ISSN 2008-0050 (Print), ISSN 1927-0097 (Online)

Benchmarking efficiency of Delhi Transport Corporation: a data envelopment analysis approach

Punita Saxena [1]
[1] Department of Mathematics, Shaheed Rajguru College of Applied Sciences for Women
Vasundhara Enclave, Near Chilla Sports Complex, New Delhi, Delhi 110096, India
punita.saxena@rajguru.du.ac.in

Proc. ICAOR 2016
Rotterdam, The Netherlands

Keywords:
Benchmarking
Data Envelopment Analysis
Efficiency evaluation
Public Transport

Abstract

Transport sector is a very crucial sector for any developing economy. The economic life of a country is dependent largely on this sector. Growing economy leads to more job opportunities and movement of people from rural to urban areas. The urban cities have to optimize their resources to meet the rising needs in terms of available infrastructure and resources. This paper discusses the efficiency of Delhi Transport Corporation (DTC) using the technique of DEA. A data set of 37 State Transport Undertakings of India have been considered for the study. It was observed that DTC is one of the worst performers that need special attention to improve its efficiency amongst its peers. It showed a technical inefficiency of 51.32% and was operating on decreasing returns to scale. It was also observed that DTC needs to decrease its total cost by 19% apart from increasing its increase its output in order to attain the level of efficiency. Regression analysis was performed to identify the explanatory variables for reduction in its total cost.

Introduction

India is one of the emerging economies in the world. This transition in the economy has been possible due to its shift of Gross Domestic Product (GDP) from agriculture to manufacturing and tertiary sectors. The paradigm shift has resulted in the expansion of its urban areas. Delhi, a major metropolis, is officially the National Capital Territory of India. It is the largest city in India in terms of geographical area of 1483 sq.km with a population of 16.75 million. According to the 2011 census, 97.5% of the population of Delhi lives in urban areas [Delhi Government website].

With rapid urbanization, the urban transport scenario in Delhi is also growing fast. Transport sector is the key to many aspects of economic life. The benefits from transport extend from firms to households. It results in higher productivity, more competition, enhanced employment opportunities, expanded choice of housing, and better access to recreation and leisure. Unfortunately, the share of road public transport vehicles has declined. The number of private vehicles has seen a sharp increasing trend. This leads to the problem of traffic congestion on the roads resulting in many more problems such as traffic delays, productivity loss, air and noise pollution and waste of energy. The life in metropolitan cities is hence becoming more traumatic and is creating a challenging environment for the urban transport systems. Policymakers in these cities must be able to quickly design and implement performance enhancing measures for their urban transport systems that are commensurate with the challenges they face.

Government of India in 2006 announced a National Urban Transport Policy (NUTP). The policy focuses on the need to “move people – not vehicles” and ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents. The emphasis is on encouraging greater use of public transport, establishing effective regulatory, institutional and enforcement mechanisms, and improve planning and management of transport systems. It seeks to reduce travel demand by encouraging better integration of land use and transport planning. NUTP encourages capacity building, both at the institutional and individual level [Ministry of Urban development].

The policies formulated can lead to an effective improvement only if the operators improve their performance. The managers need to identify the reasons of their poor performance in comparison to their peers who are more efficient.

The institutionalization of this *benchmarking* provides operators and policymakers with tools to continuously seek enhanced performance. Benchmarking, therefore, is not only used for the development but also for improving the efficiency of any industry. It provides a road map for performance enhancement. Researchers have recognized the problem of benchmarking as one of the major factors in the process of efficiency improvement. This issue has been studied in various fields such as in public administration by Ammons (2002), production and design by Lee *et al* (2008), business management by Tata *et al* (2000) and in public passenger transport by Hilmola and Pekki (2011).

