitations of the DEA technique

- There is a limit to the inputs and the outputs that can be defined for any analysis. This then has the same limitations as working with partial productivity. The consideration of partial productivity is incorrect because any increase in productivity due to other factors that are not being considered are passed on to the partial factors that are being considered. Likewise in the DEA analysis we might be considering only two inputs and two outputs, ignoring other inputs and the efficiency exercise would be incorrect. It might happen that the considered two inputs are already working at the optimum and the reasons for drop in productivity or efficiency could be due to some other inputs that we are not considering in our analysis.
- If the number of output and input variables are increased as mentioned above, we encounter the problem of increase in efficient firms on the efficiency frontier. A strong correlation has been seen between increased number of firms on the efficiency frontier and increased input / output variables.
- Even when we consider all the probable inputs and outputs, the problems of weighting them is an issue. In our paper, we have considered both the input parameters and output parameters to have equal weights. A new approach to DEA has been outlined in their book Data Envelopment Analysis, second edition by WILLIAM W. COOPER University of Texas at Austin, U.S.A. LAWRENCE M. SEIFORD University of Michigan, U.S.A. KAORU TONE National Graduate Institute for Policy Studies, Japan that attempts to overcome the qualitative and subjective assignment of weights to the input and output parameters.

- DEA analysis ignores the effect of exogenous variables in the analysis and any efficiency increase of a service unit is attributed to better management of their inputs. The ambitious smart cities project of the Government of India is bound to increase the efficiencies of service outlets operating in such smart cities while the service centres in non-smart cities will have an unfair disadvantage. The effects of such exogenous factors cannot be factored in the DEA analysis.
- The DEA analysis identifies the inefficient service centre and also sets a benchmark for improvement. However, it fails to address the issue of how to improve the existing services or what was lacking in these service centres to result in inefficiency. In the NMIMS SBM case, inefficient divisions A, B, C, E & J were identified, but the DEA analysis cannot indicate the factors for the deficiency in teaching and non-teaching hours and neither does it show the path to improvement. At best, it stops by identifying the inefficient divisions. In our opinion, rather than spending too much effort to identify the best DEA technique, it would be advisable to use the basic DEA technique and spend time and effort in identifying the root cause or solutions to improve the efficiency of the inefficient service centres.
- DEA analysis can best be a complement to the other analysis of efficiency in the service industry in general and the education sector in particular. An output measured by the students' scores in exams and their placements may also be dependent on other factors like their graduation, personality, verbal and non-verbal communication skills other than just the teaching and non-teaching inputs provided at NMIMS.
- As a standard formulation for DEA creates a separate linear programming problem for each service centre, large problems can be computationally difficult. In our NMIMS SBM problem we required 10 formulations, with one for each Division. Imagine a modern generation bank with 100 branches in the city of Mumbai wanting to identify the efficient and inefficient branches. This will require 100 formulations with each problem having 101 constraints.

Limitations of the DEA techniques in the Indian context

- That a theoretical efficient unit for benchmarking is not feasible given the nature of services is well known. It is also equally necessary to know that a fast changing and evolving services sector further complicates the definition of an efficient unit. The "services" sector is in a relative infancy stage in India and is fast evolving. When compared with the mature services sector in developed countries like the USA, the stark contrast in India is very clear (Figure8a and 8b).

