EVALUATING EFFICIENCY OF SUBUNITS OF STATE OWNED TRANSPORT UNDERTAKINGS USING DATA ENVELOPMENT ANALYSIS[1]

Vishnuprasad Nagadevara, Indian Institute of Management Bangalore, India
T V Ramanayya, Indian Institute of Management Bangalore, India

ABSTRACT

Improving the performance of public transport undertakings is becoming more and more critical due to the paucity of public funds, increased demand on transport services and expanding social needs. Improving efficiency of the subunits of a transport system is one possible way to increase the overall efficiency of the system itself. In public transportation, multiple outputs are produced by multiple inputs and consequently, different rankings are obtained depending on different inputs and outputs considered for the calculation of efficiency. Thus it is possible to construct different efficiency measures using different outputs and inputs. This paper uses Data Envelopment Analysis to estimate a single efficiency score of the subunits of Andhra Pradesh Road Transport Corporation and provides policy prescriptions for improving the efficiency levels of those which are found to be inefficient.

Keywords: *Data Envelopment Analysis; Efficiency; Transport subunits; Passenger Transportation*

1. INTRODUCTION

Passenger transportation has an impact on all aspects of mobility and is an important part of overall economic development. Improving the performance of public transport undertakings is becoming more and more critical due to the paucity of public funds, increased demand on transport services and expanding social needs. Of late, the performance measurement and evaluation systems have been gaining importance (Kittelson Associates et. al. 2003, Sulek and Lind 2000). Increased urbanization has increased the number of passenger vehicles in the cities in developing countries such as India. The Road Transport Corporations Act came into effect in India in 1950 and led to various state governments setting up respective State Road Transport Corporations with an objective of providing affordable transport services within the state as well as across states. Over the years, these corporations have become loss making. The trade-off between commercial objectives and social responsibility goals of these state owned corporations became an issue of major concern.

Improving efficiency of the subunits of a transport system is one possible way to increase the overall efficiency of the system itself, even though maximizing the efficiency of the subunits does not necessarily maximize the overall efficiency of the system. Overall system efficiency can be increased by correctly identifying subunit inefficiencies and then improving the performance of these units (Barnum, McNeil and Hart 2007).

Saxena, Dewan and Mustafa had analyzed the problems of state transport undertakings with special reference to Delhi Transport Corporation (Saxena, Dewan and Mustafa 2003). They have used the Data Envelopment Analysis (DEA) to compare the performance of Delhi Transport Corporation with other state owned transport undertakings. They also compared the performances of various state transport undertakings in metropolitan cities.

Barnum, McNeil and Hart (2007) had developed a procedure for comparing the efficiency of subunits of Chicago Transit Authority (CTA) Park and Ride lots. They have used DEA to develop efficiency measures that simultaneously incorporate all resource inputs and desired outputs; adjust for the influence of environmental variables and provide consistent measurements to measure subunit performance.

While evaluating the performance of the Norwegian bus companies subsidized by the government, various issues such as efficiency rankings, distribution and scale properties and potentials for efficiency improvements were addressed (Odeck and Alkadi 2001). The authors used non-parametric data

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envelopment analysis to show that average bus company exhibits increasing returns to scale in production of its services. It was also found that the average bus company has the potential to save about 28 percent.

