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TECHNICAL NOTE

DEA based estimation of the technical efficiency of state transport undertakings in India

Shivi Agarwal · Shiv Prasad Yadav · S. P. Singh

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Abstract This paper measures the technical efficiency of public transport sector in India. The study makes an attempt to provide an overview of the general status of the State Transport Undertakings (STUs) in terms of their productive efficiency. Data have been collected for 35 STUs for the year 2004-2005. Technical efficiency of the STUs is measured by applying Data Envelopment Analysis (DEA) technique with the use of four input and three output variables. Fleet size, Total staff, Fuel consumption and Accident per lakh kilometer are considered as inputs and Bus utilization, Passenger kilometers and Load factor as outputs. On the basis of the status of technical efficiency, it is concluded that the performance of the STUs are good but still very far from the optimal level. The mean overall technical efficiency (OTE) is 83.26% which indicates that an average STU has the scope of producing the same output with the inputs 16.74% lesser than their existing level. Significant variation in OTE across STUs is also observed.

Keywords DEA · Efficiency · Transport

1 Introduction

Transport sector plays a significant role in the overall development of a nation's economy. Road transport is the prime motorized mode of transport linking the remote and hilly areas with rest of the country. The State Transport Undertakings

S. Agarwal
Department of Mathematics, BITS, Pilani -333031, India
e-mail: shividma@gmail.com

S. P. Yadav (✉)
Department of Mathematics, IIT, Roorkee 247667, India
e-mail: yadavfma@iitr.ernet.in

S. P. Singh
Department of Humanities and Social Sciences, IIT, Roorkee 247667, India
e-mail: singhfhs@iitr.ernet.in

(STUs), controlled by the respective state government, are the imperative mode of passenger mobility in public road transport sector.

Since STUs are public utility service with a social objective, it is essential to regularly monitor their performance, specifically with a view to identifying appropriate measures including proper investment and pricing policy and to improve their output efficiency. In public transport sector, efficiency measurement is the first step in the evaluation of individual performance of STUs. This study is an attempt in this direction to assess the relative technical efficiency of STUs in India.

Passenger road transportation is a "service business" and evaluating the efficiency of a service business is a complex matter. Transport efficiency is often more difficult to evaluate than manufacturing business efficiency, because it is difficult to determine the efficient amount of resources required to produce various service outputs. The manufacturing standard can be used to identify operating inefficiencies through classical cost accounting variance analyses. However, in service organization like road passenger transportation system, it is difficult to identify the specific resources required to provide a specific service output.

The purpose of this article is to evaluate the performance of STUs by providing them with a mathematical technique to analyse the efficiency with which service is rendered. The paper attempts to estimate technical efficiency of the STUs, sets benchmark for inefficient STUs, and suggests alternative actions that would make them relatively efficient. The paper is organized as follows: in Section 2 methodology is given. Empirical Results and discussions are given in Section 3, followed by conclusions in the last.

2 Methodology

This paper measures the technical efficiencies of the STUs. The technical efficiency refers to the extent to which a STU can produce maximum output from its chosen combination of factor inputs.

The mathematical relationship between inputs and outputs in transport sector is not known clearly, so STU efficiency is operationalized using Data Envelopment Analysis (DEA). It is a non-parametric linear programming model that estimates the magnitude of departure from efficiency frontiers for each STU. The DEA model is used to measure the OTE. The DEA is initially proposed by Charnes, Cooper and Rhodes [2]. DEA measures the relative technical efficiency of a group of decision-making units (DMUs) by simultaneously evaluating multiple inputs and outputs common to each unit; each DMU is thus assigned an efficiency score. The DEA model is a family of fractional linear programs; each linear program measures the relative efficiency of a particular DMU. Even though the modeling is nonlinear but under appropriate transformations the efficiency rating can be derived from an equivalent linear program (Charnes and Cooper [4]).

DEA is chosen over other methods because

- ➢ It handles multiple inputs and multiple outputs;
- ➢ It does not require a prior weights (as in index numbers);
- ➢ It emphasizes individual observations rather than statistical estimates (as in regression analysis);

- ➢ It is a dynamic analytical decision-making tool that not only provides a "snapshot" of the current efficiency of the DMU compared with the group, but also indicates possibilities for improving relative efficiency;
- ➢ It uses benchmarking approach to measure STU efficiency relative to others in their group.
- ➢ It can assist in identifying best-practice or efficient STUs and inefficient STUs within the group.
- ➢ The DEA results can allow policy makers to develop policies that can assist the relatively inefficient STUs to improve their performance.

2.1 Algorithm

First Step: Selection of the Homogeneous DMUs

We measure the OTE of 35 STUs using data from CIRT [5] for the year 2004–05. A list of these 35 selected STUs is given in the Appendix A.1.

