Data Envelopment Analysis based Benchmarking for Road Transport Corporations: A Case Study

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***Abstract*—Benchmarking is a improvement technique essential in the case where similar organizations are functioning for satisfying the customers in a profitable way but delivering it with different efficiency. Here the performances of Road Transport Corporations (RTC's) are compared and a generalized methodology is formulated using the technique of Data Envelopment Analysis (DEA). This is the first attempt for a DEA study on performance of road transport corporations that is carried out in two stages ie financial analysis stage and operational analysis stage. For the purpose of analysis three Road Transport Corporation in South India where selected. In which Kerala State Road Transport Corporation (KSRTC) is regularly hitting the headlines with the reports of huge financial loss every year. The nearby Tamil Nadu State Transport Corporation (TNSTC) and Karnataka State Road Transport Corporation (KSRTC) are performing extremely opposite by making huge profits. Various variables concerning the efficiency of transport corporations where identified first to carry out Financial statement analysis and operational analysis by framing two general mathematical model. This case study pinpoints the areas where Kerala SRTC needs to concentrate to improve its standard. Although the focus of this paper is in the above three corporations, much of the approach can be generalized for any number of transport corporation in any context for the purpose of benchmarking. The work can also be viewed as the initial step for framing Theory of Constraints based strategies for the transport corporations.**

Keywords- Data Envelopment analysis; Benchmarking; Efficiency measurement

I. INTRODUCTION

Kerala State Road Transport Corporation (DMU 1) is the government transport bus operator in Kerala and is also the largest Public Sector Undertaking (PSU) of the state. But now DMU 1 is regularly hitting the headlines with the reports of huge financial loss every year. The nearby Tamil Nadu State Transport Corporation (TNSTC) and Karnataka State Road Transport Corporation (DMU 1) are performing extremely opposite by making huge profits. So there lies a possibility of benchmarking by conducting a comparative study between these three corporations such that the underlying strengths and weaknesses associated with the performance of each of the corporations can be identified.

Benchmarking has been defined as the search for companies' or industry's best practices that will lead to superior performance or organizational success (Mei-Chi Lai, A., 2011).Since its initial development by Xerox in 1979, benchmarking as a total quality management tool has been widely adopted by manufacturing and service industries, and other industries around the world. Data Envelopment Analysis (DEA) is an increasingly popular management tool in benchmarking process to evaluate the efficiency of a number of producers. In the DEA literature, a producer is usually referred to as a decision making unit or DMU. In DEA, there are a number of producers. DEA attempts to determine which of the producer is the most efficient, and to point out specific inefficiencies of the other producer or in other words DEA is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units (DMUs). DEA make use of linear programming methodology to measure the efficiency of multiple decision-making units (DMUs) when the production process presents a structure of multiple inputs and outputs.

DEA can turn out to be a perfect tool to make the comparison between the above three corporations since all the corporations are homogenous in nature and delivers the same kind of service in a similar scenario. The study plans to obtain operational statistics and financial statements like balance sheets, profit and loss statements of the last five years from the respective corporate headquarters and websites. These collected financial data will be analyzed using DEA technique by mathematically formulating the optimization model corresponding to the above three corporations. From the results of financial analysis, the most efficient corporation will be selected for the operational analysis using the DEA technique itself. The result of the model can be used to ascertain the managerial issues of the corporations to offer suggestions and recommendations. This paper also makes a comparative study of various efficiency parameters of DMU 1 with the most efficient corporation selected after the financial analysis. This study is to pinpoint the areas where DMU 1 needs to concentrate to improve its standard.

II. LITERATURE REVIEW

A. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non parametric method of measuring the efficiency of a Decision Making Unit (DMU) such as a firm or a public sector agency. According to Majid Zerafat Angiz L (2010) DEA is a powerful tool for assessing the performance of organizations and their functional units. DEA spans the boundaries of several academic areas including management science, operational research, economics and mathematics. The main idea is to evaluate the relative efficiency of a set of homogenous DMUs by using a ratio of the weighted sum of outputs to the weighted sum of inputs. It generalizes the usual efficiency measurement from a single-input, single-output ratio to a multiple-input, multiple-output ratio. This technique was originally introduced by Farell (1957) and popularized by Charnes, Cooper, and Rhodes (1978) (CCR model).

