Technical Efficiency Measurement by Data Envelopment Analysis: An Application in Transportation

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Abstract

There has been an ever-growing concern to measure efficiency of decision-making units (DMUs). Regression and Stochastic frontier analysis have been the popular methods of measuring the same. Data Envelopment Analysis (DEA) is one of the latest additions to the bracket of these techniques. DEA is essentially an optimization algorithm, which develops efficiency scores for all DMUs on a scale of zero to 100%, with units receiving 100% efficiency score being called efficient. Further a simple modification in the DEA model also accounts for scaling efficiencies especially for large sized DMUs. In this study, technical efficiency measurement of State Road Transport Undertakings (STUs) was done using the data on a sample of 44 Indian state road transport undertakings. Using a variable return to scale model, efficiency scores were developed for all the state road transport undertakings. The study has revealed that only eight out of 44 STUs were scale efficient. One of the interesting findings of the study is that STUs operating as companies were relatively more technically efficient than others.

Introduction

There is an increasing concern among organizations to study level of efficiency with which they work relative to their competitors. Traditional performance measurement system provides a very unbalanced picture of performance that can lead managers to miss important opportunities for improvement. The most common methods of comparison or performance evaluation were regression analysis and stochastic frontier analysis. These measures are often inadequate due to the multiple inputs and outputs related to different resources, activities and environmental factors. Data Envelopment Analysis (DEA) provides a means of calculating apparent efficiency levels with in a group of organizations. In DEA study, efficiency of an organization is calculated relative to the group's observed best practice. In this study a review of DEA methodology is done and with the help of an example, the working methodology, results of DEA are explained. Section 1 deals with different efficiency concepts and section 2 gives a detailed description of DEA model. Section 3 gives an illustration of DEA with the help of the data collected on a sample of state transport undertakings and Section 4 gives the summary of findings of this empirical work.

Data Envelopment Analysis and Concepts of Effectiveness, Efficiency and Productivity

Effectiveness is the extent to which outputs of service providers meet the objectives set for them. *Efficiency* is the success with which an organization uses its resources to produce outputs — that is the degree to which the observed use of resources to produce outputs of a given quality matches the optimal use of resources to produce outputs of a given quality. This can be assessed in terms of technical, allocative, cost and dynamic efficiency.

Improving the performance of an organizational unit relies on both efficiency and effectiveness. A government service provider might increase its measured efficiency at the expense of the effectiveness of its service. For example, a state transport undertaking might reduce the inputs used like fleet size, cost, bus or day to carry the same number of passengers. This could increase the apparent efficiency of that state transport undertaking but reduce its effectiveness in providing satisfactory outcomes for passengers. Therefore, it is important to develop effectiveness indicators also.

All agencies use a range of inputs, including labor, capital, land, fuel and materials, to produce services. If an agency is not using its inputs in a technically efficient manner, it is possible to increase the quantities of outputs without increasing inputs, or to reduce the inputs being used to produce given quantities of outputs.

What is Data Envelopment Analysis?

Data envelopment analysis is a Linear Programming Problem that provides a means of calculating apparent efficiency levels within a group of organizations. The efficiency of an organization is calculated relative to the group's observed best practice.

DEA and Different Efficiency Concepts

Typically using linear programming, DEA measures the efficiency of an organization within a group relative to observed best practice within that group. The organizations can be whole agencies (for example, state road transport undertaking), separate entities within the agency or disaggregated business units within the separate entities.

To discuss DEA in more detail it is necessary to look at the different concepts of efficiency. The most common efficiency concept is *technical efficiency*: the conversion of physical inputs (such as the services of employees and machines) into outputs relative to best practice. In other words, given current technology, there is no wastage of inputs whatsoever in producing the given quantity of output. An organization operating at best practice is said to be 100% technically efficient. If operating below best practice levels, then the organization's technical efficiency is expressed as a percentage of best practice. Managerial practices and the scale or size of operations affect technical efficiency, which is based on engineering relationships but not on prices and costs.

Allocative efficiency refers to whether inputs, for a given level of output and set of input prices, are chosen to minimize the cost of production, assuming that the organization being examined is already fully technically efficient. Allocative efficiency is also expressed as a percentage score, with a score of 100% indicating that the organization is using its inputs in the proportions that would minimize costs. An organization that is operating at best practice in engineering terms could still be allocatively inefficient because it is not using inputs in the proportions which minimize its costs, given relative input prices.