Dattakumar and Jagadeesh in 2003 defined Benchmarking as a process that compares an organization's performance based on certain parameters in relation to a group of successful peer organizations and providing information on the areas of potential improvements. Basically the intention is to learn from the top performers and adopt best practices for potential improvements. Thus, the first step is to identify the best performer which leads to the efficiency evaluation of a group of performers working under similar conditions and with similar objectives. This set of best performers then set the targets for potential improvements for the inefficient performers. Hence to identify the best performer and to set the benchmarking targets, data envelopment analysis (DEA) is used.

Model used

Data Envelopment analysis (DEA) as it is commonly called, was put forth by Farrell in 1957 and extended by Charnes, Cooper and Rhodes in 1978. It was initially used to evaluate and compare the efficiencies of non-profit organizations whose performance cannot be measured on the basis of profits.

The frequently used models of DEA are the CCR given by Charnes, Cooper and Rhodes(1978) and BCC model given by Banker, Charnes and Cooper (1984). In the CCR model, the frontier is spanned by the linear combination of the units in the data set. The efficiency scores obtained from this model are known as technical efficiencies (TE). These scores reflect the radial distance from the estimated frontier to the unit under consideration. A score less than unity amounts to inefficiency in that unit. The CCR model is based on the assumption of constant returns to scale (CRS).

Mathematically, the CCR model can be described as a set of *n* units, each operating with *m* inputs and *s* outputs, let y_{rj} be the amount of the *rth* output from unit *j*, and x_{ij} be the amount of the *ith* input to the *jth* unit. According to the classical DEA model, the relative efficiency of a target unit j_0 is obtained by maximizing the ratio of the virtual output to the ratio of the virtual input subject to the condition that this ratio is less than unity for all the units of the data set. Thus, the objective is to:

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

subject to

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

$$\frac{u_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij}} \ge \varepsilon, \quad r = 1,2,....,s \tag{1}$$

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

The decision variables $u = (u_1,..,u_r,.,u_s)$ and $v = (v_1,.,v_i,.,v_m)$ are respectively the weights given to the *s* outputs and to the *m* inputs. To obtain the relative efficiencies of all the units, the model is solved *n* times, for one unit at a time. Model (1) allows for great weight flexibility, as the weights are only restricted by the requirement that they should not be zero (the infinitesimal ε ensures that) and they should not make the efficiency of any unit greater than one.

The fractional model (1) is solved as a linear program by setting the denominator in the objective function equal to some constant, say, 1 and then maximizing its numerator, as shown in the following model:

$$maxh_{j_0} = \sum_{r=1}^{s} u_r y_{rj_0}$$

subject to

$$\sum_{i=1}^{m} v_i x_{ij_0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \qquad j = 1,\ldots,n \tag{2}$$

$$u_r, v_i \ge \varepsilon \qquad \forall r, i$$

Thus, the objective is now to maximize the virtual output of the target unit subject to the condition that virtual output cannot exceed virtual input for every other unit. Technical Efficiencies (TE) are obtained from this model.

DEA is a useful tool for performance improvement through efficiency evaluation and benchmarking. This is done by providing a reference set that consists of efficient units that can be utilized as benchmarks for improvement. The reference set can be obtained by the dual model as shown in (3)

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

subject to

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

$$\sum \lambda_{jj_0} x_{ij} + S_{ij_0}^{-} = \theta_{j_0} x_{ij_0}, \quad i = 1,2,\ldots,m$$

$$\lambda_{jj_0} \ge 0, \qquad j = 1,2,\ldots.,n \tag{3}$$

$$\theta_{j_0}, \textit{unrestricted in sign}$$

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

By solving model (3) we can identify a linear combination of DMUs (a composite DMU) that utilize less input than the DMU under study while maintaining the same level of outputs. The set of units involved in the construction of the composite DMU are to be treated as benchmarks for improvements of the inefficient DMU under study.

Methodology

The data for the present study was obtained from the open government data platform of India that is released under National Data Sharing and Accessibility Policy (NDSAP). This data was contributed by the Ministry of Road Transport and Highways. In the present paper, the data for the year 2012-13 by 37 reporting State Transport Undertakings have been considered.