Data Envelopment Analysis (DEA) is an increasingly popular management tool. For a more in-depth discussion of DEA, the interested reader is referred to Seiford and Thrall (1990) or the seminal work by Charnes, Cooper, and Rhodes (1978). DEA is commonly used to evaluate the efficiency of a number of producers. A typical statistical approach is characterized as a central tendency approach and it evaluates producers relative to an average producer. In contrast, DEA compares each producer with only the "best" producers. By the way, in the DEA literature, a producer is usually referred to as a decision making unit or DMU. DEA is not always the right tool for a problem but is appropriate in certain cases. (See Strengths and Limitations of DEA.)

In DEA, there are a number of producers. The production process for each producer is to take a set of inputs and produce a set of outputs. Each producer has a varying level of inputs and gives a varying level of outputs. For instance, consider a set of Road Transport Corporations (RTC's). Each RTC has a certain number of buses, infrastructure, and a certain number of employees (the inputs). There are a number of measures of the output of a RTC, including number of passengers travelled, number of schedules operated, and so on (the outputs). DEA attempts to determine which of the RTC's are most efficient, and to point out specific inefficiencies of the other RTC. A fundamental assumption behind this method is that if a given producer, A, is capable of producing Y(A) units of output with X(A) inputs, then other producers should also be able to do the same if they were to operate efficiently. Similarly, if producer B is capable of producing Y(B) units of output with X(B) inputs, then other producers should also be capable of the same production schedule. Producers A, B and others can then be combined to form a composite producer with composite inputs and composite outputs. Since this composite producer does not necessarily exist, it is typically called a virtual producer.

The heart of the analysis lies in finding the "best" virtual producer for each real producer. If the virtual producer is better than the original producer by either making more output with the same input or making the same output with less input then the original producer is inefficient. The subtleties of DEA are introduced in the various ways that producers A and B can be scaled up or down and combined.

DEA is most useful when a comparison is sought against "best practices" where the analyst doesn't want the frequency of poorly run operations to affect the analysis. DEA has been applied in many situations such as: health care, education (ChuenTseKuaha and Kuan Yew Wonga, 2011), banks, manufacturing, law and order (Emmanuel Thanassoulis, 1995), benchmarking, management evaluation, fast food restaurants, retail stores and traffic safety (Elke Hermans et al., 2009). The analyzed data sets vary in size. Some analysts work on problems with as few as 15 or 20 DMUs while others are tackling problems with over 10,000 DMUs.

B. Strengths and Limitations of DEA

As the earlier list of applications suggests, DEA can be a powerful tool when used wisely. The major advantage of DEA is that, it can handle multiple input and output models which doesn't require an assumption of a functional form relating inputs to outputs. Also the inputs and outputs can have very different units as well. In DEA methodology DMUs are directly compared against a peer or combination of peers which is another advantage in using DEA. The same characteristics that make DEA a powerful tool can also create problems. An analyst should keep these limitations in mind when choosing whether or not to use DEA. Since DEA is an extreme point technique, noise (even symmetrical noise with zero mean) such as measurement error can cause significant problems. Also DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to "absolute" efficiency. In other words, it can tell you how well you are doing compared to your peers but not compared to a "theoretical maximum". Another disadvantage associated with DEA is that being a nonparametric technique, statistical hypothesis tests are difficult perform for which research is ongoing to overcome. Since a standard formulation of DEA creates a separate linear program for each DMU, large problems can be computationally intensive which makes DEA cumbersome.

C. Relative efficiency measurement

The measurement of relative efficiency where there are multiple possibly incommensurate inputs and outputs was addressed by Farrell and developed by Farrell and Fieldhouse, focusing on the construction of a hypothetical efficient unit, as a weighted average of efficient units, to act as a comparator for an inefficient unit.

