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# Benchmarking State Road Transport Undertakings of India: A DEA-based stepwise approach.

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**Abstract**
Benchmarking is the practice of any decision making unit to compare key metrics of its operations with the peers. It has a twofold advantage. Firstly, it allows the units to see how efficiently they are performing in comparison to others. Secondly, it allows the units to identify and analyze the areas of potential improvements to become more competitive. Data Envelopment Analysis (DEA) is a non-parametric tool used for efficiency evaluations and to yield a reference benchmark target for each inefficient unit in the data set under study. However, the benchmarks provided are at times practically infeasible to attain. The inefficient units need to strategize the best practices to be adopted in a stepwise manner so that gradually they can raise themselves up to the level of the reference target. In the present paper, a stepwise benchmarking approach has been developed by selecting intermediate targets. The transitional target units have been selected on the basis of similarity between uses of inputs, yield of outputs and peer appraisal. Initially the units were classified as efficient, marginally efficient, below average and highly inefficient units based on their DEA scores. For a highly inefficient unit, an intermediate target from the next cluster was selected using the criterion of distance between the input and output values and maverick index. In this manner a feasible efficient path has been identified to be adopted by a highly inefficient unit to grow to an efficient unit.

*Key words: Data Envelopment Analysis, Stepwise benchmarking, Public transport, Delhi Transport Corporation.*

## 1. Introduction

Transport refers to the activity that facilitates physical movement of goods and people from one location to another. It has a significant role in promoting national integration. An efficient transport system helps in increasing productivity leading to a sustainable economic development. Road transport is the oldest and primary form of transport that links remote areas with the rest of the country. It facilitates door to door services and is very flexible with less overheads and maintenance cost.

Generally public transport is the predominant mode of motorized local and interstate travel. The operators offer service with a social aim and are controlled by the government. The transport undertakings assume a place of prominence and account for recognizable share of contribution to the GDP of the country.

India's public transport system is among the most heavily used in the world. India is the seventh largest country in South Asia by geographical area and the second most populous country in the world. It is basically rural in character as majority of the population lives on agriculture. Thus, development of the country begins with the development of its villages. Since the villages are spread throughout, hence only road transport can effectively meet the needs of these growing villages.

Public road transport in India is catered to by the State Road Transport Undertakings (SRTUs) incorporated by respective State Governments under section 3 of the Road Transport Corporations Act, 1950. Since its inception, bus based public transport continues to be dominated by SRTUs in terms of coverage and patronage. There are 67 SRTUs operating with more than a hundred thousands of vehicles. Initially, the objective was to provide an efficient, adequate, economical and coordinated road transport. Gradually over the period of time, these undertakings have turned into loss incurring units. Majority of the states also allow certain routes for operation by private operators as well but by controlling and approving the fare structure. Consequently, the SRTUs are caught between the two divergent objectives, namely of plying the services on commercial considerations and fulfilling the social obligations simultaneously.

Thus it becomes imperative now for the mangers of these undertakings to reasonably reconcile the two social and commercial objectives. Evaluating the performance of a road public transport system is essential for making suitable amendments in its improvement strategy. It is required to identify gaps and problems in operations and service both. However, the performance measure should be technically sound and robust in nature so that the managers of the decision making units can formulate and modify their policies and operations strategy. Moreover, in the increasing competitive scenario, it is vital to know how one's competitor is performing and growing along with one's own growth curve.

Benchmarking can be defined as the process of comparing of one's own performance with the industry's best performers. It is a measurement of the quality of an organization's policies and strategies. It is not a simple tool and there is no single universally accepted benchmarking process. The objectives of benchmarking are to identify the areas where improvement is required, analyze how others are achieving their high performance levels and implement in one's own organization to improve the performance. Thus, benchmarking is to be used not only for development but also for improving the productivity and efficiency.

Various studies have been conducted to evaluate the performance and efficiencies in this area by Levaggi (1994), Odeck and Alkadi (2001), Cowie and Asenova (1999), Boame (2004) and Cruz et al. (2012). In India, similar studies have been carried out by Ramanathan (1999), Jha and Singh (2000), Anjaneyulu et al.(2006), Agarwal (2011) and Saxena (2011, 2013, 2016).