Finally, *cost efficiency* refers to the combination of technical and allocative efficiency. An organization will only be cost efficient if it is both technically and allocatively efficient. Cost efficiency is calculated as the product of the technical and allocative efficiency scores (expressed as a percentage), so an organization can only achieve a 100% score in cost efficiency if it has achieved 100% in both technical and allocative efficiency.

These concepts are best depicted graphically, as in Figure 1 which plots different combinations of two inputs, labor and capital, required to produce a given output quantity. The curve plotting the minimum amounts of the two inputs required to produce the output quantity is known as an isoquant or efficient frontier. It is a smooth curve representing theoretical best engineering practice. Producers can gradually change input combinations given current technological possibilities. If an organization is producing at a point on the isoquant then it is technically efficient. The straight line denoted as the budget line plots combinations of the two inputs that have the same cost. The slope of the budget line is given by the negative of the ratio of the capital price to the labor price. Budget lines closer to the origin represent a lower total cost. Thus, the cost of producing a given output quantity is minimized at the point where the budget line is tangent to the isoquant. At this point both technical and allocative efficiencies are attained.

The point of operation marked A would be technically inefficient because more inputs are used than are needed to produce the level of output designated by the isoquant. Point B is technically efficient but not cost efficient because the same level of output could be produced at less cost at point C. Thus, if an organization moved from point A to point C its cost efficiency would increase by (OA-OA")/OA. This would consist of an improvement in technical efficiency measured by the distance (OA-OA')/OA and an allocative efficiency improvement measured by the distance (OA'-OA")/OA'. Technical efficiency is usually measured by checking whether inputs need to be reduced in equal proportions to reach the frontier. This is known as a "radial contraction" of inputs because the point of operation moves along the line from the origin to where the organization is now.

Input-Orientated Measures

Farrell (1957) illustrated his ideas using a simple example involving firms that use two inputs (x_1 and x_2) to produce a single output (y), under the assumption of constant returns to scale. Knowledge of the unit isoquant of the *fully efficient firm represented* by SS' in Figure 2 permits the measurement of technical efficiency. If a given firm uses quantities of inputs, defined by the point P, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced without a reduction in output. This is usually expressed in percentage terms by the ratio QP/OP, which represents the percentage by which all inputs could be reduced. The technical efficiency (TE) of a firm is most commonly measured by the ratio TE_1=OQ/OP, which is equal to one minus QP/OP. It will take a value between zero and one, and hence provides an indicator of the degree of technical inefficiency of the firm. A value of one indicates the firm is fully technically efficient. For example, the point Q is technically efficient because it lies on the efficient isoquant.

If the input price ratio, represented by the line AA' in Figure 2, is also known, allocative efficiency may also be calculated. The *allocative efficiency (AE)* of the firm operating at P is defined to be the ratio AE_1 = OR/OQ, since the distance RQ represents the reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point Q', instead of at the technically efficient, but allocatively inefficient, point Q. The total *economic efficiency (EE)* is defined to be the ratio EE_1 = OR/OP where the distance RP can also be interpreted in terms of a cost reduction. Note that the product of technical and allocative efficiency provides the overall economic efficiency $TE_1 \times AE_1$ = (OQ/OP) $\times$ (OR/OQ) = (OR/OP) = EE_1. Note that all three measures are bounded by zero and one.