The inputs for any study on transport should include the size and quality of the network, spending on investment and maintenance and user inputs such as time, fleet and fuel. Since the availability of the data on the first parameter is difficult to obtain, hence the three variables namely, the Fleet Size (FS), Total Staff (TS) and Total cost (TC) have been taken as the input variables.

The outcomes on the other hand can be classified into two broad categories namely the desirable or the intended outcomes such as passenger kilometers and the undesirable or the unintended outcomes such as congestion or the accidents. In the present study, the unforeseen outcomes have not been considered and only two variables, namely the passenger-kilometers (PK) and Total revenue (TR) have been taken as the output variables. The descriptive statistics of these variables are given in Table 1.

Table 1. Descriptive Statistics of the Variables

Variables	*Maximum*	*Minimum*	*Average*	*Standard Deviation*
Fleet size	22477	33	3607.757	4639.532
Total staff	122287	288	19619.46	25555.24
Total Cost	771990.1	1401.2	133145.7	170001.5
Passenger Kilometers	1476933	91.33	210433.6	291439.4
Total Revenue	763919	146	113482	157884.9

A relationship amongst the input and the output variables was measured. Table 2 shows that the output and the input variables are strongly correlated. Thus, the cause and effect relationship of the variables has not been violated during the period of study. Since, the paper deals with the analysis of efficiency scores between the Public Transport Undertakings, and the two output variables are passenger kilometers and total revenue, the output maximizing models of DEA are used for efficiency evaluations.

Table 2. Correlation between the input and the output variables

Inputs/Outputs	*Fleet size*	*Total staff*	*Total Cost*
Passenger kilometers	0.992929	0.981712	0.960345
Total Revenue	0.950226	0.916304	0.906909

Results and discussions

- Out of the 37 units under study, only 9 of them were seen to be technically efficient. The average technical efficiency was observed to be 0.768250953. The technical efficiency of DTC was observed to be 0.48670855 with a rank 31.
- The units under study were classified by computing the three quartiles of the technical efficiency scores. Only one unit had a score greater than Q_3 (0.994067) that can be called as marginally inefficient unit as it lies very close to the frontier. Nine units can be called as above average as they had their score lying between Q_2 (0.862198) and Q_3. Similarly, 9 units with scores between Q_1 (0.657889) and Q_2 can be called below average units and the remaining highly inefficient. These highly inefficient units need special attention as they are the worst performers in this set. DTC happens to be one such unit.
- In terms of pure technical efficiencies, 12 units were efficient with DTC scoring 0.61545332 and being placed at rank 30. Also DTC was found to be operating at a decreasing rate of scale with a scale efficiency of 0.790813109.
- Delhi, being the National Capital Territory is one of the important metropolitan cities of India. Over the last few years, the city has witnessed a tremendous growth in the number of private vehicles registered in the city. The population of the city has increased from 13.85 million in 2001 to more than 17 million in 2013. The share of buses has decreased from 0.57% in 2001 to 0.26% in 2013. Due to non availability of a well organized, proficient public transport system, the number of cars and jeeps has increased from 1047048 in 2001 to 2483886 in 2013 leading to their percent contribution to the total vehicles in the city from 28.94% to 31.90%.The increased use of private cars has resulted in other related problems like traffic congestion, pollution, cases of road rage and accidents multifold. An efficient public transport system in the city would thus solve a lot more related problems as well.

Table 3 summarizes the performance of the units under study.

