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DEA Framework for Evaluating Efficiency of Public Transportation System

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***Abstract*— Public transportation is the most economically feasible and practical solution for urban mobility. Unlike private transportation, public transportation provides a mode of transportation that allows a greater number of passengers to travel together along scheduled routes. Bus service is one of the most widely accessible modes of public transportation, and it is also one of the least expensive. Evaluating its performance is important in determining the current scenario and improving efficiency of the transportation system. To assess its efficiency, the data envelopment analysis (DEA) method is used.**

Evaluating the performance of public transportation is important in determining the current scenario and improving efficiency of the transportation system. To assess its efficiency, the data envelopment analysis (DEA) method is used. Organizations in the manufacturing sector, as well as those in the service industries such as finance and education, among others, aim to figure out the most productive and effective use of what they have based on the productive effectiveness of decision-making units (DMUs) in solving linear programming and performance-related problems. In this case, data envelopment analysis (DEA) is a technique that has been widely used to solve optimization problems with various variables and their impact on the growth of the economy of those institutions.

The purpose of this study is to look into the use of data envelopment analysis (DEA) to evaluate the relative efficiency of decision-making units (DMUs) in the transportation sector.

Index Terms: Public transportation system, DEA, Efficiency measurement.

I. INTRODUCTION

The transportation sector is critical to the economic growth of a country. It is true that transportation is a key indicator of growth in the economy. Road transportation is the primary mode of transportation connecting many areas to the rest of the country. In India, the public and private sectors interact in terms of road transportation. Although the private sector plays an important role in passenger mobility, its day-to- day operations are separated and unorganized, whereas public transportation's operational activities are closely monitored and arranged. State Transport Undertakings (STUs), which are governed by each state's government, are the primary mode of passenger mobility in the public road transport sector.

It is critical to periodically track how they operate in order to identify appropriate measures; to enhance their overall efficiency. It can be hard to determine the particular sources needed to provide a specific service output in a service oriented organization such as a road passenger transit system. Efficiency evaluation is the first step in evaluating individual STU performance in the public transportation sector. Because the mathematical relationship between STU inputs and outputs is not well understood, STU efficiency can be quantified using Data Envelopment Analysis (DEA). It is a non-parametric linear programming model that estimates the magnitude of each STU's deviation from efficiency borders. This research is an attempt to evaluate the relative technical efficiency of State Road Transportation Corporation in Kerala.

II. RELATED WORKS

In the last three decades, using Data Envelopment Analysis (DEA) has been concerned about having enough Decision Making Units (DMUs) in comparison to the number of input and output variables. Several DEA studies have attempted to address this issue by providing additional procedures to increase the number of DMUs, decrease the number of vari- ables, or find a relationship between the number of DMUs and variables. However, when the Kourosh and Arash Method (KAM) is used, there are no concerns about the number of DMUs in comparison to the number of variables. A geometric reason is provided to demonstrate the method's validity in the absence of any additional conditions or methodologies. The method is straightforward and requires no special equipment.

The origins of efficiency or benchmarking can be traced back to Farrell's (1957) study, with Charnes et al. (1978) producing a measure of efficiency for decision-making units (DMU). One of the main approaches is based on the computa- tion of individual partial indicators that can be developed as ra- tios, such as the responsiveness of each healthcare system and the amount of resources expended. This paper sketches some of the major research directions in data envelopment analysis (DEA). The emphasis here is primarily on methodological advancements. Specifically, emphasis is placed on various models for measuring efficiency, approaches to incorporating multiplier

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restrictions, variable status considerations, and data variation modeling. [8]

Similarly Hahn.J.S, Kim H.R Kho S.Y. discusses A DEA Approach for Evaluating the Efficiency of Exclusive Bus Routes. Using data from Seoul's exclusive bus routes for the first half of 2008 and the DEA model, this study assumes the efficiency of each route. It is assumed in the estimation that the number of passengers and profits of each route are calculated by taking into account the number of buses and stops, travel distance, intervals, and management cost. Based on data from the first half of 2008 and one of the DEA models, the BCC model, this study calculated the efficiency scores of each bus line in Seoul. [3].

III. FRAMEWORK FOR CONDUCTING DEA

Data Envelopment Analysis (DEA) is a multi-facto productivity analysis model based on linear programming (LP) that measures the relative efficiency of a homogeneous set of Decision making units (DMU). It computes a maximum performance measure for each DMU in comparison to all other DMUs in the observed population, with the only requirement that each DMU be situated on or below the external frontier. Each DMU that does not exist on the outer boundary is brought against a combination of the DMUs closest to it on the border. The step-by-step methodology used for determining the technical efficiencies of transportation units is as follows.

A. Selection of Decision making units

The operational efficiency of selected 10 routes of a particular bus depot over a period of 3 months in 2022 in Kerala is selected as the Decision making units.