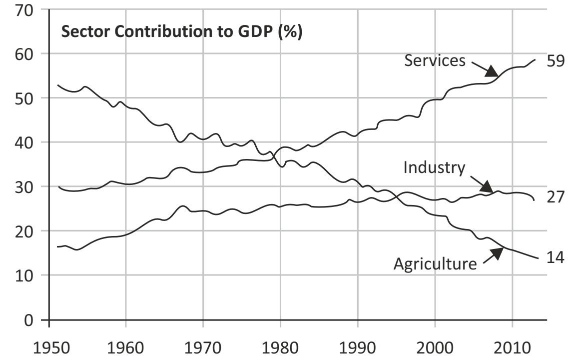

Figure 8a: Services in India

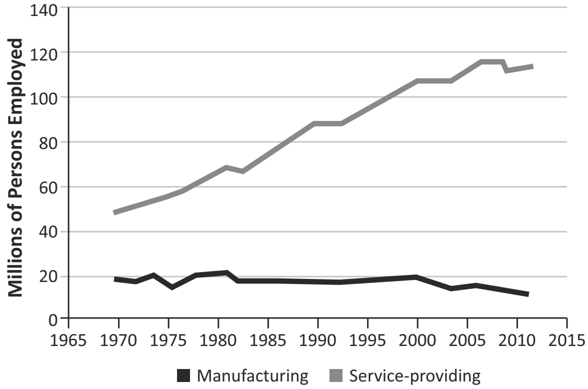

Figure 8b: Services in USA

- India is geographically very large with area being approximately 3,287,263 sq km. This expanse brings with it many diverse cultures and practices. To measure the efficiency parameters for such vast exogenous divergences is a mammoth challenge. For example, in the NMIMS SBM case discussed here, if the comparisons are made with divisions of other NMIMS centres like the Hyderabad campus or the Indore campus or the Bangalore campus, the analysis could be redundant. Neither can we compare the NMIMS SBM Mumbai campus performance data with performance data of other institutes within Mumbai. This then puts a question mark on the practical application of the DEA analysis in the Indian context.
- DEA analysis for services efficiency besides being a relative measure requires the data to be current and relies heavily on the cross-sectional data. Temporal data can make the analysis in fructuous.
- Data reliability or the lack of it can adversely impact the correctness of the DEA analysis. Data in the Indian context is generally not very reliable in terms of being current and error free. The ex-Reserve Bank of India governor, Dr. Subba Rao had mentioned 5 major problems of the economic statistic systems in India, they being more data revisions, inflation measurement practices, limited information on key indicators for business cycles, limited financial soundness indicators and data on employment.
- DEA analysis requires the data to be homogenous and this could be a major limitation in the Indian context. Finding homogeneity in a heterogeneous business limits the space of operations to a very limited area and also subjects it to wide variations in its applications. Nevertheless the DEA approach with refinements could be the only approach for services efficiency benchmarking.
- Another weakness of the DEA approach to service efficiency is that the results tend to be sensitive to the selection of appropriate inputs and outputs. In our case, we have only focused on the materialistic outputs whereas the learning or the long term developments of the students are not considered, in the absence of metrics to measure these qualitative aspects. It can well mean that if some of the additional qualitative outputs were considered, the analysis and efficiency frontier could have been different. In a developing economy like India, getting all the important and relevant input and output data for a service centre could be difficult, thus weakening the efficiency frontier calculations using DEA.
- One of the generic disadvantages of the DEA method is that it does not indicate the best specification for efficiency and would keep on changing the efficiency frontier along with changes in data. This in a fast changing and expanding businesses country like India could seriously impact the efficacy of the process. A cross-efficiency approach developed by Saxton in 1985, giving factor weightages to the various inputs and outputs may be considered for further analysis for services in India.

Conclusions:

The services sector is not only the dominant sector in India's GDP, but has also attracted significant foreign investment flows, contributing significantly to exports and employment. The services sector in India comprises activities like trade, hotel and restaurants, transport, storage, retail, communications, financing, insurance, real estate advisory, social and personal services besides many more. With growth comes competition and with competition comes the need for efficiency. Sooner or later the quest will be for highly efficient working in all these areas. Given the inherent nature of services, an absolute benchmark is not possible and we are required to develop relative benchmarks. Data Envelopment Analysis provides the required framework to identify and enhance the efficiency of services. Although the DEA analysis is not entirely perfect, its imperfections can be overruled for the sake of improving the efficiency of services. With an example of a B school, the application of the DEA analysis is demonstrated in this paper. If the data is accurate, current and homogenous, the DEA analysis could provide an opportunity for efficient working.

Managerial Implications:

DEA is a benchmarking technique and the efficiency scores provide information about a firm's capacity to improve output or input and thus DEA offers strong support in decision making. In case of services in India, the outputs and inputs are not well defined as the services are growing at a very fast pace. The success of the process of Benchmarking with DEA depends on the availability of the correct and relevant data. The accuracy of the data is also important from the perspective that in a service setup, it is at times acceptable to be inefficient, which may be termed as a "special" case. Factually the service centres can each claim to be different than the others as some may possess a specificity which others do not. However, since it is likely that the difference in specificity of one output or input is compensated by the other outputs or inputs, any such claim can be disregarded. The efficiency figures obtained by solving the formulations should at best be considered as an order of magnitude. What we are saying is that in case a service centre obtains an efficiency of 85 percent, it does not mean that it has a capacity to improve 15 percent on all counts. Thus this number should be more of an objective for improvement rather than being strictly implemented, as often this may not be entirely feasible. It is not always necessary that efficiency is the only measure of a service outlet's performance. Effectiveness or Equity or market share may also be considered as criteria for overall performance. A last point that needs to be noted is that the gap between the efficient frontier and the inefficient service units should be realistic. If the gap is too wide (say an inefficient firm is at 45 percent efficiency) then this may not be because of something drastically wrong with the inefficient firm. It could well be because the problem parameters were not defined correctly.

Applicability and Generalizability:

- Data Envelopment Analysis (DEA) is the most commonly used approach for evaluating service centre efficiency but a long-standing concern is that DEA assumes that data are measured without error. This is quite unlikely, and DEA and other efficiency analysis techniques may yield biased efficiency estimates if the data is not without error.
- Another factor that needs to be considered is that the data needs to be dynamic, real and current. In the NMIMS SBM case, the analysis did identify the inefficient divisions and management could review the reasons behind the inefficiency. However, the corrections, if any, can only be carried out in the next academic year for the next batch of students. There is no method by which those students from the inefficient divisions can be coached to better their performance on the output parameters. The lack of real time improvement measures is the limitation of this analysis, which a researcher should be aware about. As such, the DEA analysis technique cannot be a prescriptive tool whereas in present times, prescriptive data analytics is the need of the hour.
- DEA analysis is more about the input variables and less about the output variables. It is so because the internal factors like inputs can be within the realm of the service centre, but the outputs are external to them. Any macro factor affecting the output variable can skew the input efficiency analysis.
- Although DEA analysis uses quantitative data, the result interpretation is more subjective and qualitative. As a result, the post DEA analysis can lose its efficacy. Just identifying the inefficient service centres without identifying the reasons for the inefficiency does not help in the improvement process.

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