Figure 3
Illustration of different efficiency concepts

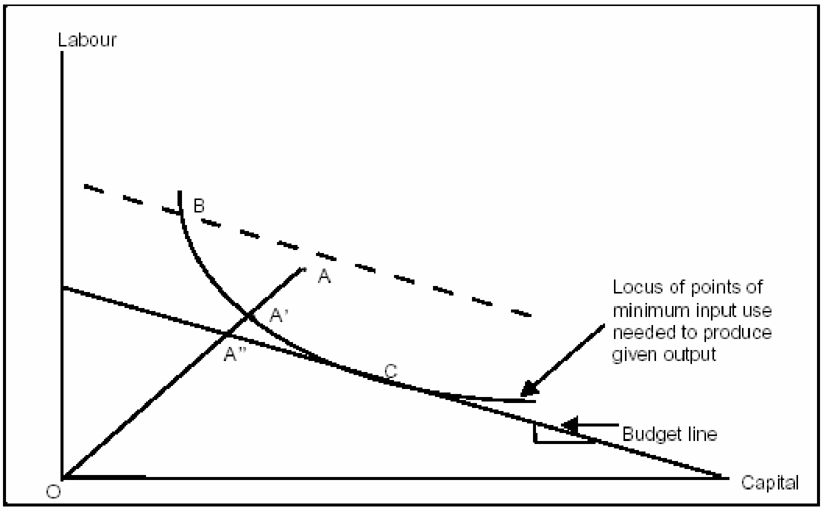


Figure 4
Technical and Allocative Efficiencies

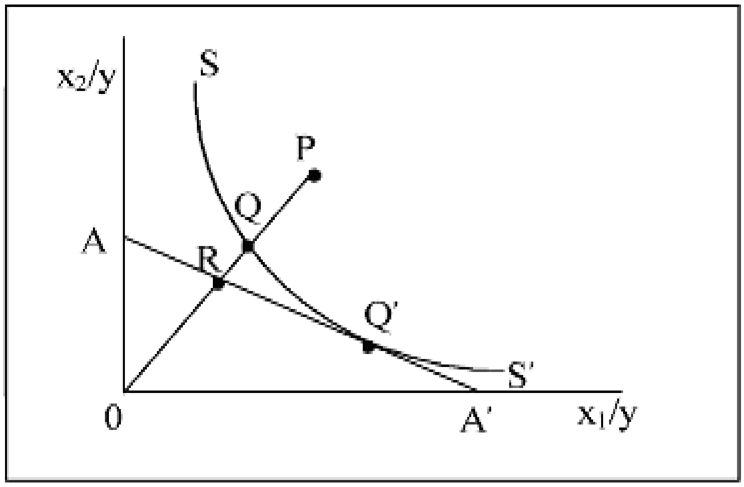
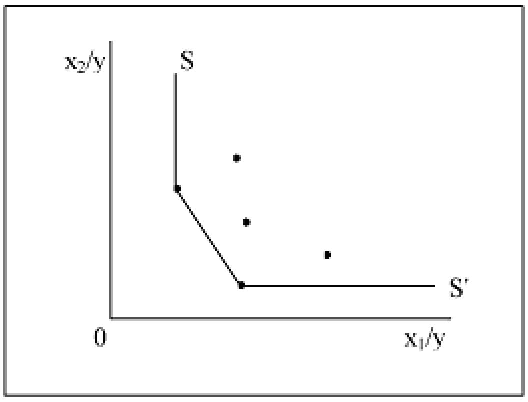


Figure 5
Piecewise Linear Convex Isoquant



These efficiency measures assume the production function of the fully efficient firm is known. In practice this is not the case, and the efficient isoquant must be estimated from the sample data. Farrell (1957) suggested the use of either (a) a non-parametric piecewise-linear convex isoquant constructed such that no observed point should lie to the left or below it (refer to Figure 3), or (b) a parametric function be fitted to the data, again such that no observed point should lie to the left or below it.

Output-Orientated Measures

The above input-orientated technical efficiency measure addresses the question: "By how much can input quantities be proportionally reduced without changing the output quantities produced?" One could alternatively ask the question, "By how much can output quantities be proportionally expanded without altering the input quantities used?" This is an output-orientated measure as opposed to the input-oriented measure discussed above. The difference between the output- and input-orientated measures can be illustrated using a simple example involving one input and one output. This is depicted in Figure 4(a) where we have decreasing returns to scale technology represented by $f(x)$, and an inefficient firm operating at the point P. The Farrell input-orientated measure of TE would be equal to the ratio AB/AP, while the output-orientated measure of TE would be CP/CD. The output- and input-orientated measures will only provide equivalent measures of technical efficiency when constant returns to scale exist, but will be unequal when increasing or decreasing returns to scale are present (Fare and Lovell 1978). The constant returns to scale case is depicted in Figure 4(b) where we observe that AB/AP=CP/CD, for any inefficient point P we care to choose.

One can consider output-orientated measures further by considering the case where production involves two outputs (y_i and y) and a single input (x_i). Again, if we assume constant returns to scale, we can represent the technology by a unit production possibility curve in two dimensions. This example is depicted in Figure 5 where the line ZZ' is the unit production possibility curve and the point A corresponds to an inefficient firm. Note that the inefficient point, A, lies *below* the curve in this case because ZZ' represents the upper bound of production possibilities.