The performance of different decision making units (DMUs) can be compared based on the efficiencies of each of the DMUs. In economics, technical efficiency is measured by the ratio of output to input (Cooper, Seiford and Zhu 2004). In public transportation, multiple outputs are produced by multiple inputs and consequently, different rankings are obtained depending on different inputs and outputs considered for the calculation of efficiency. Thus it is possible to construct different efficiency measures using different outputs and inputs (Barnum, McNeil and Hart 2007). In order to obtain a comprehensive efficiency measure for different decision making units, a single aggregate measure of all the output could be obtained by an appropriate weighting scheme. Similarly, an aggregate measure for all the inputs could be obtained through a similar weighting process. Then, the overall efficiency could be calculated by obtaining the ratio of the aggregate measure of the outputs to the aggregate measure of the inputs. While this estimation of efficiency is simple in its approach, it would be difficult to assign appropriate weights for each of the inputs and outputs. It is even more difficult to defend such weights. On the other hand, data envelopment analysis offers an innovative approach to the problem of assigning weights to compare the efficiency of the subunits. Such comparison of subunits using DEA in banking and retail sectors had been made earlier (Cooper, Seiford and Zhu 2004). DEA uses linear programming to create appropriate weights and calculates a single comprehensive efficiency measure, with the most efficient units scoring exactly 100 percent. The efficiency of the other subunits is measured as a percentage of the efficiency of its most efficient peers. Thus, the efficiency measures of DEA are relative efficiencies and not absolute efficiencies. One of the special aspects of DEA is that the weights for aggregation can be different for each subunit. For each subunit, the weights are assigned such that it will obtain the highest possible efficiency measure when compared to the other subunits. Thus, the weights assigned to different subunits will be different, but the weights for any given subunit will be such that the efficiency of the subunit will be the highest possible.

The objectives of this study are:

1. To estimate the relative efficiencies of the subunits (district depots) of the road transport corporation
2. to identify those subunits which are inefficient and also to estimate their efficiency scores
3. to identify the “peer” subunits which have an efficiency score of 100 percent
4. to estimate the appropriate weightages for the peer subunits in order to provide appropriate policy recommendations for improving the efficiency levels of the less-efficient subunits

2. METHODOLOGY

The passenger bus services in the state of Andhra Pradesh in India are provided by the Andhra Pradesh State Road Transport Corporation (APSRTC), which is fully owned by the state government. This transport corporation is selected for this study. The Corporation operates under monopoly conditions in the sense that the share of private operators is less than 1 percent of the passenger traffic. At the same time, the primary objective of the Corporation is to provide an affordable, safe and reliable bus service connecting all the villages and towns in the state. APSRTC runs around 19,000 buses carrying about 20 million passengers every day. The annual revenue of the corporation is Rs. 36 billion. In addition, the corporation also provides a subsidized travel to one million students. The Corporation also provides city commuter services within the major urban centers of the state. The APSRTC provides transport services in all the 23 districts of the state. These 23 districts are geographically grouped in three regions namely Telangana, Rayala Seema and Coastal Andhra. The districts in each of these three regions are summarized in Table 1. Data on various aspects of the operation was collected for each district for the year 2004-05, which was the latest year for which data complete data was available for all the districts.

TABLE 1. LIST OF DISTRICTS IN EACH OF THE THREE GEOGRAPHICAL REGIONS IN THE STATE

Telangana Region	Coastal Andhra Region	Rayala Seema Region
Hyderabad	Nellore	Chittor
Mahaboobnagar	Prakasam	Anantapur

Telangana Region	Coastal Andhra Region	Rayala Seema Region
Nalgonda	Guntur	Kadapa
Medak	Krishna	Kurnool
Rangareddy	West Godavari	
Karimnagar	East Godavari	
Nizamabad	Visakhapatnam	
Adilabad	Vizianagaram	
Khammam	Srikakulam	
Warangal		

Each district has at least one depot and the transport services in each of the districts are managed by the respective depot. The services offered by each depot can be categorized into four different services namely, Inter-district services, Intra-district services, Interior Rural services and Inter-state services. In addition to these four services, the depots in four districts namely Hyderabad, Krishna (Vijayawada), Visakhapatnam and Warangal offer city transport services. These city transport services are not considered for the purpose of this study because these services are available in four districts only.

Table 2 presents the characteristics of various categories of services in the form of average of the 23 districts. It can be seen that the number of routes, buses as well as the average earnings per district are the highest in the case of interior rural routes. At the same time, the operating ratio and vehicle utilization for interior rural routes are the lowest. On the other hand, the personnel employed per Km is the highest for the interior rural routes. The operating ratio and vehicle utilization are the highest for inter-district routes.