A common measure for relative efficiency is,

$$= \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}$$

which introducing the usual notation can be written as

Efficiency of unit j = $\frac{\sum uY}{\sum vx}$

Where u_i = weight assigned to output variable y_i

y_i = amount of output variables

v_i = weight assigned to input variable x_i

x_i = amount of input variables

(Note efficiency is usually constrained to the range [0,1]).

The initial assumption is that this measure of efficiency requires a common set of weights to be applied across all units. This immediately raises the problem of how such an agreed common set of weights can be obtained. There can be two kinds of difficulties in obtaining a common set of weights. First of all it may simply be difficult to value the inputs or outputs. For example in the depot data the weights on the outputs presumably relate to the values or cost of producing the outputs but these costs or values may be difficult to measure. Alternatively different depots may choose to organise their operations differently so that the relative values of the different outputs may legitimately be different. This perhaps becomes clearer if an attempt has been made to compare the relative efficiency of schools with achievements at music and sport amongst the outputs. Some schools may legitimately value achievements in sport or music differently to other schools, and in general units may value inputs and outputs differently and thus require different weights. This measure of efficiency coupled with the assumption that a single common set of weights is required is thus unsatisfactory.

Data Envelopment Analysis (DEA) is a fractional linear programming based technique that has gained wide acceptance in recent times due to its effectiveness in comparing efficiencies of departments, sectors, organizations, etc

D. DEA- Models

Farrell introduces a framework for efficiency evaluation and measurement, which is subsequently studied by Charnes et al, Bankeret al. etc. The development of linear programming approach is known as DEA. The DEA model assumes that the random error is zero so that all unexplained variations can be treated as reflecting inefficiencies. The linear programming approach is flexible. It can measure input or output efficiency under the assumption of various types of constant returns to scale (CRS) and variable returns to scale (VRS).

E. CCR Model

The CCR model was developed by Charnes, Cooper and Rhodes. For any special DMUs, the CCR model with constant return to scale can be formulated as follows to obtain a score of technical efficiency:

$$Maximize\ W_0 = \sum_r U_r Y_{rjo}$$
$$Subject\ to\ \sum_i V_i X_{ijo} = 1$$
$$\sum_r U_r Y_{rj} - \sum_i V_i X_{ij} \le 0, j = 1, \dots . n$$
$$U_r \ge \epsilon, r = 1, \dots . s$$
$$V_i \ge \epsilon, i = 1, \dots \dots m$$

Where m is the number of inputs and s is the number of outputs

III. DATA AND EMPIRICAL STRATEGY

An efficient benchmarking procedure can sort out the issues in a loss making Transport Corporation for which a set of Road Transport Corporations (DMU's) are identified which deliver their service in almost the similar scenario. The general benchmarking methodology framed for Road Transport Corporations (DMU's) consist of:

a. Financial Analysis: A general DEA model is framed for financial analysis where major working parameter of DMU's measured in monetary terms are taken into account. The input variables selected are Salaries and wages, Fuel and Lubrication cost, Depreciation. The output variable is Operating Revenue. The analysis is carried out for each year separately, to calculate the relative efficiency and the most efficient DMU is identified.

b. Operational Analysis: The most efficient and inefficient DMU's identified in the above financial analysis is selected and another DEA model is framed to pinpoint the weak areas of the inefficient DMU. The input variables selected for this analysis are Number of Buses, Effective kilometers operated/day, Staff strength, Schedules and output variable is Annual profit.

c. Comparison of other efficiency parameters is done along with a financial statement analysis to frame recommendations and suggestions for the weaker one.