Figure 6
Input- and Output Orientated Technical Efficiency Measures and Returns to Sale

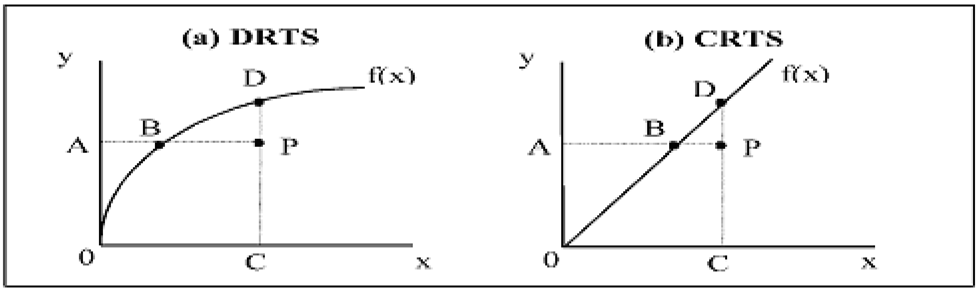
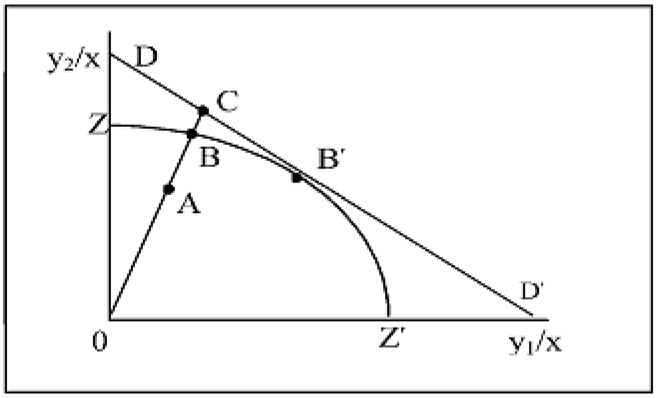


Figure 7
Technical and Allocative Efficiencies from an Output Orientation



The Farrell output-orientated efficiency measures would be defined as follows. In Figure 4, the distance AB represents technical inefficiency. That is, the amount by which outputs could be increased without requiring extra inputs. Hence a measure of output-orientated technical efficiency is the ratio $TE_0 = OA/OB$. If we have price information then we can draw the isorevenue line DD', and define the allocative efficiency to be $AE_0 = OB/OC$ which has a revenue increasing interpretation (similar to the cost reducing interpretation of allocative inefficiency in the input-orientated case). Furthermore, one can define overall economic efficiency as the product of these two measures $EE_0 = (OA/OC) = (OA/OB) \times (OB/OC) = TE_0 \times AE_0$. Again, all of these three measures are bounded by zero and one.

Operationalizing the Concepts

There are several ways to use the data from the sample to try and approximate the smooth curve in Figure 1. Early attempts used ordinary least squares regression techniques that plot an average curve through the sample points. However, this was not satisfactory because an individual organization's efficiency was compared with an average level of performance in the sample rather than an estimate of best practice within the sample. This led to attempts to approximate best practice in the sample by estimating frontiers. The two techniques used to estimate the frontier are DEA and stochastic frontier analysis. The focus in this introduction is on DEA, which is a deterministic means of constructing a "piece-wise linear" approximation to the smooth curve of Figure 1 based on the available sample. In simple terms, the distribution of sample points is observed and a "kinked" line is constructed around the outside of them, "enveloping" them (hence the term data envelopment analysis).

What Questions can DEA help us answer?

Fried, Lovell and Schmidt (1994) listed the following as questions that DEA can help to answer for managers:

- How do I select appropriate role models to serve as possible benchmarks for a program of performance improvement?
- Which production facilities are the most efficient in my organization?
- If all my operations were to perform according to best practice, how many more service outputs could I produce and by how much could I reduce my resource inputs, and in what areas?
- What is the optimum scale for my operations and how much would I save if all my facilities were the optimum size?

Advantages and Limitations of DEA

The main advantage of DEA is that it can readily incorporate multiple inputs and outputs to calculate technical efficiency. By identifying the "peers" for organizations that are not observed to be efficient, it provides a set of potential role models that an organization can look to, in the first instance, for ways of improving its operations. However, like any empirical technique, DEA is based on a number of simplifying assumptions that need to be acknowledged when interpreting the results of DEA studies. DEA's main limitations include the following:

- Being a deterministic rather than statistical technique, DEA produces results that are particularly sensitive to measurement error. DEA only measures efficiency relative to best practice within the particular sample. Thus, it is not meaningful to compare the scores between two different studies.
- DEA scores are sensitive to input and output specification and the size of the sample. Despite these limitations, data envelopment analysis is a useful tool for examining the efficiency of government service providers. Just as these limitations must be recognized, so must the potential benefits of using DEA (in conjunction with other measures) be explored to increase our understanding of public sector performance and potential ways of improving it.

