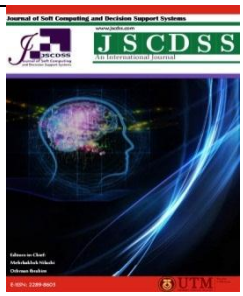
An International Journal
JSCDSS
http://www.jscdss.com
Vol.2 No.3June2015: 9-13
Article history:
Accepted 28April2015
Published online 28April2015

Journal of Soft Computing and Decision Support Systems



E-ISSN: 2289-8603

A DEA and Regression-based Financial Performance Evaluation Framework for Public Bus Transport

ArnabAdhikari [a,*], Indranil Biswas [a], Ashim Banerjee [b], ParthaPratim Sengupta [c], Sumanta Basu [d]
[a] Doctoral student, Indian Institute of management Calcutta, Operations Management Group, Diamond Harbour Road, Kolkata, India, 700104
[b] Officer, Public Vehicles Department, Government of West Bengal, Beltola Road, Kolkata, India 700020
[c] Faculty of Humanities Group, National Institute of Technology Durgapur, Mahatma Gandhi Road, Durgapur, India, 713209
[d] Faculty of Operations Management Group, Indian Institute of management Calcutta, Diamond Harbour Road, Kolkata, India, 700104

*** Corresponding author email address**: arnaba10@email.iimcal.ac.in

Abstract

This paper proposes a regression and DEA based financial performance evaluation frame work in the context of Kolkata, a metropolitan city of India. Now a day, performance of Kolkata bus transport is affected abysmal financial performance because of increasing cost and decreasing profitability. The lack of proper financial performance monitoring aggravates the situation. For this reason, devising a financial performance evaluation framework to capture the efficiency of different bus routes of Kolkata becomes order of the day. Here, we have investigated into the daily cost structure of a bus across the routes and identified the significant cost parameters using Multi Linear Regression (MLR) model. Next we have implemented a DEA model and determined the financial efficiency of different routes by taking significant cost parameters as inputs and revenue as output.

Keywords: Public Bus Transport, Performance Measurement, Efficiency, Data Envelopment Analysis, Multi Linear Regression

1. Introduction

An efficient public transport system is instrumental for any country's economic growth and social welfare. Public transport can be defined as the transport services offered to the general public at a fixed charge using different transit modes like buses, trains, ferries, and railways. Often public transport is criticized for the inefficiency. The lack of convenience and poor service compel passengers to select private mode of journey. The sky rocketing private transport aggravate problems like pollution, road congestion etc. So designing an effective public transport is an order of the day across the world.

Today's urban life is very much dependent on intra-city bus transport. In India, more than 60% of the passengers use public bus transport on regular basis (Phanikumar and Maitra, 2006).Specially, metropolitan cities like Kolkata, Delhi, Mumbai, and Chennai general public rely on intra city bus service very much for daily travel. In the context of Kolkata, performance of bus transport is affected by increasing cost, lack of inter-agency co-ordination, absence of regular system for performance monitoring, etc. Many a scholars suggest that the financial inefficiency stems from the absence of proper mechanisms to monitor the financial performance of different routes (Agarwal and Singh, 2010). It serves as a motivation for us to develop a financial performance evaluation framework.

Here, we have considered 18 routes under evaluation. The Data related to the daily cost structure and revenue of a bus along with the passenger concentration is provided by Public Vehicles department, Kolkata. In this paper, at first we have investigated into the daily cost structure of the bus. Using Multi Linear Regression (MLR) model, we have identified the cost parameters which have significant impact on the overall daily cost of a bus. As per our finding, driver wage, conductor wage, fuel cost, office running cost, Stationary cost, tyre cost, and servicing cost are the significant cost components which influence the cost structure. Next, we have employed a Data Envelopment Analysis (DEA) model to measure the financial performance by taking daily revenue of a bus as an output variable and aforementioned significant cost components as input parameters. Finally, we have identified the efficient and inefficient routes based on those performance measures.

This paper is organized as follows. In Section 2, we demonstrate the methodology regarding cost structure analysis and present the significant cost parameters in this

specific context. In Section 3, we describe the DEA model and describe the result of efficiency analysis. The paper is concluded by discussing contributions, research limitations, and future research avenues.