B. Selection of Inputs and Outputs

To evaluate the efficiency inputs and outputs selected are according to defined efficiency, and based on data availability.

- Time taken: The time taken for total trip ran by a buson a particular route.
- Vehicle-km: It is defined as the total distance traveled bythe bus on a particular route.
- Number of Stops: The maximum number of stops for aparticular route in one direction.
- Number of passengers: Defined as the average number of passengers using the service during a particular period.

TABLE I
INPUT AND OUTPUT VARIABLES

ROUTE	INPUT VARIABLES			OUTPUT VARIABLES
No:	***Time Taken(min)***	***Vehicle Km***	***No. of stops***	***Average Passenger***
R1	550	21022	17	1492
R2	1630	21960	29	10691
R3	1020	10022	40	5827
R4	1850	20234	20	3272
R5	855	10897	35	8481
R6	785	10930	36	9783
R7	965	12420	7	8126
R8	1015	11262	5	14202
R9	945	16472	25	13725
R10	690	8570	6	4282

C. Selection of DEA Model and software

The DEA model is of two types, Input oriented or output oriented. In input oriented model supply is compared with best efficient DMU and to minimize inputs and output oriented model maximizes the output. the model makes Variable returns to scale ,which means efficiency can be increased or decreased according to change in characteristics of input and output. As per VRS method if efficiency score found is 1 is always feasible solution to DEA model. If score is between 0.6 and 1 means fairly efficient . An efficiency score less than 0.6 indicates inefficient system. The ranks were obtained considering this score based on the peer counts(which is the number of times an efficient route acts as reference for inefficient routes).For conducting the analysis, input oriented model VRS model in WIN4DEAP2 software is used.

D. Calculating Technical efficiency

The use of Win4DEAP is illustrated below

1) *Enter basic input, output details (Fig. 1.)*

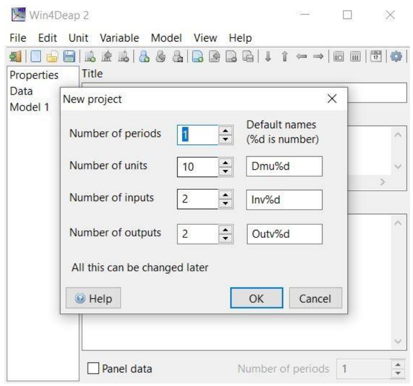

Fig 1. Entering basic data

2) *Import Microsoft Excel data into Win4DEAPs (Fig. 2.)*

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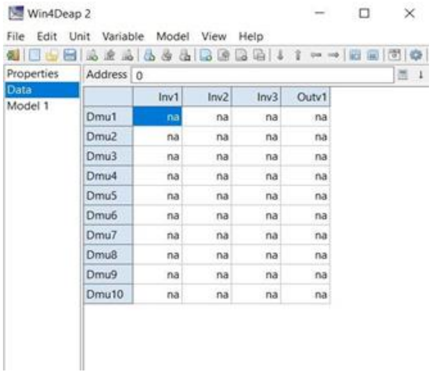

Fig 2. Import Microsoft Excel data

3) *Selecting the DEA model.*

To select a DEA model, the user has to click" model" shown on left side. Then window (Fig .3) will appear. The displayed window is called Win4DEAP cockpit window. From this window select whether we need input or output oriented model. After that select CRS or VRS model from returns to scale. Choose type of DEA analysis from calculate box.

4) *Running the DEA Model.*

Select how to generate the model result from "Report" as full report or summary. After that click on Report to generate the results

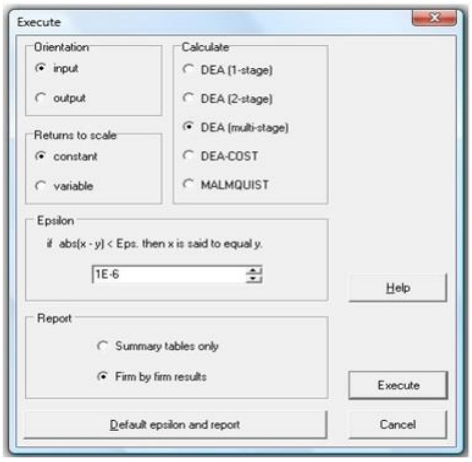

Fig 3. Win4DEAPs cockpit

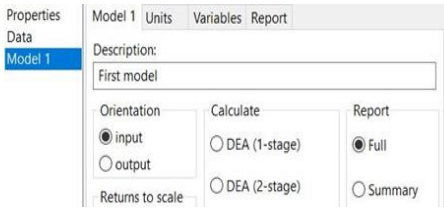

Fig 4. Win4DEAPs cockpit-Running DEA model

IV. Results and Discussion

A. Results

TABLE II
TECHNICAL EFFICIENCY AND PEER GROUPS

DMUs	Technical efficiency	Peer Groups
R1	1.000	R1
R2	0.534	R6 R8 R1 R10
R3	0.897	R8 R10
R4	0.424	R10
R5	0.925	R8 R10 R6
R6	1.000	R6
R7	0.844	R8 R1 R10
R8	1.000	R8
R9	1.000	R9
R10	1.000	R10