DEA Model

DEA is a linear programming based technique for measuring the relative performance of organizational units where the presence of multiple inputs and outputs makes comparisons difficult. The DEA mathematical model is as follows:

$$Max\ h = \frac{\sum_r u_r y_{rj_0}}{\sum_i v_i x_{ij_0}} \quad \text{subject to}$$

$$\frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1, \quad j = 1, \Lambda, n(\text{ for all } j)$$

performance of organizational units where the presence of multiple inputs and outputs makes comparisons difficult. The DEA mathematical model is as follows:

The u's and v's are variables of the problem and are constrained to be greater than or equal to some small positive quantity ϵ in order to avoid any input or output being ignored in computing the efficiency.

$$u_r,\ v_i \geq \epsilon$$

The solution to the above model gives a value h, the efficiency of the unit being evaluated. If $h = 1$ then this unit is efficient relative to the others. But if it is less than l then some other units are more efficient than this unit, which determines the most favorable set of weights. This flexibility can be a weakness because the judicious choice of weights by a unit possibly unrelated to the value of any input or output may allow a unit to appear efficient.

To solve the model, we need to convert it into linear programming formulation:

$$Max\ h = \sum_r u_r y_{ry_0}$$

subject to dual variable

$$\sum_i v_i x_{ij_0} = 100(\%) \qquad Z_0$$

$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0,\ \ j = 1, \Lambda, n \qquad \lambda_j$$

$$-v_i \leq -\epsilon \ \ i = 1, 2, \Lambda, m \qquad s_i^+$$

$$-u_r \leq -\epsilon \ r = 1, 2, \Lambda, t \qquad s_r^-$$

We call this formulation CCR (Charnes, Cooper, and Rhodes, 1978) model. The dual model can be constructed by assigning a dual variable to each constraint in the primal model. This is shown below.

$$Min 100 Z_0 - \epsilon \sum_i s_i^+ - \epsilon \sum_r s_r^-$$

Subject to

$$\sum_j \lambda_j x_{ij} = x_{ij_0} Z_0 - s_i^+,\ \ i = 1, \Lambda, m$$

$$\sum_j \lambda_j y_{rj} = y_{rj_0} + s_r^-,\ \ r = 1, \Lambda, t$$

$$\lambda_j, s_i^+, s_r^- \geq 0$$

The dual variables λ's are the shadow prices related to the constraints limiting the efficiency of each unit to be no greater than 1. Binding constraint implies that the corresponding unit has an efficiency of 1 and there will be a positive shadow price or dual variable. Hence positive shadow prices in the primal, or positive values for the λ's in the dual, correspond to and identify the peer group for any inefficient unit.

The above models assume constant return to scale. If we add a variable to the model, we can construct a DEA model with variable return to scale. Variable returns means that we might get different levels of output due to reduced performance or economics of scale. This version of the model is popularly known as BCC (Banker, Charnes, and Cooper 1984)

The concern with the DEA model is that by a judicious choice of weights a high proportion of units will turn out to be efficient and DEA will thus have little discriminatory power. The first thing to note is that a unit which has the highest ratio of one of the outputs to one of the inputs will be efficient, or have an efficiency very close to one by putting as much weight as possible on that ratio and the minimum weight zero on the other inputs and outputs. Further empirical studies justify that the number of decision making units evaluated should be greater than two times the total number of variables.

Application To Efficiency Measurement of State Transport Undertakings

Since DEA was first introduced by Charnes, Cooper, and Rhodes (1978), this methodology has been widely applied to the efficiency measurement of many organizations. Sherman and Gold (1985) used DEA model for evaluating bank branch operating efficiency. Shang and Sueyoshi (1995) applied the model to the selection of flexible manufacturing systems. Sueyoshi (1994) developed a model for evaluating the efficiencies of 24 public telecommunication companies in 23 countries.

In this study DEA methodology has been used to measure the technical efficiency of state road transport undertakings in India. The transportation system of the country is one of the engines to growth, creating skills and wealth for the nation and generating employment for millions of people both in rural and urban areas. The development of any country takes place around such activity generators. Substantial contribution to the city's efficiency is possible only when the people and materials are transported at minimal investment and operating cost. Thus an able, adequate and efficient transportation system permits cities and towns to become catalysts for economic, social and industrial development.