The problem of finding the best performer or selecting the benchmark target is of utmost importance in this process. Firstly, an effective methodology is required for finding the target benchmark and secondly a path needs to be identified to attain the same level of performance as the target. Researchers have worked at both the levels in various sectors such as in public administration by Ammons (2002), marketing productivity by Donthu et al(2005), production and design by Lee et al(2008) and in public passenger transport by Hilmola and Pekki (2011) and Saxena(2016). Sometimes, it becomes infeasible for any organization to raise itself up to the level of the best performer directly. In such cases the managers of the organization need to be provided with a path and interim targets so that the ultimate goal of reaching the best performer can be achieved in a feasible manner. Researchers have also been working in identifying this route based on the choice of the decision maker like Shaneth et al(2009) and Park et al(2010).

In the present paper, it is intended to

1. Identify the efficient and inefficient units and rank the State Road Transport Undertakings (SRTUs) of India using Data Envelopment Analysis (DEA).
2. Identify the ultimate benchmark target for the inefficient units.
3. Classify the inefficient units as marginally efficient, below average and highly inefficient units based on their DEA scores.
4. Identify the interim benchmarks for highly inefficient units by computing the Cross efficiencies, Maverick index and vectorial distance from other units belonging to the same group.

## 2. Methodology

Data Envelopment Analysis (DEA) is a non parametric linear programming based model used to evaluate efficiencies of homogeneous decision making units using similar set of multiple inputs to give similar set of multiple outputs. It was put forth by Farrel in 1957 and extended by Charnes, Cooper and Rhodes in 1978. The mathematical model of CCR-DEA as given by them is

$$\max \theta_{j_0}(u,v) = \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \qquad j = 1,2,....,n$$

$$\frac{u_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij}} \geq \varepsilon, \qquad r = 1,2,....,s \qquad (1)$$

$$\frac{v_{ij_0}}{\sum_{i=1}^{m} v_i x_{ij}} \geq \varepsilon, \qquad i = 1,2,.......m$$

where $u_r$ is the weight given to the r-th output, $v_i$ is the weight given to the i-th input, n is the number of decision making units, s is the number of outputs and m is the number of inputs, $j_0$ is the unit being evaluated, $y_{rj}$ is the amount of the r-th output produced by unit j, and $x_{ij}$ is the amount of the i-th input used by unit j. The efficiency scores computed by using this formula are called as the Technical Efficiency (TE) scores

DEA is used for efficiency evaluation and for benchmark target selection by providing a reference set of efficient peer units for each inefficient unit. These reference set serves as benchmarks for improvements. Mathematically, the reference set can be evaluated by solving the dual of model (1) as

$$\min \ z_{j_0} = \theta_{j_0} - \varepsilon \sum_{r=1}^{s} S_{rj_0}{}^{+} - \varepsilon \sum_{i=1}^{m} S_{ij_0}{}^{-}$$

subject to

$$\sum_{j=1}^{n} \lambda_{jj_0} y_{rj} - S_{rj_0}^{+} = y_{rj_0}, \qquad r = 1, 2, ...., s$$

$$\sum \lambda_{jj_0} x_{ij} + S_{ij_0}^{-} = \theta_{j_0} x_{ij_0}, \qquad i = 1, 2, ..., m \qquad (2)$$

$$\lambda_{jj_0} \geq 0, \quad j = 1, 2, ...., n, \ \theta_{j_0}, \ unrestricted \ in \ sign,$$

$$S_{rj_0}^{+}, S_{ij_0}^{-} \geq 0 \quad r = 1, 2, ...., s; \ i = 1, 2, ....., m$$

In this model, θ is the efficiency score, $\lambda_j$'s are the dual variables and $\varepsilon$ is a non-Archimedian infinitesimal. Solving model (2) gives a composite linear combination of efficient units that use less input than the evaluated unit to give the same level of outputs. The optimal values of the dual variables are the coefficients in the linear combination of units. The units that form the composite unit become the reference peers and the one with maximum value of the dual variable becomes the ultimate benchmark target for the inefficient evaluated unit.