Second Step: Selection of Input and Output Variables

To evaluate the relative efficiency of the STUs, four inputs, viz., Fleet size (FS), Total Staff (TS), Fuel consumption (FC) and Accident per lakh kilometers (APLK) and three outputs, namely, Bus Utilisation (BU), Passenger kilometers (Pass-Kms) and Load Factor (LF) are considered.

2.2 Inputs

1. Fleet Size (number of buses in hundred) comprises the average number of buses on-road in a STU; it is representative of the capital input.
2. Total Staff (numbers in thousand) refers to the total number of employees worked in a STU; it is representative of the labour input.
3. Fuel Consumption refers to the fuel consumed (in ten thousand kilolitres) which is measured by dividing total earned kilometer by fuel average; it is representative of the material input.
4. Accident per lakh kilometers is important parameter of safety in bus operation.

2.3 Outputs

1. Bus Utilisation (in kilometers) is defined as kilometers done per bus on road per day. It is calculated from dividing total effective kilometers done on a day by total buses on road on that day.
2. Passenger-kilometers (in Billions) is a measure of service utilization which represents the cumulative sum of the distances ridden by each passenger. It is normally calculated by summation of the passenger load times the distance between individual bus stops.
3. Load Factor is the percent of the ratio of passengers actually carried versus the total passenger seating capacity.

The details of the observed data for the selected STUs of the input and output variables are shown in Table 1. There is a perceptible variation in the inputs and the

Table 1 Observed data of the sample STUs in India (2004–05)

Sr. No	STU name	Inputs				Outputs		
		FS (No. in hundred	TS (No. in thousand)	FC (in ten thousand kilolitres)	APLK (No.)	BU (%)	Pass Kms (No. in Billion)	LF (%)
S1	APSRTC	191.05	117.4	43.951	0.1	333.4	762.554	62
S2	MSRTC	152.29	102.231	37.373	0.18	323.4	514.126	45
S3	GSRTC	71.13	52.043	17.825	0.15	356.3	272.587	57.6
S4	UPSRTC	64.48	39.757	14.431	0.13	308.4	234.704	62.2
S5	RSRTC	44.09	22.651	11.148	0.12	346.4	203.756	70.3
S6	KnSRTC	43.47	24.989	11.003	0.16	366.2	225.627	69.6
S7	NWKnSRTC	31.51	20.527	8.466	0.13	394.6	174.015	63.9
S8	NSKnSRTC	23.7	10.073	4.859	0.09	305.6	100.05	74.2
S9	STHAR	31.41	18.354	8.435	0.08	359.1	146.63	68.5
S10	STPJB	14.44	9.5	3.000	0.07	244.8	40.254	60
S11	BSRTC	4.95	4.873	0.997	0.01	216.3	12.611	67.2
S12	CBE	23.52	15.91	7.608	0.32	405.9	168.517	72.5
S13	KUM-1	5.55	3.758	1.905	0.25	469.2	43.018	71.1
S14	KUM-2	8.36	5.707	2.820	0.32	440.8	61.732	72.6
S15	MDU	32.94	22.198	10.643	0.32	427.5	234.234	69
S16	SLM	15.41	10.687	5.233	0.19	447.5	120.124	71
S17	VPM-1	10.39	7.222	4.012	0.29	485.6	105.375	82.8
S18	VPM-3	7.42	5.433	2.518	0.24	440.7	55.911	73.5
S19	TN	8.2	6.971	3.973	0.31	621.3	61.932	78.5
S20	NBSTC	4.23	5.576	0.992	0.23	243.4	12.806	68.1
S21	SBSTC	3.26	2.825	0.887	0.2	305	9.907	54.6
S22	KDTC	3.27	1.983	0.669	0.37	258.2	9.644	53.4
S23	OSRTC	2.28	1.336	0.584	0.04	307.4	8.296	69
S24	HRTC	16.64	8.711	3.838	0.1	230	40.104	49.5
S25	TRPTC	0.61	0.72	0.081	0.03	130	1.01	71.8
S26	MZST	0.28	0.831	0.045	0.001	126.5	0.185	38.9
S27	BEST	30.71	35.785	7.508	0.34	213.7	106.961	60.5
S28	DTC	30.1	29.2	8.082	0.16	229.6	108.193	63.8
S29	CNI	21.87	18.523	5.712	0.52	261.2	122.995	80.8
S30	BMTC	35.34	17.759	6.273	0.19	230.5	124.822	77.2
S31	CSTC	7.07	7.741	1.513	0.2	216.9	19.496	86.8
S32	AMTS	3.71	3.986	0.814	0.75	208.7	10.325	54.7
S33	PCMT	1.23	1.895	0.327	0.49	265.7	4.093	73
S34	KMTU	1.28	0.78	0.301	1.11	237.7	4.567	79.4
S35	PMT	7.64	6.913	1.797	0.37	212	22.748	62
Mean		27.25	18.42	6.85	0.24	313.41	118.40	66.71

Available on www.asrtu.org\scan0012.pdf accessed on 15 March 2006 outputs across STUs. All the inputs used are in some cases hundred times larger than that used by other STU. The variations in outputs produced are not so high except Pass-Kms.