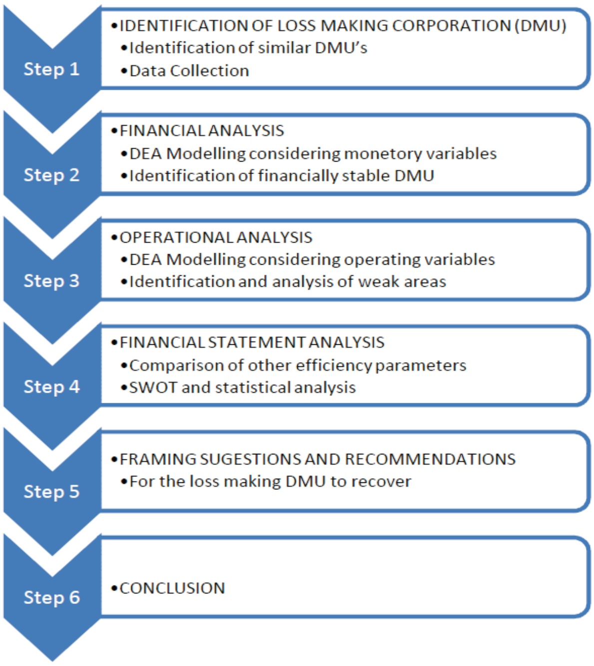

Fig 3.1 Analysis framework

A. DEA Frame Work- Financial Analysis

Finance is one of the major elements, which activates the overall growth of economy. Bottom line of any company is profit. So the objective becomes to maximize the revenue generated. Thus the profit measurement is one of the best means through which efficiency of an organization is measured. Many other factors like Customer satisfaction, Quality of service etc. get reflected in revenue- the final result. For model framed here is based on the very popular CCR model proposed by Charles, Cooper and Rhodes as discussed earlier.

Terms and Abbreviations

Input variables selected are Salaries and allowances (u_1), Fuel and lubricant cost (u_2) and Depreciation (u_3). While operating revenue (v) is selected as output variable. Weights corresponding to inputs u_1, u_2, u_3 and output v are denoted as x_1 x_2, x_3 and x_4 respectively. Suffixes m, n, o are used to identify among DMU's KSRTC, Karnataka RTC and TNSTC respectively.

Efficiency = (Weighted sum of outputs)/ (Weighted sum of inputs)

= $(x_4 v)/(x_1 u_1 + x_2 u_2 + x_5 u_3)$

DEA Model

DMU 1: Kerala Road Transport Corporation (KSRTC)

DMU 2: Karnataka Road Transport Corporation (Karnataka RTC)

DMU 3: Tamil Nadu State Express Transport Corporation (TNSETC)

The linear programming problem (as depicted below) is solved using TORA with the data collected through RTI Act (Right to Information Act, Constitution of India) and DMU 2 turned out to be most effective among the three and is selected for operational analysis

Financial Analysis model of DMU 1

$$Maximize\ Z = v_m x_4$$

Subject to

$$u_{1m}x_1 + u_{2m}x_2 + u_{3m}x_3 = 1$$
$$-u_{1n}x_1 - u_{2n}x_2 - u_{3n} \le 0$$
$$-u_{1m}x_1 - u_{2m}x_2 - u_{3m}x_3 \le 0$$
$$-u_{1o}x_1 - u_{2o}x_2 - u_{3o} \le 0$$
$$x_1, x_2, x_3, x_4 \le 0$$

B. DEA Frame Work- Operational Analysis

Terms and Abbreviations

Input Variables Selected are Number of Buses (u_1), Effective kilometers operated/day (u_2), Staff (u_3) and Schedules (u_4) while Annual Profit (v_1) is selected as Output Variable. Weights corresponding to inputs u_1, u_2, u_3, u_4 and output v_1 are denoted as x_1 x_2, x_3, x_4 and x_5 respectively.

Efficiency = (Weighted sum of outputs)/ (Weighted sum of inputs)

= $(x_5 v_1)/(x_1 u_1 + x_2 u_2 + x_3 u_3 + x_4 u_4)$

Data for operational analysis

TABLE 3.2 Operational analysis data

Serial No	Parameter	DMU 1	DMU 2
1	Annual Profit	- 7218 Lakh INR	4885 Lakh INR
2	Number of Buses held	6132	7599
3	Effective kilometers/day	14.38 lakh	24.91 lakh
4	Staff	30738	34019
5	Schedules	5567	6881

INR- Indian Rupees

Operational analysis model of DMU 1

$$Maximize\ Z = -7218x_5$$

Subject to

$$6132x_1 + 14.38x_2 + 30738x_3 + 5567x_4 = 1$$
$$-6132x_1 - 14.38x_2 - 30738x_3 + 5567x_4 - 7x_5 \le 0$$
$$-7599x_1 - 24.91x_2 - 34019x_3 + 6881x_4 + 4885x_5 \le 0$$
$$x_1, x_2, x_3, x_4, x_5 \ge 0$$

IV. RESULT AND ANALYSIS

While analyzing the results obtained from the DEA operation we can note that, in financial analysis it is clear that DMU 2 is the most consistent profit maker among the three road transport corporations. So we selected DMU 2 for the operational Analysis.