Data and Variables for the Study

In this study, three input variables and one output variable are considered for efficiency measurement. Input variables include fleet size, average kilometers traveled per bus per day and cost per bus per day. The output variable considered for the study was revenue per bus per day. Cost and Revenue data is given in Indian Rupees (One Indian Rupee [Rs] = 0.022 US$ approximately). The study involves the application of DEA to assess the efficiency of 44 STUs during the year 2000-01 (Table 1).

The data used for assessment was obtained from the Association of State Road Transport Undertakings and also from the Central of Road Transport, Pune (Table 2). The analysis was conducted by using a computer program DEAP (Coelli, T., 1996), which is available free in the webpage `www.uq.edu.au/economics/cepa/software.htm`.

Findings of the Study – Efficiency Scores:

Under the assumption of VRS, it was found that average technical efficiency score for STUs is 89.4%, which implies that on an average STUs could have used 10.6% fewer resources to produce the same amount of output. Under the CRS assumption, the average efficiency score is 83.4%, which is less than mean efficiency score under VRS assumption. For scale efficiency the average score is found to be 93.4%, which means that on an average the actual scale of production has diverged from the most productive scale size by 6.6%. Only eight STUs are found to have unity scale efficiency score, which means they operate at most productive scale size. To test the stability of the results obtained, a few efficient STUs were deleted and again efficiency scores were computed and the results are found to be stable. The efficiency scores (CRS, VRS and Scale) are given for individual STUs in Table 3 along with the direction of return to scale. An interesting point in the results is that STUs working as companies are found to be relatively more efficient than others.

Conclusion:

In this paper an introduction to efficiency measurement of decision making units and the DEA methodology of measuring the same is given. With the help of a set of input and output variables from state road transport undertakings technical efficiency scores were computed both under CRS and VRS assumption along with scale efficiencies. It was found that only a small portion of STUs were scale efficient. However, the use of these efficiency scores must be made more cautiously. The set of input and output variables selected may be made more exhaustive by adding a few more relevant variables in the efficiency measurement, which may make the measure more robust.

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Table 1
List of State Road Transport Undertakings

Firm No.	Acronym	Name	Nature of the organizations
1	APSRTC	Andhra Pradesh State Road Transport Corporation	Corporation
2	MSRTC	Maharashtra State Road Transport Corporation	Corporation
3	KSRTC	Karnataka State Road Transport Corporation	Corporation
4	GSRTC	Gujarat State Road Transport Corporation	Corporation
5	UPSRTC	Uttar Pradesh State Road Transport Corporation	Corporation
6	RSRTC	Rajasthan State Road Transport Corporation	Corporation
7	STHAR	State Transport Haryana	Government Depts.
8	KSRTC	Kerala State Road Transport Corporation	Corporation
9	NWKSRTC	North West Karnataka Road Transport Corporation	Corporation
10	MPSRTC	Madhya Pradesh State Road Transport Corporation	Corporation
11	STPJB	State Transport Punjab	Government Depts.
12	PRTC	Pepsu Road Transport Corporation	Corporation
13	SBSTC	South Bengal State Transport Corporation	Corporation
14	OSRTC	Orissa State Road Transport Corporation	Corporation
15	KDTC	Kadamba Transport Corporation Limited	Company
16	TNSTC (CBE-I+III)	TamilNadu State Transport Corp. (Coimbatore Dvn-I+III) Ltd	Company
17	TNSTC (CBE-II)	TamilNadu State Transport Corp. (Coimbatore Dvn-II) Ltd.	Company
18	TNSTC (KUM-I)	TamilNadu State Transport Corp. (Kumbakonam Dvn-I) Ltd.	Company
19	TNSTC (KUM-II)	TamilNadu State Transport Corp. (Kumbakonam Dvn-II) Ltd.	Company
20	TNSTC (KUM-III)	TamilNadu State Transport Corp. (Kumbakonam Dvn-III) Ltd.	Company
21	TNSTC(KUM-IV)	TamilNadu State Transport Corp. (Kumbakonam Dvn-IV) Ltd	Company
22	TNSTC(MDU-I)	TamilNadu State Transport Corp. (Madurai Dvn-I) Ltd.	Company
23	TNSTC(MDU-II)	TamilNadu State Transport Corp. (Madurai Dvn-II) Ltd.	Company
24	TNSTC(MDU-III)	TamilNadu State Transport Corp. (Madurai Dvn-III) Ltd.	Company
25	TNSTC(MDU-IV)	TamilNadu State Transport Corp. (Madurai Dvn-IV) Ltd.	Company
26	TNSTC(MDU-V)	TamilNadu State Transport Corp. (Madurai Dvn-V) Ltd.	Company
27	TNSTC(SLM-I)	TamilNadu State Transport Corp. (Salem Dvn-I) Ltd.	Company
28	TNSTC(SLM-II)	TamilNadu State Transport Corp. (Salem Dvn-II) Ltd.	Company
29	TNSTC(VPM-I)	TamilNadu State Transport Corp. (Villupuram Dvn-I) Ltd.	Company
30	TNSTC(VPM-II)	TamilNadu State Transport Corp. (Villupuram Dvn-II) Ltd.	Company
31	TNSTC(VPM-III)	TamilNadu State Transport Corp. (Villupuram Dvn-III) Ltd.	Company
32	HRTC	Himachal Road Transport Corporation	Corporation
33	NGST	Nagaland State Transport	Government Depts.
34	SKMNT	Sikkim Nationalized Transport	Government Depts.
35	TRPTC	Tripura Road Transport Corporation	Corporation
36	MZST	Mizoram State Transport	Government Depts.
37	BEST	Brihan Mumbai Electric Supply & Transport Undertaking	Muncipal Undertakings
38	DTC	Delhi Transport Corporation	Corporation
39	MTC(CHENNAI)	Metro. TC (Chennai) Ltd.	Company
40	CSTC	Calcutta State Transport Corporation	Corporation
41	AMTS	Ahmedabad Municipal Transport Service	Muncipal Undertakings
42	CHNTU	Chandigarh Transport Undertaking	Government Depts.
43	PCMT	Pimpri Chinchwad Municipal Transport	Muncipal Undertakings
44	BMTC	Bangalore Metropolitan Transport Corporation	Corporation