Third Step: Fourth Step: Selection of the model

In this study, CCR input-oriented model has been employed, i.e., how much resources can be reduced without changing the outputs produced to make STUs efficient (Charnes et al. [4]). In order to decompose the overall technical efficiency (OTE) into pure technical efficiency (PTE) and scale efficiency (SE), BCC input-oriented model is also applied to the data. Descriptive statistics of the results are given in Tables 2 and 5.

Fourth Step: Calculating the overall technical efficiency (OTE) of STU

To describe DEA efficiency evaluation, assume that the performance of the homogeneous set of n decision making units (DMU_j; j=1…n) be measured by DEA. The performance of DMU_j is characterized by a production process of m inputs (x_{ij}; i=1…m) to yield s outputs (y_{rj}; r=1… s). According to Charnes et al. [2], the ratio of the virtual output to the virtual input of any DMU_k is to be maximized with the condition that the ratio of virtual output to virtual input of every DMU should be less than or equal to unity.

Mathematically,

$$\mathrm{Max}\ \mathrm{E}_k = \frac{\sum_{r=1}^{s} u_{rk} y_{rk}}{\sum_{i=1}^{m} v_{ik} x_{ik}}$$

subject to

$$\begin{aligned} &\frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}} \leq 1 \quad \forall \mathrm{j} = 1, 2, \ldots, \mathrm{n} \\ &\frac{u_{rk}}{\sum_{i=1}^{m} v_{ik} x_{ik}} \geq \varepsilon \quad \forall \mathrm{r} = 1, 2, \ldots, \mathrm{s} \\ &\frac{v_{ik}}{\sum_{i=1}^{m} v_{ik} x_{ik}} \geq \varepsilon \quad \forall \mathrm{i} = 1, 2, \ldots, \mathrm{m} \end{aligned} \tag{1}$$

where y_{rk} is the amount of the r^{th} output produced by the k^{th} DMU; x_{ik} is the amount of the i^{th} input used by the k^{th} DMU; u_{rk} is the weight given to the r^{th}output of the k^{th} DMU; v_{ik} is the weight given to the i^{th} input of the k^{th} DMU; n is the no. of DMUs ; s is the no. of outputs; m is the no. of inputs and ε is a non-Archimedean (infinitesimal) constant.

The model (1) is popularly known as the classical CCR ratio model named after Charnes, Cooper and Rhodes. The theory of fractional linear programming

Table 2 Resulting efficiency scores of STUs by DEA model

STU No.	Efficiency scores	Reference set	Peer weight	Peer count
S1	1.00	S1	1.00	4
S2	0.790	S1, S7	0.51, 0.70	0
S3	0.821	S1, S7	0.17, 0.82	0
S4	0.853	S1, S6, S26	0.13, 0.61, 0.33	0
S5	1.00	S5	1.00	0
S6	1.00	S6	1.00	5
S7	1.00	S7	1.00	3
S8	1.00	S8	1.00	1
S9	1.00	S9	1.00	0
S10	0.638	S6, S7, S16, S26	0.06, 0.06, 0.14, 1.09	0
S11	0.725	S1, S6, S26	0.01, 0.03, 1.66	0
S12	0.943	S16, S17	1.15, 0.29	0
S13	1.00	S13	1.00	2
S14	0.862	S17, S23, S25, S34	0.58, 0.12, 0.86, 0.07	0
S15	1.00	S15	1.00	0
S16	1.00	S16	1.00	6
S17	1.00	S17	1.00	12
S18	0.873	S17, S23, S25, S34	0.51, 0.04, 1.34, 0.02	0
S19	0.866	S13, S17, S26, S34	0.37, 0.43, 1.80, 0.04	0
S20	0.548	S17, S25, S26	0.12, 0.04, 1.43	0
S21	0.626	S13, S23, S25, S26, S34	0.14, 0.37, 0.25, 0.61, 0.06	0
S22	0.743	S17, S23, S25, S34	0.05, 0.26, 0.79, 0.20	0
S23	1.00	S23	1.00	5
S24	0.499	S8, S16, S23, S26	0.25, 0.12, 0.12, 0.52	0
S25	1.00	S25	1.00	7
S26	1.00	S26	1.00	13
S27	0.599	S16, S17	0.64, 0.28	0
S28	0.637	S6, S16, S26	0.35, 0.24, 0.58	0
S29	0.820	S17	1.17	0
S30	0.895	S6, S16, S26	0.14, 0.78, 0.32	0
S31	0.519	S17, S25, S26	0.18, 1.00, 0.02	0
S32	0.542	S17, S26	0.10, 1.28	0
S33	0.842	S17, S26, S34	0.02, 1.43, 0.31	0
S34	1.00	S34	1.00	6
S35	0.501	S17, S25, S26	0.21, 0.34, 0.51	0
Mean	0.833			