TABLE III
INPUT SLACK VALUES

DMUs	S1	S2	S3
R1	0.000	0.000	0.000
R2	0.000	0.000	0.000
R3	174.275	0.000	30.034
R4	93.557	0.000	2.471
R5	0.000	0.000	13.698
R6	0.000	0.000	0.000
R7	0.000	505.699	0.000
R8	0.000	0.000	0.000
R9	0.000	0.000	0.000
R10	0.000	0.000	0.000

TABLE IV
OUTPUT SLACK VALUES

DMUs	S1
R1	0.000
R2	0.000
R3	0.000
R4	1010.000
R5	0.000
R6	0.000
R7	0.000
R8	0.000
R9	0.000
R10	0.000

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B. Discussion

The results of the DEA model are shown in Table 2. To say that a route is efficient using this method, it should get a value of 1. Any value less than one indicates a discrepancy in the efficiency of the route's performance and clearly indicates a need for improvement. A total of 5 routes received an overall efficiency score of 1, indicating that these routes are maximizing the use of available resources. That is, the inputs considered here, such as the time taken for total trip ran by a bus on a particular route. the total distance travelled by the bus on a particular route, the maximum number of stops for a particular route in one direction are sufficient. According to the results obtained for the 10 routes surveyed, 5 need to improve their resources and activities in order to achieve greater efficiency. The findings clearly show a relative inefficiency in routes such as R2,R3,R4,R5,R7. Route 4 is the least efficient of the identified routes, with 42.4 percentage efficiency, closely followed by route 2 53.4 percentage This can be interpreted broadly as route 4 being able to support its activity levels with only 42.4 percentage of its resources. Furthermore, route 3 have an efficiency below 0.9, indicating a fair degree of discrimination. The technique used to solve each linear program attempts to maximize the efficiency of the target unit. The search procedure ends when either the efficiency of the target unit or the efficiency of one or more of the other units reaches the upper limit of 1.

DEA finds the closest efficient firms to each inefficient firm. These efficient firms are referred to as peer group in Table II. If inefficient route wants to improve their performance, they must examine the best practices developed by their peers. Since R1, R6, R8, R9, R10 has efficiency score 1 it is designated as the peer group for itself. Route 2 has peer groups of R6, R8, R1, and R10 which indicates that the projected point of route 2 on the efficient frontier lies between these benchmarks. Similarly for other routes.

The DEA model was used to calculate both input and output slack values, which indicate a further improvement, that is, the increase in output and/or decrease in input required for a unit to become efficient. Slacks are useful for recognizing the per- romance issues that is faced and providing a suitable path for improvement in order to achieve fully efficient performances. As a result, slacks are only seen on DMUs that perform inefficiently, indicating the remaining portion of inefficiency. Slack is required to push a DMU into efficient performance when it is incapable of reaching frontier efficiency. When the efficiency score on the VRS model is one, slack values on both input and output variables have zero value. Table III and table IV shows the input and output slacks values of the route performance.

From the results in Table 3 it can be found that the efficient input target value for time taken in route 4 is 93.557 units and approximate 2 in number of stops. It shows route 2 could 'produce' the same quantity of output with fewer inputs. The decreases in inputs 1 and 3 are equal to 57.6 percentages of the original values. Similarly in route with efficiency score less than 1. The variable discrepancy between constant output and input is represented by this value. The same is true for output slack, as shown in Table. 4 Similarly for other routes.

V. Conclusion

This paper has provided a synopsis of framework for conducting for assessing efficiency in the transport sector in Kerala using DEA. It has the advantage over other (para- metric) methods in that it can be used in multiple input, multiple output scenarios. The disadvantage is that there are no significance tests for comparing models or the efficiency scores of individual or groups of DMUs in their basic form. Developments of the DEA approach that attempt to address these shortcomings have been presented and illustrated using a data set of transportation routes. Improved performance may result from the proper time scheduling and assigning less number of stops in these routes to reduce input slacks in an inefficient STU. Inefficient routes have a great opportunity to change their practice patterns and become more like best running routes in order to significantly reduce their aggregate expenditures. To become technical efficient for technical inefficient routes, time utilization must be decreased. But this is not practicable in some situation since the road system is not only underdeveloped, but the roads that do exist are of poor quality, particularly in monsoon areas.

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