TABLE 2. CHARACTERISTICS OF DIFFERENT SERVICES (AVERAGE OF THE 23 DISTRICTS)

Item	Interior Rural	Inter District	Intra District	Inter State
Routes	306.25	20.74	127.09	70.33
Buses	828.25	47.39	170.75	230.70
OPTD (Million Km)	73.65	7.49	18.71	27.31
Earnings (Rs. Million)	1099.56	107.21	194.28	328.87
Operating Ratio	52.71	70.42	53.14	60.34
Vehicle Utilization	224.65	477.02	304.44	338.78
Personnel (Per km)	4.86	3.95	4.42	4.07

The Data Envelopment Analysis uses linear programming approach to identify the subunits which are efficient and those which are inefficient. The depot level operations at the district level are considered as the subunits for the study. The mathematical model for the analysis is given below:

Min θ_k

Subject to

$\Sigma_j A_{ij} \lambda_j \leq a_k\theta_k$ (for inputs)

$\Sigma_j A_{ij} \lambda_j \geq a_k$ (For outputs)

$\Sigma_j \lambda_j = 1$

Where θ = efficiency score of the subunit k which is under consideration
A_{ij} are the coefficients corresponding to ith subunit and jth input/output
λ_j = are the weightages associated with jth subunit

The above problem is a linear programming problem. The optimal solution of this problem will result in a value of 1 for θ_k, if kth subunit is efficient. If the kth subunit is not efficient, then the optimal solution will result in a value of less than 1 and the values of λ_j will be the corresopinding weights associated with the "peer subunits" (which are most efficient) of the kth subunit. Appropriate policy directions in terms of the desirable levels of inputs and outputs can be given to the inefficient subunits by using these weights. It is important to emphasize here that the above linear programming problem needs to be solved for each of the subunits separately.

3. RESULTS AND DISCUSSION

As mentioned earlier, district level depot data with respect to each of the 23 districts in Andhra Pradesh was obtained. The input variables considered for DEA were the Cost of Personnel, Cost of Fuel and the Number of Buses in each of the districts. The output variables considered were Vehicle Utilization, Operating Ratio, OPTD, Total Earnings and Earnings per Bus. Since the city services were offered in only four districts namely Hyderabad, Krishna (Vijayawada), Warangal and Visakhapatnam, this category of service was not taken up for DEA. As mentioned earlier, the linear programming problem was solved for each category of services and for each of the 23 districts separately. The results are presented in Appendix Tables 1 to 4 at the end of this paper.

Each appendix table presents the details of the districts which are found to be inefficient under a particular category of services. Thus, Appendix Table A1 presents the results for the inefficient districts under Interior Rural Routes category; Appendix Table A2 presents the results of inefficient district under Inter-district routes; Appendix Table A3 presents the results of inefficient district under Intra-district routes and Appendix Table A4 presents the results of inefficient district under Inter-state routes. The efficiency score along with the peer districts and the corresponding weightages are also presented in these tables.

Two districts namely Adilabad and Srikakulam were inefficient with respect to all the four categories of services. No other district had this dubious distinction of being inefficient in all the four services. Khammam district had an interesting situation. It was inefficient with respect to Interior Rural routes and Intra-district routes. At the same time, it was not only most efficient with respect to the other two categories of services, but also was the "peer district" for each and every district that was inefficient with respect to Inter-district routes. Similar is the case with Prakasam district where it was found to be inefficient in Inter-state services, but was the "Peer District" for most of the inefficient districts in all the other three categories. In other words, these districts appear to be concentrating their efforts in only limited categories of services and sacrificing the efficiencies in other categories of services.

Rangareddy district with an efficiency score of 0.8146 had the lowest efficiency score across all the four categories of services. Adilabad district had the lowest score with respect to Interior Rural routes where as West Godavari and Prakasam districts had the lowest scores in the categories of Intra-district and Inter-state respectively. Since Rangareddy district had the lowest efficiency score, it was selected to demonstrate the policy recommendations for becoming most efficient in its class. Table 3 presents the existing level of each of the six characteristics of the district used for DEA along with the desired level of these characteristics. It can be seen from Table 3 that the district needs to increase the earnings per bus by 48.72 percent and total earnings by 36.54 percent. It could also consider reducing the input costs (personnel costs by 21.57 percent or fuel cost and number of buses by 18.54 percent). Another possibility is to increase vehicle utilization or operating ratio. These desired increases (for outputs) and decreases (for inputs) are also presented in Table 3.