[3] makes it possible to replace (1) with an equivalent linear programming problem by imposing the condition $\sum_{i=1}^{m} v_{ik}x_{ik} = 1$ which provides:

$$\text{Max } \mathrm{w}_k = \sum_{r=1}^{s} u_{rk}y_{rk}$$

subject to

$$\begin{array}{llll}\sum_{i=1}^{m} v_{ik}x_{ik} = 1 & & & \\ \sum_{r=1}^{s} u_{rk}y_{rj} - \sum_{i=1}^{m} v_{ik}x_{ij} & \leq & 0 & \forall j = 1,2,...,n \\ u_{rk} & \geq & \varepsilon & \forall r = 1,2,...,s \\ v_{ik} & \geq & \varepsilon & \forall i = 1,2,...,m \end{array} \tag{2}$$

Model (2) is interpreted that the objective is to maximize virtual output of DMU$_k$ subject to unit virtual input of DMU$_k$ while maintaining the condition that virtual output cannot exceed virtual input for every DMU. This is known as CCR multiplier model whose dual LPP is

$$\text{Min } z_k = \theta_k - \varepsilon \sum_{r=1}^{s} S_{rk}^{+} - \varepsilon \sum_{i=1}^{m} S_{ik}^{-}$$

subject to

$$\begin{array}{ll}\sum_{j=1}^{n} \lambda_{jk}y_{rj} - S_{rk}^{+} = y_{rk} & \forall r = 1 \ldots\ldots\ldots s \\ \sum_{j=1}^{n} \lambda_{jk}x_{ij} + S_{ik}^{-} = \theta_k x_{ik} & \forall i = 1 \ldots\ldots\ldots m \\ \lambda_{jk} \geq 0 & \forall j = 1 \ldots\ldots\ldots n \\ \theta_k \text{ is unrestricted in sign} & \\ S_{rk}^{+}, S_{ik}^{-} \geq 0; r = 1 \ldots..s, i = 1 \ldots\ldots m & \end{array} \tag{3}$$

where S_{rk}^{+} is slack in the rth output of the kth DMU; S_{ik}^{-} is slack in the ith input of the kth DMU; $\lambda_{jk}'s$ are non negative dual variables and θ_k (scalar) is the (proportional) reduction applied to all inputs of DMU$_k$ to improve efficiency. This reduction is applied simultaneously to all inputs and results in a radial movement towards the envelopment surface. This is popularly known as CCR envelopment model.

The interpretation of the results of the envelopment model (3) can be summarized as:

The k$^{\text{th}}$ STU is Pareto efficient if

(a) $\theta_k^* = 1$

(b) All slacks are zero, i.e., S_{rk}^{+*} and $S_{ik}^{-*} = 0$ for every r and i.

The non-zero slacks and (or) $\theta_k^* \leq 1$ identify the sources and amount of any inefficiency that may exist in the DMU$_k$. If the optimal value λ_{jk}^* of λ_{jk} is non zero then jth DMU represents the reference set (peers) of the kth DMU.

Fifth Step: Calculate OTE of every sample STU. The detailed information of the results is given in Table 2

Sixth Step: Calculating the pure technical efficiency (PTE) and scale efficiency (SE) of STU: Another version of DEA is BCC model given by Banker, Charnes and Cooper [1]. The primary difference between BCC model and CCR model is the convexity constraint, which represents the returns to scale. Returns to scale reflects the extent to which a proportional increase in all inputs increases outputs. In the BCC model λ_{jk}'s are now restricted to $\sum_{j=1}^{n}\lambda_{jk} = 1$ which is known as convexity constraint. Technical efficiency assessed by BCC model is pure technical efficiency because it has net of any scale effect. The impact of scale-size on efficiency of a DMU is measured by scale efficiency.

$$\begin{aligned} Scale\,Efficiency\,of\;the\,k^{th}\,DMU &= \frac{Overall\,Technical\,Efficiency\,of\;the\,k^{th}\,DMU}{Pure\,Technical\,Efficiency\,of\;the\,k^{th}\,DMU} \\ &= \frac{CCR\,Efficiency\,Score\,of\;the\,k^{th}\,DMU}{BCC\,Efficiency\,Score\,of\;the\,k^{th}\,DMU} \end{aligned}$$

The overall technical efficiency (OTE) of a DMU can never exceed its pure technical efficiency (PTE). All the three efficiencies (overall technical, pure technical and scale) are bounded by zero and one.