The DEA model described above gives the technical efficiencies of various decision making units in the given data set along with the reference peers that serve as the ultimate benchmark target for all the inefficient units in the data set. Based on these scores, arranged in a descending order, the units can further be classified into various levels by computing the quartiles. The units with scores above the value of the third quartile but less than 1 were classified as “marginally inefficient” units as they were close to the frontier. Similarly, units with score lying between the second and third quartile were classified as “above average units” and with those having scores between the first and second quartile were classified as “below average” units. The units with scores less than the first quartile were classified as “highly inefficient”. These highly inefficient units need special attention as they are the worst performers in the data set under study.

In order to select interim benchmark for an inefficient unit, the criterion of direction has been used. The target that is closer to the evaluated unit serves as the interim benchmark, thus improving the direction towards the ultimate target benchmark. Two vectors were evaluated based on the patterns of input. One from the evaluated unit to the ultimate target unit and the other from the evaluated unit to the compared unit. The direction cosines of the covariance between the evaluated unit from the compared unit and the ultimate target unit define the measure of vectorial distance given by

$$d_{j_0}{}' = \cos^{-1} \frac{\sum_{i=1}^{m} (x_{ij_0} - x_{it})(x_{ij_0} - x_{ic})}{\sqrt{\sum_{i=1}^{m} (x_{ij_0} - x_{it})^2} \sqrt{\sum_{i=1}^{m} (x_{ij_0} - x_{ic})^2}} \qquad (3)$$

where $x_{ij_0}$ is the i-th input of the evaluated unit, $x_{it}$ is the i-th input of the ultimate target unit and $x_{ic}$ is the i-th input of the compared unit. A relative magnitude of this measure defined as $d_j = \left[ \frac{\max(d_j') - d_j'}{\max(\delta_j')} \right]$ has been used. A compared unit with maximum value of this relative measure is the one that is closest to the evaluated unit.

Cross efficiencies are the efficiency scores derived when a rated DMU is evaluated using the optimal weights of some other rating DMU. These scores reflect how well the rated unit is performing with the optimal weighing scheme of the other DMUs. Thus, if there are n units in a data set, an nxn square cross efficiency matrix (CEM) is obtained. For this, an element $E_{pr}$ (pth row, rth column) corresponds to the efficiency score of the pth unit calculated using the optimum weights of the rth unit. The leading diagonal coincides with ordinary DEA scores. The mean cross efficiency $e_p$ is computed for each row by ignoring the value in the leading diagonal.

$$e_p = \frac{1}{n-1} \sum_{\substack{k=1 \\ k \neq p}}^{n} E_{pk} \tag{4}$$

This serves as a measure of average appraisal by peers. Doyle and Green (1994) proposed the use of Maverick index as an effective way of measuring the asymmetry between peer appraisal and self-appraisal. It measures the relative increment when shifting from average cross efficiency $e_p$ to ordinary simple efficiency $E_{pp}$. Thus,

$$M_p = \frac{E_{pp} - e_p}{e_p}$$

## 3. Data and variables

The data for this study was taken from the open platform of government of India under the National Data Sharing and Accessibility Policy (NDSAP). The data for the year 2012-13 by 37 STUs has been considered as shared by the Ministry of Road Transport and Highways. Three variables, namely the Fleet size (FS), Total Staff (TS) and Total Cost (TC) have been taken as the input variables and Passenger-kilometers (PK) and Total Revenue (TR) have been taken as the output variables. A relationship amongst these variables was studied and it was observed that they are strongly correlated.

DEA models as given by Charnes, Cooper and Rhodes can be either input oriented or output oriented. The input oriented models minimize the inputs while maintaining the same level of outputs whereas the output oriented models maximize the outputs while using the same level of inputs. In this paper, CCR-output oriented model has been used.