TABLE 3. EXISTING AND DESIRED LEVEL OF CHARACTERISTICS FOR RANGAREDDY DISTRICT

Characteristic	Existing level	Desired Level	Desired increase/ decrease
OPTD (Km Million)	18.91	18.91	0.00%
Earnings (Rs. Million)	45.96	62.75	36.54%
Earnings Per Bus	4351.35	6471.36	48.72%
Personnel Cost	697.85	547.34	-21.57%

Characteristic	Existing level	Desired Level	Desired increase/ decrease
Fuel Cost	992.88	808.84	-18.54%
No. of BUSES	153	124.64	-18.54%
Operating Ratio	65.86	67.59	2.63%
Vehicle Utilization	338.65	496.32	46.56%

The desired increases/decreases listed in Table 3 provide alternate strategies for improvement of the depot. For example, the primary focus could be to decrease the number of buses to 125 and still cater to the existing demand through scientific routing and scheduling. This in turn will improve vehicle utilization, operating ratio and personnel cost. After implementing this strategy, the model could be rerun in order to identify the possible areas of further improvement. Thus, over a period of time, this depot could be made more efficient. Thus, this exercise provides an opportunity to the top management to develop an action plan specific to each depot to improve the overall functioning of the corporation.

4. SUMMARY AND CONCLUSIONS

Improving efficiency of the subunits of a transport system is one possible way to increase the overall efficiency of the system itself, even though maximizing the efficiency of the subunits does not necessarily maximize the overall efficiency of the system. Overall system efficiency can be increased by correctly identifying subunit inefficiencies and then improving the performance of these units. This paper used Data Envelopment Analysis to identify the inefficient depots at the district level in APSRTC. The efficiency scores for each of the depots are obtained through DEA. The identification and role of “peer depots” in recommending the policy prescriptions for improving the efficiencies is demonstrated by selecting the depot which had the lowest efficiency score. Ultimately, this paper demonstrates the use of DEA in improving the efficiency levels of the subunits of a passenger transport organization.

5. REFERENCES

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APPENDIX TABLE A1. INTERIOR RURAL ROUTES – LIST OF INEFFICIENT DISTRICTS

District	Efficiency	Peer1	Weight	Peer2	Weight	Peer3	Weight	Peer4	Weight
Nalgonda	0.9733	Nizamabad	0.02	Nellore	0.49	East Godavari	0.02	Visakhapatnam	0.47
Adilabad	0.9155	Mehaboobnagar	0.04	Nellore	0.08	Chittor	0.03	Visakhapatnam	0.85
Khammam	0.9904	Rangareddy	0.39	Visakhapatnam	0.61				
Warangal	0.9692	Nizamabad	0.20	Vijayanagaram	0.17	East Godavari	0.09	Visakhapatnam	0.54
Karnool	0.9847	Nizamabad	0.11	Nellore	0.10	East Godavari	0.18	Prakasam	0.61
Guntur	0.9683	Visakhapatnam	0.05	Nellore	0.38	East Godavari	0.31	Prakasam	0.26
Krishna	0.9156	Nizamabad	0.01	Nellore	0.48	East Godavari	0.26	Visakhapatnam	0.25
West Godavari	0.9433	Nizamabad	0.05	Nellore	0.32	East Godavari	0.08	Visakhapatnam	0.55
Srikakulam	0.9376	Nizamabad	0.12	Vijayanagaram	0.17	Visakhapatnam	0.71		