Seventh Step: Calculate PTE and SE of every sample STU. The detailed information of DEA results is given in Table 5.

3 Empirical results and discussions

Table 2 presents the information on OTE, reference set, peer weights and reference count (peer count) of the sample STUs for the year 2004–05. The DEA analysis evaluates the set of STUs which construct the production frontier. The STUs having values of the OTE score equal to 1.00 are form the efficient frontier and those having the values less than 1.00 are less efficient relative to the STUs on the frontier. The lower the efficiency score, the higher scope for the potential reduction in inputs (while maintaining the existing level of outputs) relative to the best practice STUs.

The results indicate that out of 35 STUs, 14 STUs (40%) are relatively efficient (efficiency score =1) while remaining 21 STUS are relatively inefficient (efficiency score <1). These fourteen efficient STUs are APSRTC (S1), RSRTC (S5), KnSRTC (S6), NWKnSRTC (S7), NSKnSRTC (S8), STHAR (S9), KUM-1 (S13), MDU (S15), SLM (S16), VPM-1 (S17), OSRTC (S23), TRPTC (S25), MZST (S26), and KMTU (S34). These STUs are on the best-practice frontier and thus form the "reference set", i.e., these STUs can set an example of good operating practice for the remaining 21 inefficient STUs to emulate. HRTC (S24) is the most technical inefficient STU. Among the inefficient STUs, 7 STUs have the efficiency scores above the average efficiency scores.

The average of OTE scores works out to be 0.833. This reveals that an average STU can reduce its resources by 16.74% to obtain the existing level of outputs.

We use the frequency of efficient STUs in the reference set (i.e., peer count) to discriminate among them. The higher peer count represents the extent of robustness of that STU compared with other efficient STUs. In other words, a STU with higher peer count is likely to be a STU which is efficient with respect to a large number of factors and is probably a good example of a "global leader" or a STU with a high robustness. Efficient STUs that appear seldom in the reference set are likely to possess a very uncommon input/output mix so when the peer count is low, one can safely conclude that the STU is somewhat of an odd unit and cannot be treated as a good example to be followed. On the basis of robustness of efficiency scores, the STUs on the frontier are classified as:

1. High robustness: MZST (S26, peer count = 13) and VPM-1 (S17, peer count = 12) are high robust STU and can be considered as global leaders in terms of OTE.
2. Middle robustness: APSRTC (S1), KnSRTC (S6), SLM (S16), OSRTC (S23), TRPTC (S25) and KMTU (S34) are classified in the middle robust group.
3. Low robustness: RSRTC (S5), NWKnSRTC (S7), NSKnSRTC (S8), STHAR (S9), KUM-1 (S13) and MDU (S15) are graded in the low robust group in terms of OTE.

3.1 Input/Output targets for inefficient STUs

When a STU is inefficient, DEA allows to set the targets for its inputs and outputs so that it can improve its performance. Thus, each of the inefficient STU can become overall efficient by adjusting its operation to the associated target point determined by the efficient STUs that define its reference frontier. According to model, the targets of the inefficient STUs are as follows:

$$\begin{aligned} &\text{For outputs :} \\ &\qquad \overline{y_{rk}} = y_{rk} + S_{rk}^{+*} = \sum_{j=1}^{n} \lambda_{jk}^{*} y_{rj} \\ &\text{For inputs :} \\ &\qquad \overline{x_{ik}} = \theta_k^{*} x_{ik} - S_{ik}^{-*} = \sum_{j=1}^{n} \lambda_{jk}^{*} x_{ij} \end{aligned} \tag{4}$$

where $\overline{y_{rk}}$ (r=1, 2, 3) and $\overline{x_{ik}}$ (i=1, 2, 3, 4) are the target outputs and inputs respectively for the kth STU; y_{rk} and x_{ik} are the actual outputs and inputs respectively of the kth STU; θ_k^{*} = optimal efficiency score of the kth STU; S_{ik}^{-*} is the optimal input slack of the kth STU for i =1…4; and S_{rk}^{+*} is the optimal output slack of the kth STU for r=1…3. The optimal input and output slacks for every inefficient STU are shown in Table 3.

Table 4 presents the target values of all inputs and outputs for inefficient STUs along with percentage reduction in inputs and percentage expansion in outputs. It can be observed from the table that an average STU has a significant scope to reduce the inputs and expand the outputs, relative to the best practice STU. A perusal of the Table, it can be observed that on average, approximately 30% of FS, 37.75% of TS, 23.93 of FC, 41.24% of APLK can be reduced and 19.34% of BU, 26.14% of LF can be expanded if all the inefficient STUs operate at the level of efficient STUs. The results reveal that in order to become efficient, the worst inefficient STU, i.e., HRTC (S24, TE score=49.94%), can reduce its FS by 51.18%, TS, FC, APLK by 50.06%, and expand LF by 11.09% relative to the best practice STU.