Table 3. Summary of the efficiency scores

DMU	*CCR Scores*	*BCC Scores*	*Super Efficiencies*	*Scale efficiencies*	*Scale of operation*	*Ranking*
Ahmedabad MTC	0.445108602	0.45071392	0.445108602	0.98756346	Dec	32
Andhra Pradesh SRTC	0.994066763	1	0.994066763	0.994066763	Dec	10
Andaman and Nicobar ST	0.191218117	0.20433585	0.191218117	0.935803077	Inc	36
Assam STC	0.564261612	0.58417378	0.564261612	0.965913957	Dec	30
BEST Undertaking	0.76438136	0.8321706	0.76438136	0.918539256	Dec	23
Bangalore Metropolitan TC	0.930442777	0.95565705	0.930442777	0.973615772	Dec	16
Bihar SRTC	0.65788871	0.98462735	0.65788871	0.668160103	Inc	28
Calcutta STC	0.315008552	0.31538304	0.315008552	0.998812607	Dec	34
Chandigarh TU	0.726119137	0.74817441	0.726119137	0.97052122	Inc	26
Delhi TC	**0.48670855**	**0.61545332**	**0.48670855**	**0.790813109**	**Dec**	**31**
Gujarat SRTC	0.902167564	0.92032365	0.902167564	0.980272067	Dec	17
Haryana ST	0.833654302	0.8353978	0.833654302	0.997912971	Dec	20
Himachal RTC	0.867538675	0.87023322	0.867538675	0.996903647	Inc	18
Jammu and Kashmir SRTC	0.599871021	0.60920716	0.599871021	0.984674929	Dec	29
Kadamba TC Ltd.	0.862198419	0.87036091	0.862198419	0.990621716	Inc	19
Karnataka SRTC	1	1	1.008091546	1	Con	8
Kerala SRTC	0.787710536	0.7890039	0.787710536	0.998360765	Dec	22
Maharashtra SRTC	0.954008238	1	0.954008238	0.954008238	Dec	12
Meghalaya STC	0.733859443	1	0.733859443	0.733859443	Inc	25
Metro TC (Chennai) Limited	0.932112892	0.932223	0.932112892	0.999881889	Inc	15
Mizoram ST	9.92E-02	0.99989965	9.92E-02	0.099245933		37
Nagaland ST	0.240192013	0.28666482	0.240192013	0.837884515	Inc	35
North Bengal STC	0.444261349	0.46574819	0.444261349	0.95386597	Inc	33
North Eastern Karnataka RTC	0.961712941	0.9892686	0.961712941	0.972145423	Dec	11
North Western Karnataka RTC	0.943226816	0.95661088	0.943226816	0.986008877	Dec	14
Odisha SRTC	1	1	1.141244041	1	Cons	2
Pune Mahamandal	0.818935077	0.81951543	0.818935077	0.999291832	Inc	21
Rajasthan SRTC	0.946481556	0.96950111	0.946481556	0.976256292	Dec	13
South Bengal STC	0.744073275	0.76060325	0.744073275	0.978267288	Inc	24
State Exp.TC TN Ltd.	1	1	1.159037965	1	Cons	1
TN STC (Coimbatore) Ltd.	1	1	1.00987595	1	Cons	7
TN STC (Kumbakonam) Ltd.	1	1	1.001425048	1	Cons	9
TN STC (Madurai) Ltd.	1	1	1.026736131	1	Cons	5
TN STC (Salem) Ltd.	1	1	1.022139963	1	Cons	6
TN STC (Villupuram) Ltd.	1	1	1.028191859	1	Cons	4

DMU	*CCR Scores*	*BCC Scores*	*Super Efficiencies*	*Scale efficiencies*	*Scale of operation*	*Ranking*
Tripura RTC	0.678841001	1	0.678841001	0.678841001	Inc	27
Uttar Pradesh SRTC	1	1	1.078819793	1	Cons	3

- Potential improvements in the value of outputs for inefficient units were also studied. Since the model used was output oriented model, therefore, the inefficient units need to improve their efficiency scores by increasing their level of outputs without changing their level of inputs. However, for most of the units it was observed that they not only need to improve their outputs but also need to decrease their inputs so as to reach the efficiency level as per their peers. Among these units they all need to decrease their staff. A few of them need to decrease their fleet size also. This means that the Undertakings have enough fleet size to provide better services and earn revenues but an improper management of infrastructure leads to inefficiency. However, DTC was the only unit that needs to decrease its cost by around 19% apart from increasing its revenue and passenger kilometers. Table 4 depicts the potential improvements in various inputs and outputs required by the inefficient units.