Table 2
Input and Output Data for STUs

Inputs and Outputs of State Transport Undertakings					
Firm No.	**Units**	**Fleet Size**	**Km/Bus/Day**	**Cost/Bus/Day(Rs.)**	**Revenue/Bus/Day(Rs.)**
1	APSRTC	18946	318	3792.7	3489.1
2	MSRTC	16916	308.8	4264.8	4102.6
3	KSRTC	5128	285.1	4005.3	3910.6
4	GSRTC	9847	368.1	4199.1	3044.5
5	UPSRTC	7801	269.8	2937.3	2593.7
6	RSRTC	4466	326.3	3794.8	3309.2
7	STHAR	3470	313.3	4465.8	3911.6
8	KSRTC	4478	283.6	4395.4	3432.8
9	NWKSRTC	3477	310.2	3679.9	3719.8
10	MPSRTC	2393	289	3324.8	2635.7
11	STPJB	2369	261.4	3714.4	2598.1
12	PRTC	1156	269.3	4286.3	3560.5
13	SBSTC	516	280.8	3366.5	2579
14	OSRTC	383	304.1	2980.8	2145
15	KDTC	372	263.3	2888.4	2609.1
16	TNSTC(CBE-I+III)	1461	367.5	4684.2	4166.6
17	TNSTC(CBE-II)	916	452.8	5013.7	5020.4
18	TNSTC(KUM-I)	923	425.8	4980.5	4917.6
19	TNSTC(KUM-II)	895	484.1	4980.9	4990.3
20	TNSTC(KUM-III)	589	459.8	5237.4	4999.6
21	TNSTC(KUM-IV)	383	446.6	5112.3	4850.3
22	TNSTC(MDU-I)	921	364.6	4906.7	4512.9
23	TNSTC(MDU-II)	835	418.1	5332.4	4141.4
24	TNSTC(MDU-III)	676	379.8	4961.2	4266.7
25	TNSTC(MDU-IV)	730	426.6	5048.6	4544.4
26	TNSTC(MDU-V)	368	452.5	5073.8	4986.1
27	TNSTC(SLM-I)	945	437.9	4988.5	4834.8
28	TNSTC(SLM-II)	693	437.4	4805.6	4882.2
29	TNSTC(VPM-I)	1035	464.3	5143.9	5387.3
30	TNSTC(VPM-II)	837	428.5	4858.5	4595.6
31	TNSTC(VPM-III)	752	416.7	4992.2	4565.1
32	HRTC	1728	223.4	3976.5	2141.8
33	NGST	151	132.5	2666	819.35
34	SKMNT	115	80.9	4233.9	2577.6
35	TRPTC	77	143.9	3758.9	756.16
36	MZST	93	118.8	2548.6	677.33
37	BEST	3432	212	6947.8	5596.7
38	DTC	2133	196.2	3455.6	2575.6
39	MTC(CHENNAI)	2819	250.8	3976.2	3490.1
40	CSTC	1235	193	2938.3	1225
41	AMTS	905	207.5	3703.1	2559.3
42	CHNTU	417	323.3	4337.6	4240.4
43	PMCT	232	284.1	2752.8	2138.4
44	BMTC	2264	220.2	3035.3	3186.7