Table 3 Slacks in inputs/outputs

STU No	STU Name	Inputs				Outputs		
		FS	TS	FC	APLK	BU	Pass Kms	LF
S2	MSRTC	0	6.02	1	0	123.82	0	31.54
S3	GSRTC	0	5.9	0.21	0	22.82	0	5.17
S4	UPSRTC	4.13	3.49	0	0	0	0	1.18
S10	STPJB	2.4	1.01	0	0	0	0	0
S11	BSRTC	0.44	0.55	0	0	7.43	0	0
S12	CBE	1.46	0.63	0	0	248.51	0	32.98
S14	KUM-2	0.44	0	0	0	0	0	49.91
S18	VPM-3	0.21	0	0	0	0	0	69.46
S19	TN	0	0	0.91	0	0	0	56.95
S20	NBSTC	0.66	0.98	0	0.09	0	0	0
S21	SBSTC	0	0	0	0	0	0	27.59
S22	KDTC	0.52	0	0	0	0	0	42.24
S24	HRTC	0.19	0	0	0	0	0	5.49
S27	BEST	5.55	12.52	0	0	210.8	0	8.46
S28	DTC	0.02	6.77	0	0	78.4	0	0
S29	CNI	5.8	6.76	0	0.09	305.6	0	15.85
S30	BMTC	13.5	3.84	0	0	208.08	0	0
S31	CSTC	1.23	2.02	0	0.02	0	0	0
S32	AMTS	0.66	0.4	0	0.38	0	0	3.11
S33	PCMT	0	0	0.03	0.06	0	0	9.14
S35	PMT	1.28	1.26	0	0.11	0	0	0
Mean		1.83	2.48	0.10	0.036	57.40	0	17.10

3.2 Pure technical efficiency

CCR model is based on the assumption of constant returns to scale (CRS) which does not consider the scale-size of STU to be relevant in assessing technical efficiency. Therefore, in order to know whether inefficiency in any STU is due to inefficient production operation or due to unfavorable conditions displayed by the size of STU, BCC input model is also applied.

BCC efficiency (PTE) is always greater or equal to CCR efficiency (OTE). Hence, number of STUs on the frontier under BCC model is always greater or equal to the number of STUs on the frontier under CCR model.

Table 5 provides details about DEA results drawn from this model. It is evident from the Table that out of 35 STUs, 18 STUs are pure technical efficient (BCC score =1), i.e., none of these have scope to further reduce inputs (maintaining same output level) while remaining 17 STUs are relatively inefficient (score <1). PTE measures how efficiently inputs are converted into output(s) irrespective of the size of the STUs. The average of pure technical efficiency is worked out to be 0.875; this means that given the scale of