Table 4. Potential improvements (in percentage)

DMU	*Fleet Size*	*Total Staff*	*Total Cost*	*Total Revenue*	*Passenger kilometers*
Ahmedabad MTC	0.00%	-25.62%	0.00%	124.66%	124.66%
Andhra Pradesh SRTC	0.00%	-10.38%	0.00%	0.60%	3.98%
Andaman and Nicobar ST	0.00%	-0.07%	0.00%	422.96%	999.90%
Assam STC	-24.48%	-59.54%	0.00%	77.22%	178.18%
BEST Undertaking	0.00%	-22.40%	0.00%	30.82%	149.95%
Bangalore Metropolitan TC	0.00%	-33.93%	0.00%	7.48%	11.60%
Bihar SRTC	-74.16%	-65.11%	0.00%	52.00%	52.00%
Calcutta STC	0.00%	-46.34%	0.00%	217.45%	217.45%
Chandigarh TU	0.00%	0.00%	0.00%	37.72%	70.36%
Delhi TC	**0.00%**	**-1.20%**	**-19.03%**	**105.46%**	**123.70%**
Gujarat SRTC	0.00%	-0.65%	0.00%	10.84%	15.22%
Haryana ST	0.00%	0.00%	0.00%	19.95%	53.31%
Himachal RTC	0.00%	0.00%	0.00%	15.27%	118.03%
Jammu and Kashmir SRTC	-36.47%	-58.50%	0.00%	66.70%	106.00%
Kadamba TC Ltd.	0.00%	-16.98%	0.00%	15.98%	999.90%
Karnataka SRTC	0.00%	0.00%	0.00%	0.00%	0.00%
Kerala SRTC	0.00%	-18.52%	0.00%	26.95%	999.90%
Maharashtra SRTC	0.00%	-5.59%	0.00%	4.82%	59.35%
Meghalaya STC	0.00%	-35.91%	0.00%	36.27%	416.46%
Metro TC (Chennai) Limited	0.00%	-14.27%	0.00%	7.28%	24.27%
Mizoram ST	0.00%	-66.09%	0.00%	907.70%	999.90%
Nagaland ST	0.00%	-46.65%	0.00%	316.33%	316.33%
North Bengal STC	-41.86%	-21.53%	0.00%	125.09%	125.09%

DMU	*Fleet Size*	*Total Staff*	*Total Cost*	*Total Revenue*	*Passenger kilometers*
North Eastern Karnataka RTC	0.00%	-15.29%	0.00%	3.98%	3.98%
North Western Karnataka RTC	0.00%	-14.93%	0.00%	6.02%	6.02%
Odisha SRTC	0.00%	0.00%	0.00%	0.00%	0.00%
Pune Mahamandal	0.00%	-22.96%	0.00%	22.11%	118.42%
Rajasthan SRTC	0.00%	0.00%	0.00%	5.65%	17.11%
South Bengal STC	0.00%	0.00%	0.00%	34.40%	92.79%
State Exp.TC TN Ltd.	0.00%	0.00%	0.00%	0.00%	0.00%
TN STC (Coimbatore) Ltd.	0.00%	0.00%	0.00%	0.00%	0.00%
TN STC (Kumbakonam) Ltd.	0.00%	0.00%	0.00%	0.00%	0.00%
TN STC (Madurai) Ltd.	0.00%	0.00%	0.00%	0.00%	0.00%
TN STC (Salem) Ltd.	0.00%	0.00%	0.00%	0.00%	0.00%
TN STC (Villupuram) Ltd.	0.00%	0.00%	0.00%	0.00%	0.00%
Tripura RTC	0.00%	-12.34%	0.00%	47.31%	862.12%
Uttar Pradesh SRTC	0.00%	0.00%	0.00%	0.00%	0.00%

- DTC was the only unit in the data set that required a reduction in its total cost. Thus, the factors responsible for total cost were also explored. This was done to examine the factors that are significantly responsible statistically. Regression analysis was used to analyze the root cause of inefficiency due to the input variable of total cost. A linear relationship between total cost and the explanatory variables namely, cost/km, cost/bus/day, staff costs, fuel and lubricants cost, cost of tyres and tubes, cost of spares, taxes and other costs was studied. Table 5 summarizes the regression analysis.