## 4. Results and discussions

- Out of 37 units in the data set, 8 were found to be technically efficient. The three quartiles of the efficiency scores were computed and the units were classified as marginally inefficient, above average, below average and highly inefficient.

| | | |
|---|---|---|
| Level I | Efficient units TE = 1 | Odisha SRTC, State Exp. TC TN Ltd., TN STC(Coimbatore) Ltd., TN STC(Kumbakonam) Ltd., TN STC(Madurai) Ltd., TN STC(Salem) Ltd., TN STC(Villupuram) Ltd., Uttar Pradesh SRTC |
| Level II | Marginally efficient units 0.89424<TE<1 | Gujarat SRTC, Bangalore Metropolitan TC, Metro(TC) Chennai Ltd., North Western Karnataka RTC, Rajasthan SRTC, North Eastern Karnataka RTC, Karnataka SRTC, Andhra Pradesh SRTC. |
| Level III | Above Average units 0.7453<TE<0.89424 | Kerala SRTC, BEST Undertaking, Pune Mahamandal, Harayana ST, Kadamba TC Ltd., Himachal RTC, Maharashtra SRTC. |
| Level IV | Below Average units 0.5637<TE<0.7453 | Assam STC, Jammu and Kashmir SRTC, Bihar SRTC, Tripura SRTC, Chandigarh TU, Meghalaya STC, South Bengal STC. |
| Level V | Highly inefficient units TE<0.5637 | Mizoram ST, Andaman and Nicobar ST, Nagaland ST, Calcutta STC, Ahmedabad MTC, North Bengal STC, Delhi TC. |

- For analysis purpose, Delhi Transport Corporation (DTC) was chosen. This unit is in the category of highly inefficient. Delhi, being the capital is an important metropolitan city of India. The operators have to cater to the needs of not only the local residents but also to the needs of the floating population that visit the city for various reasons.
- Reference peer units were identified for the inefficient units and potential improvements in the value of outputs were also studied. It was observed that DTC had only one peer namely State Exp. TC TN Ltd. This peer would be the ultimate target for DTC. Also, DTC needs to increase its total revenue by 105% and passenger kilometers by 124%. Apart from increasing the outputs, it also needs to reduce its total cost by 19% and total staff by 1.2%. Also DTC is the only unit that needs to decrease its total cost. The target outputs to be achieved by DTC seem to be practically infeasible. Thus, the managers need to identify a feasible and practical strategy to help them improve their performance.
- The interim target selection to improve the efficiencies of highly inefficient units was done using equations (3) and (4). DTC was selected as the evaluated unit $(j_0)$ to determine a feasible efficient path to reach the ultimate target of State Exp TC TN Ltd $(t)$. The intermediate target $(c)$ was selected from each level in a step wise manner. For DTC, a unit in Level V, the next interim benchmark was selected from Level IV.
- Using the directional distance function of equation (3) for inputs and outputs, $d_j$ and $h_j$ were computed with DTC as the evaluated unit, State Exp TC TN Ltd as the ultimate target unit and all the units in Level IV as the compared units. Average cross efficiencies $e_j$ were also calculated for each of the compared units.
- The decision maker can now choose the intermediate target by weighing out various options. In case an inefficient unit needs to choose the next target based on inputs or outputs or the cross efficiencies or a combination of all, accordingly weightage can be assigned to these three measures and the unit with the maximum value becomes the intermediate target. In this study for

DTC equal weightage was assigned to three measures and South Bengal TC was the intermediate target unit.

- The advantage of using this procedure is that the interim target may or may not be the best performer in that level but it would be the best possible for the inefficient unit to move a step further.
- For the next level, now South Bengal TC becomes the evaluated unit and the units from Level III become the compared units. The same process was repeated and Maharshtra SRTC was the next intermediate target for DTC.
- The same process was repeated for Level II units and the feasible benchmarking path for DTC was evaluated as

  DTC → South Bengal TC → Maharashtra TC → Karnataka SRTC → State Exp TC TN Ltd

## 5. Conclusions

This paper is an attempt to suggest feasible and practical targets for an inefficient unit so that it can improve its productivity. The managers of such units need to work at two levels. One, they need to identify the areas where improvements are needed and secondly design strategies so that the improvements are quick and fruitful. DEA identifies potential improvements and the best performers. Thus, the solutions at first level are provided by DEA. But these solutions at times are not practically attainable. Stepwise benchmarking helps inefficient units move towards their goal of matching the best performers in a systematic manner

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