Table 4 Target values of input and output variables under CCR input model

STU No	STU Name	Inputs				Outputs		
		FS	TS	FC	APLK	BU	Pass Kms	LF
S2	MSRTC	120.37(20.96)	74.78(26.85)	28.54(23.63)	0.14(20.96)	447.22(38.29)	514.13(0)	76.54(70.10)
S3	GSRTC	58.43(17.86)	36.85(29.18)	14.43(19.02)	0.12(17.86)	379.12(6.41)	272.59(0)	62.77(8.97)
S4	UPSRTC	50.89(21.08)	30.43(23.45)	12.31(14.67)	0.11(14.67)	308.4(0)	234.70(0)	63.38(1.9)
S10	STPJB	6.81(52.84)	5.05(46.86)	1.91(36.25)	0.04(36.25)	244.8(0)	40.25(0)	60(0)
S11	BSRTC	3.15(36.36)	2.98(38.88)	0.72(27.53)	0.001(0)	223.73(3.43)	12.61(0)	67.2(0)
S12	CBE	20.72(11.89)	14.38(9.64)	7.18(5.67)	0.30(5.67)	654.41(61.23)	168.52(0)	105.48(45.48)
S14	KUM-2	6.76(19.08)	4.92(13.85)	2.43(13.85)	0.28(13.85)	440.8(0)	61.73(0)	122.51(68.74)
S18	VPM-3	6.27(15.46)	4.74(12.68)	2.20(12.68)	0.21(12.68)	440.7(0)	55.91(0)	142.96(94.5)
S19	TN	7.1(13.42)	6.04(13.42)	2.53(36.31)	0.27(13.42)	621.3(0)	61.93(0)	135.45(72.54)
S20	NBSTC	1.66(60.86)	2.07(62.83)	0.54(45.24)	0.04(83.94)	243.4(0)	12.81(0)	68.1(0)
S21	SBSTC	2.04(37.37)	1.77(37.37)	0.56(37.37)	0.13(37.37)	305(0)	9.91(0)	82.19(50.54)
S22	KDTC	1.91(41.70)	1.47(25.73)	0.50(25.73)	0.27(25.73)	258.2(0)	9.64(0)	95.64(79.10)
S24	HRTC	8.12(51.18)	4.35(50.06)	1.92(50.06)	0.05(50.06)	230(0)	40.10(0)	54.99(11.09)
S27	BEST	12.85(58.17)	8.91(75.09)	4.50(40.09)	0.20(40.09)	424.5(98.64)	106.96(0)	68.96(13.98)
S28	DTC	19.16(36.34)	11.83(59.48)	5.15(36.28)	0.10(36.28)	308(34.15)	108.19(0)	63.8(0)
S29	CNI	12.13(44.55)	8.43(54.49)	4.68(18.02)	0.34(34.91)	566.80(117)	122.99(0)	96.64(19.61)
S30	BMTC	18.13(48.69)	12.05(32.12)	5.61(10.50)	0.17(10.50)	438.58(90.27)	124.82(0)	77.2(0)
S31	CSTC	2.44(65.55)	2.00(74.18)	0.78(48.11)	8.08E–02(59.58)	216.9(0)	19.50(0)	86.8(0)
S32	AMTS	1.35 (63.51)	1.76(55.92)	0.44(45.78)	2.90E–02(96.13)	208.7(0)	10.32(0)	57.81(5.68)
S33	PCMT	1.03 (15.83)	1.59(15.83)	0.25(23.76)	0.35(28.02)	265.7(0)	4.09(0)	82.14(12.52)
S35	PMT	2.55 (66.60)	2.20(68.17)	0.90(49.91)	7.22E–02(80.49)	212(0)	22.75(0)	62(0)
Mean		17.33 (30)	11.36(37.75)	4.67(23.93)	0.16(41.24)	354.20(19.34)	95.93(0)	82.50(26.14)

Figures in braces are the percentage reductions in the corresponding inputs and percentage additions in corresponding outputs to make the STU efficient

Table 5 OTE, PTE and SE

STU No.	Overall technical efficiency	Pure technical efficiency	Scale efficiency
S1	1.00	1.00	1.00
S2	0.790	0.797	0.992
S3	0.821	0.821	1.00
S4	0.853	0.855	0.998
S5	1.00	1.00	1.00
S6	1.00	1.00	1.00
S7	1.00	1.00	1.00
S8	1.00	1.00	1.00
S9	1.00	1.00	1.00
S10	0.638	0.668	0.955
S11	0.725	1.00	0.725
S12	0.943	0.954	0.988
S13	1.00	1.00	1.00
S14	0.862	0.884	0.975
S15	1.00	1.00	1.00
S16	1.00	1.00	1.00
S17	1.00	1.00	1.00
S18	0.873	0.917	0.952
S19	0.866	1.00	0.866
S20	0.548	0.618	0.886
S21	0.626	0.696	0.899
S22	0.743	0.788	0.943
S23	1.00	1.00	1.00
S24	0.499	0.499	0.999
S25	1.00	1.00	1.00
S26	1.00	1.00	1.00
S27	0.599	0.599	0.999
S28	0.637	0.641	0.994
S29	0.820	0.861	0.952
S30	0.895	0.923	0.970
S31	0.519	1.00	0.519
S32	0.542	0.583	0.930
S33	0.842	1.00	0.842
S34	1.00	1.00	1.00
S35	0.501	0.504	0.994
Mean	0.833	0.875	0.953

operation, on average, STUs can reduce its inputs by 12.5% of its observed level without detriment to its output levels.

Pure technical efficiency is concerned with the efficiency in converting inputs to outputs for the given the scale-size of STUs, whereby we observe that S11, S19, S31 and S33 are CCR technical inefficient but pure technical efficient. This clearly evinces that these STUs are able to convert its inputs into outputs with 100**%** efficiency, but their overall efficiency (OTE) is low due to their scale-size disadvantageous (low scale efficiency).

3.2.1 Scale efficiency (SE)

A comparison of the results for CCR and BCC gives an assessment of whether the size of a STU has an influence on its OTE. Scale efficiency (SE) is the ratio of OTE to PTE scores. If the value of SE score is one, then the STU is apparently operating at optimal scale. If the value is less than one, then the STU appears either small or big relative to its optimum scale-size. Table 5 represents the SE score of the STUs at fourth column. Results show that out of 35 STUs, 15 STUs are scale efficient while remaining 20 STUs are scale inefficient. The average of scale efficiency is 0.953. It indicates that an average STU may be able to decrease its inputs by 4.7% beyond its best practice targets under variable returns to scale, if it were to operate at constant returns to scale.

