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A linear programming based solution for problems of traffic & transportation sector

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Abstract

Passenger transportation is an important part of the overall development problem of the nation and affects in some way nearly all aspects of mobility in general. Transportation is defined as the movement of freight and passengers from one place to another. Delhi is a fast growing city, which over the years has undergone landmark change in the characteristic of its transportation sector. The mobility in Delhi is inevitable. This paper attempts to deal with the problems & the critical issues in the traffic & transportation of the city. Further it attempts at proposing solutions to improve and manage the system caused due to a decline in the performance of the state transport undertaking with a special reference to Delhi Transport Corporation. A linear Programming based technique called as Data envelopment Analysis is used to measure the efficiencies of various decision-making units. The analysis on this study is sought to provide a way to obtain a valid efficiency measure for each State Transport Undertaking.

Keywords: Linear Programming Problem, Data Envelopment Analysis, Transportation Problem

1. Introduction

Data Envelopment Analysis (DEA) is a very powerful service management and benchmarking technique originally developed by Charnes *et al* (1) to evaluate nonprofit and public sector organizations. DEA has since been proven to locate ways to improve service not visible with other techniques. Yet there is an anomaly surrounding this developing methodology. Moreover, every service organization can be benefitted from DEA in different ways and DEA can be adapted to help improve service productivity. Increased use by service managers will identify new strengths and benefits that can be derived from DEA along with gaps and weaknesses. The latter can set the agenda for future research on adapting DEA and will help identify areas where this methodology is inappropriate and ineffective, allowing managers to identify these types of applications of DEA. Linear programming is the underlying methodology that makes DEA particularly powerful compared with alternative productivity management tools. DEA has been widely studied, used and analyzed by academics (2-5) that understand linear programming. Managers have not widely adopted DEA to improve organization performance, in part, because most DEA publications are in academic journals or books requiring the ability to understand linear programming and supporting mathematical notation. In fact, some managers trying to use DEA based on their understanding of academic publications have misunderstood the way to apply DEA. They erroneously attribute weak results to the technique when the problem is often due to the misapplication of DEA. Here an attempt has been made to explain what DEA does, how DEA evaluates efficiency, how DEA identifies paths to improve efficiency, limitations of DEA, and how to use DEA. This will enable managers to explore and assess the value of using DEA in their service operations. 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 provides a means of calculating apparent efficiency levels within a group of organizations.

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In DEA study, efficiency of an organization is calculated relative to the group's observed best practice. Our nation's transportation system has a pervasive impact on each of us. The trade-off between the commercial objective and social responsibility goals of State Transport Undertaking is an issue of serious concern. This paper deals with the problems caused due to decline in the performance of the Delhi Transport Corporation.

2. 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, allocate, 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.

3. 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.

4. 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. Allocate 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. Allocate 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 allocatively 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 allocatively 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 allocatively efficiency.

1. DEA compares service units considering all resources used and services provided, and identify the most efficient units or best practice units (branches, departments, individuals) and the inefficient units in which real efficiency improvements are possible. This is achieved by comparing the mix and volume of services provided and the resources used by each unit compared with those of all the other units. In short, DBA is a very powerful benchmarking technique.
2. DBA calculates the amount and type of cost and resource savings that can be achieved by making each inefficient unit as efficient as the most efficient - best practice ~ units.
3. Specific changes in the inefficient service units are identified, which management can implement to achieve potential savings located with DEA. These changes would make the efficient units performance approach the best practice unit performance. In addition, DEA estimates the amount of additional service an inefficient unit can provide without the need to use additional resources.

5. Mathematical Formulation of the Problem

The technique of DEA is being used to compare the efficiencies of highways, combined transport terminals, Railroads and motor carriers. DEA is a suitable method for analyzing and productivity in multiple input-output productions. The usual measures of efficiency that is

Efficiency = Output/Input

Is often inadequate due to existence of multiple inputs and outputs related to different resources, activities and environmental factors. Moreover different patterns of activities levels are supported by different amounts of resources making comparisons difficult. DEA allows relative efficiency measures to be determined. A common measure of relative efficiency is

Efficiency = Weighted sum of outputs/Weighted sum of inputs

The efficiency derived for each unit is on the scale of 0 – 1, where a ‘0’ denotes an extremely inefficient unit and a score of ‘1’ represent an efficient unit. Efficiency scores are relative and are derived by comparison between the units in the data set being analyzed. The solution of this linear program also provides a set of target inputs and outputs for the inefficient units. For each inefficient target units that would attain an efficient score of ‘1’ with the same set of inputs and outputs as the target unit. These units are called as the peer units and their values of the inputs and the outputs serve as the target values for the inefficient units. These target values of the inputs and the outputs from the basis for the potential improvement of the inefficient unit. The potential improvements for the inefficient unit are:

$(\text{Target value} - \text{Actual value}) / \text{Actual value} * 100$

Thus, the objective of the study could be summarized as a solution to the problems of Public Transport Undertakings in providing management with information such as:

1. An efficiency evaluation of Transport Undertakings.
2. Identification of areas in which efficiency could be increased.

6. Data Analysis

Delhi has strong and vibrant economy. The economy has been divided into many different sectors. Out of these, sector like Medical & Public Health, Education, Energy, Water supply, urban department and Transport are considered as core sectors because they not only provide infrastructure support but also help in covering all socio-economic development of Delhi. In the analysis, the Transportation Department of Delhi Government is considered as a sector and the efficiencies are calculated for the various sectors with regard to the budgetary allocations and the expenditures by these sectors. Data was collected for the various sectors and it was observed that six of them turned out to be efficient and six were inefficient with the Transport Department showing an efficiency score of 0.83. The efficiency scores of all the sectors are given in Table-1.

Table 1: Relative efficiencies

Sectors	Relative efficiencies
Urban development	1.00
Education	1.00
Technical Education	1.00
Housing	1.00
Industries	1.00
Energy	1.00
Science & Technology	0.75
Medical	0.93
Public health	0.92
Rural development	0.91
Economics services	0.96
Transport	0.83

It was observed that the peer units for the Transport sector were Energy, Urban development and Housing. The inputs for the Transport sector are high while the outputs are low as compared to the peer units making the Transport sector an inefficient unit.

7. 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:

1. 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.
2. 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?

8. 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. The result of the analysis of the DEA technique for the Transport sector of Delhi Government projected the fact that if the budgetary allocations of the department are decreased or the output is increased then the optimal level of efficiency by the department can be attained. 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.

9. References

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