Table 5. Regression Analysis for Total Cost

	Coefficients	*Standard Error*	*t Stat*	*p-value*
Intercept	-14807.26699	7804.796632	-1.897200874	0.067799714
Cost/KM	-0.477839165	0.666183212	-0.717278905	0.478940108
Cost/Bus/Day	2.200466321	0.94067583	2.339239779	0.026420202
Staff Costs	0.735940939	0.178659731	4.119232337	0.000289151
Fuel & Lubricant Costs	1.043847324	0.469933023	2.221268295	0.034299534
Cost of Tyres & Tubes	-1.725909378	3.864588881	-0.446595856	0.658484175
Cost of Spares	11.05890001	1.463958122	7.554109537	2.50713E-08
Taxes	1.249784275	0.382665715	3.265994903	0.002801973
Other Cost	0.467814992	0.309865785	1.509734262	0.141930975

- It was observed that variables like cost/km, cost of tyres and tubes and other costs had a p-value for their coefficients greater than 0.05. Thus, they can be neglected for further study. Also cost of spares, staff costs and taxes paid by DTC are the ones that had the smallest p-values. These variables can be considered to be the ones that need to be controlled on first priority. The predicted cost was computed for DTC and it was observed that a reduction up to 14% in total cost for DTC can be attained.

Conclusions

This paper is an attempt to evaluate the efficiencies of State Transport Undertakings of India with a special reference to Delhi Transport Corporation in the year 2012-13. The results show that DTC is one of the worst performing undertaking that needs special attention. It needs to increase its revenue to an extent of 105% and passenger kilometers offered by 123% to be able to reach the frontiers as created by its peers. Further, it also needs to decrease its total cost by 19% and staff by 1.2%. Thus, the claim by DTC that they are under staffed loses its significance. Also, it can function efficiently without changing its fleet size. Moreover, the cost spent by DTC on spares, staff and taxes need to be controlled on first priority. This means that the number of the buses should not change but the physical state should improve. Instead of spending money on repair and spares, the managers of DTC should replace the over age buses with new ones. Hence, there is a vast scope for DTC to improve its efficiency by optimally utilizing its resources.

References

Ammons, D.N (2002),"Benchmarking as a performance management tool:Experiences among municipalities in North Carolina" European Journal of Operational research, vol.140,pp.249-265.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984), "Some models for estimating technical and scale inefficiencies in data envelopment analysis", Management Science, Vol. 30 No. 9, pp. 1078-1092.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978), "Measuring the efficiency of decision making units", European Journal of Operational Research, Vol. 2 No. 6, pp. 429-444.

Dattakumar, R., and Jagadeesh, R. (2003) "A review of literature on benchmarking." Benchmarking: An International Journal, 10 (3), 176-209.

Farrell, M.J. (1957), "The measurement of productive efficiency", Journal of the Royal, Statistical Society, Series A (General), Vol. 120 No. 3, pp. 253-290.

Hilmola, Olli-Pekka (2011),"Benchmarking efficiency of public passenger transport in larger cities", Benchmarking: An International Journal, vol.18, no.1, pp.23-41.

Lee S. K.Ryu, H.Bae and Y.Park (2008),"A framework for evaluating reconfigurability of collaboration system using DEA", ICIC Express Letters, vol.5, no.5, pp.1673-1678.

Tata J, S.Prasad and J.Motwani (2000),"Benchmarking quality Management practices: US versus Costa Rica, Multinational Business Review, vol.8, no.2, pp. 37-51.

Transforming City Bus Transport in India through Financial Assistance for Bus Procurement under JnNURM. Ministry of Urban Development, http://www.data.gov.in/catalog/.

www.delhi.gov.in, Economic Survey of Delhi, 2012-2013.