4 Conclusions and policy implementations

This paper measures technical efficiency (OTE) of 35 STUs in India through DEA methodology. The study finds that 14 STUs have the maximum degree of efficiency. The overall mean TE of the STUs is 83.26%, indicating that on average 16.74% of the technical potential of the STUs is not in use. This implies that these STUs have the scope of producing the same output with the inputs 16.74% lesser than their existing level. The most efficient STUs are MZST and VPM-1 while HRTC is the most inefficient STU.

The targets setting results show that all the inputs have the significant scope to reduce. The model suggests that on average, non-frontier STUs may be able to reduce Fleet Size by 30%, Total Staff by 37.75%, Fuel Consumption by 2.93%, APKL by 41.24%, and to expand BU by 19.34%, LF by 26.14%, relative to the best practice STUs.

The results of BCC model show that out of 35 STUs, 18 STUs are pure technical efficient as they efficiently convert their inputs into the output. However, 4 STUs of them are technical inefficient due to scale-size effect. S31 has the least scale efficiency score (51.9%), implying that S31 has the maximum effect of scale-size on its efficiency score.

Appendix A.1

STUs selected for the study are as follows:

STU No.	STU acronym	STU name	State of operation	Nature of organization
S1	APSRTC	Andhra Pradesh State Road Transport Corporation	Andhra Pradeshation	Corporation
S2	MSRTC	Maharashtra State Road Transport Corporation	Maharashtra	Corporation
S3	GSRTC	Gujarat State Road Transport Corporation	Gujarat	Corporation

(continued)

STU No.	STU acronym	STU name	State of operation	Nature of organization
S4	UPSRTC	Uttar Pradesh State Road Transport Corporation	Uttar Pradesh	Corporation
S5	RSRTC	Rajasthan State Road Transport Corporation	Rajasthan	Corporation
S6	KnSRTC	Karnataka State Road Transport Corporation	Karnataka	Corporation
S7	NWKnSRTC	North West Karnataka State Road Transport Corporation	Karnataka	Corporation
S8	NSKnSRTC	North South Karnataka State Road Transport Corporation	Karnataka	Corporation
S9	STHAR	State Transport Haryana	Haryana	Government Deptt.
S10	STPJB	State Transport Punjab	Punjab	Government Deptt
S11	BSRTC	Bihar State Road Transport Corporation	Bihar	Corporation
S12	CBE-1	Coimbatore Division	Tamil Nadu	Company
S13	KUM-1	Kumbakonam Division 1	Tamil Nadu	Company
S14	KUM-2	Kumbakonam Division 2	Tamil Nadu	Company
S15	MDU	Madurai Division	Tamil Nadu	Company
S16	SLM	Salem Division	Tamil Nadu	Company
S17	VPM-1	Villuparam Division 1	Tamil Nadu	Company
S18	VPM-3	Villuparam Division 3	Tamil Nadu	Company
S19	TN	Tamil Nadu State Express Transport Corporation Limited	Tamil Nadu	Company
S20	NBSTC	North Bengal State Road Transport Corporation	West Bengal	Corporation
S21	SBSTC	South Bengal State Road Transport Corporation	West Bengal	Corporation
S22	KDTC	Kadamba Transport Corporation Limited	Goa	Company
S23	OSRTC	Orissa State Road Transport Corporation	Orissa	Corporation
S24	HRTC	Himachal Road Transport Corporation	Himachal Pradesh	Corporation
S25	TRPTC	Tripura Road Transport Corporation	Tripura	Corporation
S26	MZST	Mizoram State Transport	Mizoram	Government Deptt.
S27	BEST	Brihan Mumbai Electric Supply & Transport Undertaking	Mumbai city	Municipal Undertakings
S28	DTC	Delhi Transport Corporation	Delhi	Corporation
S29	CNI	Chennai Metropolitan Transport Corporation Limited	Chennai city	Company
S30	BMTC	Bangalore Metropolitian Transport Corporation	Bangalore city	Corporation
S31	CSTC	Calcutta State Transport Corporation	Kolkatta city	Corporation
S32	AMTS	Ahmedabad Municipal Transport Service	Ahmedabad city	Municipal Undertakings

(continued)

STU No.	STU acronym	STU name	State of operation	Nature of organization
S33	PCMT	Pimpri Chinchwad Municipal Transport	Pune city	Municipal Undertakings
S34	KMTU	Kohlapur Municipal Transport Undertakings	Kohlapur city	Municipal Undertakings
S35	PMT	Pune Municipal Transport	Pune city	Municipal Undertakings

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