In the financial analysis results we can see that more relative weights are assigned to fuel and lubrication cost which seems to be more for DMU 1 when compared to the other corporations. From analyzing the past figures of DMU 1 we can see that the fuel consumption per passenger kilometer is shooting up consistently as shown in the figure that increases the annual expenditure considerably in the past decade.

TABLE 4.1 Result of Operational Analysis

Sl No	Parameter	DMU 1	DMU 2
1	Number of Buses held	$x_1 = 0.00001$	$x_1 = 0.00001$
2	Effective kilometers/day	$x_2 = 0.00001$	$x_2 = 0.00001$
3	Staff	$x_3 = 0.00003$	$x_3 = 0.00003$
4	Schedules	$x_4 = 0.00001$	$x_4 = 0.00001$
5	Annual Profit (2010-11)	$x_5 = 0.00001$	$x_5 = 0.00020$
6	DEA Efficiency	0	83.8%

In the operational analysis results we can see that more relative weights are assigned to two factors

1. Annual profit
2. Staff strength

When analyzing the staff allocation we can see that staff ratio per schedule is more for DMU 1 when compared with that of DMU 2 as shown in figure below.

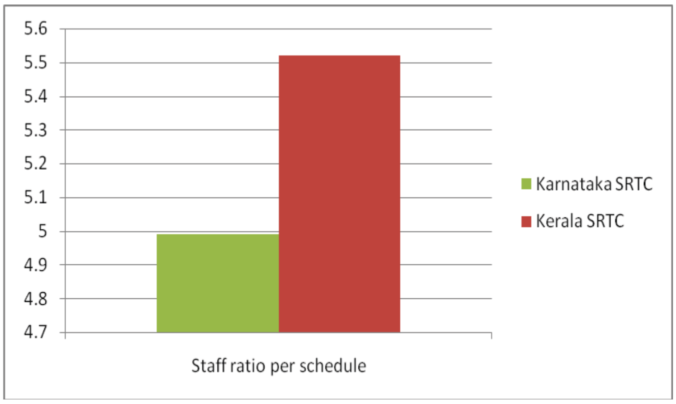

Fig 4.1 Staff ratio per schedule

The same can be identified when analyzing the average revenue per kilometer of the two corporations which is the major factor which determines the annual profit of the organizations

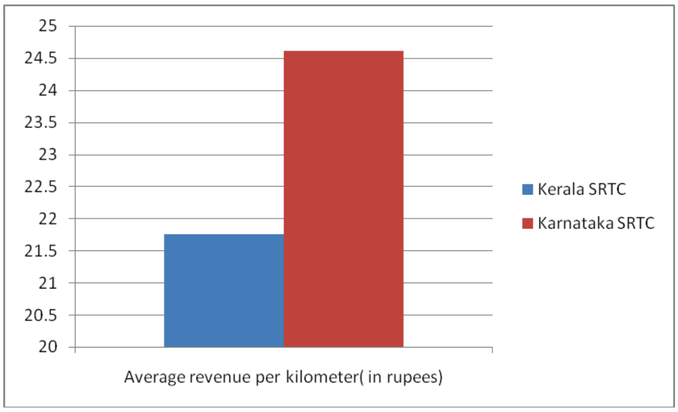

Fig 4.2 Average revenue per kilometer (in INR)

A. *Financial Statement Analysis*

The other major factor that came across on analyzing the financial statements of the company was the huge interest burden of DMU 1 when compared to the others as shown below.