APPENDIX TABLE A2. INTER-DISTRICT ROUTES – LIST OF INEFFICIENT DISTRICTS

District	Efficiency	Peer1	Weight	Peer2	Weight	Peer3	Weight	Peer4	Weight	Peer5	Weight
Nalgonda	0.9712	Karimnagar	0.20	Khammam	0.32	Vijayanagaram	0.48				
Medak	0.8821	Karimnagar	0.05	Khammam	0.12	Vijayanagaram	0.83				
Rangareddy	0.8146	Hyderabad	0.34	Khammam	0.23	Vijayanagaram	0.43				
Nizamabad	0.9994	Hyderabad	0.05	Khammam	0.49	Vijayanagaram	0.13	Karimnagar	0.03	Mehaboobnagar	0.30
Adilabad	0.9626	Hyderabad	0.29	Khammam	0.61	Vijayanagaram	0.10				
Warangal	0.9859	Hyderabad	0.07	Khammam	0.43	Vijayanagaram	0.24	Karimnagar	0.17	Mehaboobnagar	0.09
Prakasam	0.9527	Mehaboobnagar	0.34	Khammam	0.22	Vijayanagaram	0.38	Karimnagar	0.06		
Chittor	0.9417	Hyderabad	0.35	Khammam	0.46	Vijayanagaram	0.11	Mehaboobnagar	0.08		
Anantapur	0.9094	Hyderabad	0.24	Khammam	0.52	Vijayanagaram	0.24				
Kadapa	0.9675	Mehaboobnagar	0.12	Khammam	0.45	Vijayanagaram	0.34	Karimnagar	0.09		
Karnool	0.9824	Hyderabad	0.36	Khammam	0.45	Karimnagar	0.19				
Guntur	0.9597	Karimnagar	0.26	Khammam	0.28	Vijayanagaram	0.46				
Krishna	0.9918	Karimnagar	0.17	Khammam	0.83						
East Godavari	0.9037	Karimnagar	0.08	Khammam	0.14	Vijayanagaram	0.78				
West Godavari	0.9754	Hyderabad	0.04	Karimnagar	0.03	Vijayanagaram	0.93				
Srikakulam	0.8981	Hyderabad	0.14	Khammam	0.21	Vijayanagaram	0.65				

APPENDIX TABLE A3. INTRA-DISTRICT ROUTES – LIST OF INEFFICIENT DISTRICTS

District	Efficiency	Peer1	Weight	Peer2	Weight	Peer3	Weight	Peer4	Weight
Nalgonda	0.9296	Rangareddy	0.11	Prakasam	0.66	Visakhapatnam	0.23		
Medak	0.9528	Rangareddy	0.49	Prakasam	0.25	Visakhapatnam	0.26		
Adilabad	0.9311	Rangareddy	0.34	Prakasam	0.35	Visakhapatnam	0.24	East Godavari	0.07
Khammam	0.9496	Rangareddy	0.19	Prakasam	0.66	Visakhapatnam	0.15		
Warangal	0.9212	Rangareddy	0.44	Mehaboobnagar	0.06	East Godavari	0.50		
Nellore	0.9475	Chittor	0.08	Kadapa	0.33	East Godavari	0.59		
Anantapur	0.9986	Chittor	0.12	Kadapa	0.67	East Godavari	0.10	Karimnagar	0.11
Guntur	0.9843	Chittor	0.48	East Godavari	0.52				
West Godavari	0.9030	Rangareddy	0.16	East Godavari	0.42	Visakhapatnam	0.42		
Vijayanagaram	0.9524	Rangareddy	0.82	Prakasam	0.10	Visakhapatnam	0.08		
Srikakulam	0.9625	Rangareddy	0.39	Prakasam	0.23	Visakhapatnam	0.38		

APPENDIX TABLE A4. INTER-STATE ROUTES – LIST OF INEFFICIENT DISTRICTS

District	Efficiency	Peer1	Weight	Peer2	Weight	Peer3	Weight	Peer4	Weight
Medak	0.9951	Karimnagar	0.08	Chittor	0.19	Visakhapatnam	0.73		
Nizamabad	0.9473	Karimnagar	0.44	Visakhapatnam	0.56				
Adilabad	0.9849	Chittor	0.13	Visakhapatnam	0.87				
Prakasam	0.8580	Karimnagar	0.53	Guntur	0.34	Visakhapatnam	0.04	Vijayanagaram	0.09
Anantapur	0.9951	Karimnagar	0.49	Chittor	0.50	Visakhapatnam	0.01		
Kurnool	0.9968	Karimnagar	0.15	Chittor	0.29	Visakhapatnam	0.40	Kadapa	0.16
East Godavari	0.9830	Karimnagar	0.05	West Godavari	0.04	Visakhapatnam	0.42	Vijayanagaram	0.49
Srikakulam	0.8953	Chittor	0.01	Visakhapatnam	0.99				