Cost and Revenue data are given in Indian Currency - Rupees abbreviated as Rs. The conversion rate of Rs is 1 Rs = 0.021645 US$ as on 23rd May -2006.

Table 3
Technical Efficiency Scores of STUs

Firm No.	Units	Technical Efficiency (TE) Scores			Return to Scale
		CRS(TE)	VRS(TE)	Scale Efficiency	
1	APSRTC	0.876	0.877	0.999	Decreasing
2	MSRTC	0.917	0.960	0.955	Decreasing
3	KnSRTC	0.937	0.971	0.965	Decreasing
4	GSRTC	0.691	0.692	0.998	Decreasing
5	UPSRTC	0.841	0.919	0.915	Decreasing
6	RSRTC	0.831	0.832	0.999	Decreasing
7	STHAR	0.845	0.886	0.955	Decreasing
8	KSRTC	0.778	0.805	0.967	Decreasing
9	NWKnSRTC	0.963	0.964	0.999	Decreasing
10	MPSRTC	0.755	0.755	1.000	——
11	STPJB	0.682	0.691	0.987	Decreasing
12	PRTC	0.883	0.889	0.994	Increasing
13	SBSTC	0.754	0.812	0.929	Increasing
14	OSRTC	0.712	0.790	0.902	Increasing
15	KDTC	0.894	1.000	0.894	Increasing
16	TNSTC(CBE-I+III)	0.874	0.880	0.993	Decreasing
17	TNSTC(CBE-II)	0.965	0.966	0.999	Increasing
18	TNSTC(KUM-I)	0.960	0.962	0.998	Decreasing
19	TNSTC(KUM-II)	0.967	0.968	0.998	Increasing
20	TNSTC(KUM-III)	0.954	0.977	0.977	Decreasing
21	TNSTC(KUM-IV)	0.967	0.978	0.989	Decreasing
22	TNSTC(MDU-I)	0.931	0.942	0.988	Decreasing
23	TNSTC(MDU-II)	0.777	0.814	0.955	Decreasing
24	TNSTC(MDU-III)	0.869	0.897	0.968	Decreasing
25	TNSTC(MDU-IV)	0.889	0.903	0.984	Decreasing
26	TNSTC(MDU-V)	1.000	1.000	1.000	——
27	TNSTC(SLM-I)	0.935	0.935	1.000	——
28	TNSTC(SLM-II)	0.997	1.000	0.997	Increasing
29	TNSTC(VPM-I)	1.000	1.000	1.000	——
30	TNSTC(VPM-II)	0.918	0.921	0.997	Increasing
31	TNSTC(VPM-III)	0.901	0.916	0.984	Decreasing
32	HRTC	0.581	0.588	0.988	Increasing
33	NGST	0.387	0.830	0.467	Increasing
34	SKMNT	1.000	1.000	1.000	——
35	TRPTC	0.438	1.000	0.438	Increasing
36	MZST	0.388	1.000	0.380	Increasing
37	BEST	1.000	1.000	1.000	——
38	DTC	0.781	0.800	0.976	Increasing
39	MTC(CHENNAI)	0.882	0.898	0.982	Decreasing
40	CSTC	0.428	0.516	0.829	Increasing
41	AMTS	0.768	0.805	0.953	Increasing
42	CHNTU	1.000	1.000	1.000	——
43	PMCT	0.786	1.000	0.786	Increasing
44	BMTC	1.000	1.000	1.000	

CRS: constant return to scale, VRS: variable return to scale SE: scale efficiency (SE=CRSTE/VRST)

ABOUT THE AUTHORS

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