TABLE 4.2 Interest remitted on loans (in Crore INR)

Sl. No	Year	DMU 1	DMU 2
1	2006-07	59.98	Not Available
2	2007-08	54.32	24.989
3	2008-09	71.86	31.66
4	2009-10	101.72	73.32
5	2010-11	Not Available	51.64
6	2011-12	Not Available	47.88

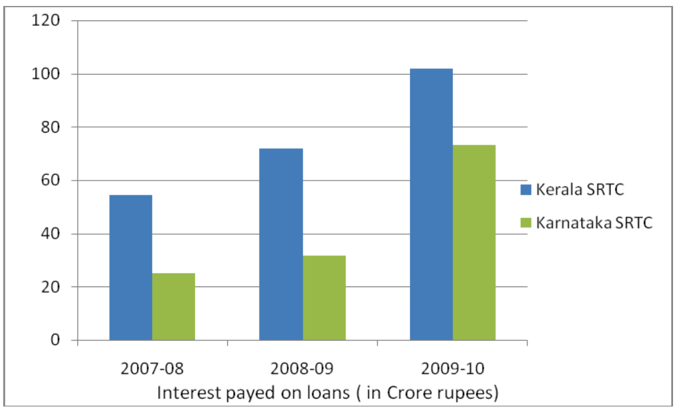

Fig 4.3 Interest remitted on loans (in Crore INR)

V. FINDINGS AND SUGGESTIONS

The finding of the analysis is summarized below that makes the DMU 1 inefficient. Various suggestions are also incorporated for the betterment of DMU 1.

A. Findings

The burden of Interest over various loans is huge.
The staff per schedule ratio is more when compared to DMU 2
Inefficient in fuel consumption
Break downs of buses are more
Average revenue per kilometer is less

B. Suggestions

With a view to improve efficiency in the operation of DMU 1 and to restore financial health of DMU 1, a number of measures have been suggested. Most of the measures are aimed at increasing revenue, controlling cost, and improving service quality. These initiatives are likely to have a positive impact on the performance of DMU 1.

Important suggestions are:

1) The government should provide with adequate financial incentives so as to enable the DMU 1 pay off outstanding debt (at least 50% outstanding loans) which improves financial viability of DMU 1. This will also help to improve services and infrastructures so as to compete with the private operators.
2) In fact, government should establish special institutional set up for funding DMU 1.
3) Proper maintenance of buses to decrease the frequency of breakdowns and to increase the fuel efficiency.
4) A dynamic Human Resource (HR) department should be set to monitor the efficiency of the employees and to determine required level in its strength.
5) Schedules of the buses must be properly planned since there is a general public comment that “DMU 1 buses are not reliable as its timing are concerned” which makes them prefer private operators. This will also increase the revenue per kilometer earned by DMU 1.
6) The government should impose the private operators for shared social obligations of connecting the rural areas with DMU 1. Otherwise, DMU 1 should adequately reimburse for fulfillment of such obligations.

VI. CONCLUSIONS

Based on the evaluation method the project may be concluded that the **Data Envelopment Analysis** has helped in analyzing the performance of various state road transport corporations (SRTCs). This is the first attempt for a DEA study on performance of road transport corporations that is carried out in two stages i.e. financial analysis stage and operational analysis stage. The strength and weaknesses of the organizations can be pinpointed by analyzing the relative weight distributions assigned to the variables considered in DEA models. As per the financial analysis DMU 2 is turned out to be best benchmark for DMU 1. Operational analysis and various statistical tools are then employed to pinpoint the areas of development that DMU 1 needs to concentrate to improve its standard. Various suggestions to improve the standards of DMU 1 is also framed and listed on the basis of the result obtained.

VII. SCOPE FOR FURTHER WORKS

The above study has identified the constraints of DMU 1 by adopting the technique of DEA, so there lies a scope of future work for framing strategies to lift those constraints, for which the recently evolved Theory of Constraints may turn up as an appropriate tool. Dr. Eliyahu Goldratt conceived the Theory of Constraints (TOC), and introduced it to a wide audience through his bestselling 1984 novel, “The Goal”. Since then, TOC has continued to evolve and develop, and today it is a significant factor within the world of management best practices.

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