2. Cost Structure Analysis

In this section we present the proposed MLR model followed by the results obtained from the model.

2.1 Multi Linear Regression (MLR) Model

The investigation into the data regarding daily cost reveals that it contains several components which can be considered as cost incurred as monthly or yearly basis and don't have any direct impact on the total daily cost. We have defined these costs as 'Fixed Cost'. On the other hand, the cost that a bus incurs on daily basis is termed as 'Variable Cost'. After this classification, we have considered only variable cost parameters for our analysis. Next, we assume that there exists Multiple Linear Relationship (MLR) between overall daily cost and variable cost given in data sheet whereas daily cost and variable costs are considered as dependent variable and independent variables, respectively. Here, Table 1 describes the classification along with the corresponding variable names assigned to the variable costs. Table 2 represents the descriptive statistics of different cost components incurred by a bus in different routes, respectively.

Table 1
Classification of cost structure.

Variable	Cost Description	Nature of the cost
	Administrative staff cost	Fixed
	Education, welfare, medical fringe benefit cost	Fixed
	Rent and taxes (vehicle & permit)	Fixed
	Insurance	Fixed
	Maintenance	Fixed
	Route cost	Fixed
	Case charges	Fixed
	Bata	Fixed
	Bank EMI	Fixed
	Depreciation cost	Fixed
$x1$	Office running cost	variable
$x2$	Stationary cost	variable
$x3$	Driver wage	variable
$x4$	Conductor wage	variable
$x5$	Helper wage	variable
$x6$	Servicing cost	variable
$x7$	Fuel cost	variable
$x8$	Tyre Cost	variable
z	Total daily cost incurred by a bus	variable

Table 2
Daily Descriptive Statistics of different cost components

Cost Description	Maximum	Minimum	Standard Deviation	Average
Administrative staff cost	55	45	2.81	50.00
Education, welfare, medical fringe benefit cost	25	20	1.54	20.28
Rent and taxes (vehicle & permit)	75	50	7.86	53.89
Insurance	135	120	5.94	122.83
Maintenance	90	70	7.99	75.28
Route cost	975	10	329.81	801.83
Case charges	970	210	199.17	579.17
Bata	55	40	5.91	42.78
Bank EMI	20	10	3.66	11.11
Depreciation cost	20	10	3.35	11.39
Office running cost	25	20	1.54	20.33
Stationary (tickets)	40	10	10.99	13.33
Driver wage	720	583	56.58	659.17
Conductor wage	900	350	174.57	443.78
Helper wage	385	240	47.48	285.00
Servicing	275	15	90.97	55.33
Oil	2700	2000	232.19	2336.11
Tyre	75	25	20.12	52.00
Total daily cost	6025	5220	254.65	5633.61

An International Journal JSCDSS E-ISSN: 2289-8603

Table 3
Goodness of fit statistics.

Description	Value of the output
Sum of square of Model	894166.33
Sum of square of Residual	13689.94
Total Sum of square	907856.28
Degree of freedom of Model	8
Degree of freedom of Residual	9
Total degree of freedom	17
Mean square of Model	111770.79
Mean square of Residual	1521.10
Total Mean square	53403.31
F(8, 9)	73.48
R-square	0.98
Adjusted R-square	0.97

Now, the MLR equation between independent variable and dependent variables can be expressed in the following way:

$$z = \alpha_0 + \sum_{i=1}^{8} \beta_i x_i + \varepsilon \qquad (1)$$

α_0, β_i, ε designate constant of the regression model, regression coefficient of corresponding cost variable, and random error part, respectively.

2.2 Result of cost structure analysis

We have performed the MLR analysis with the help of software stata for the 18 bus routes of Kolkata. The Goodness of fit statistics is demonstrated in the Table 3. Table 4 represents the regression coefficients of the dependents value and corresponding P-value.

From the adjusted R-square value, it can be inferred that that our regression model is able to explain 97 % of the variation of the data. This high adjusted R-square value justifies our regression modelling technique. From the p-values presented in Table 4, it is evident that apart from $x5$ i.e. Helper wage, every variable costs are significant. So, we use all variable cost except helper wage as input parameters, presented in the next section.

Table 4
Value of regression coefficients and corresponding P-value for cost variables.

Variable	Value of co efficient	Corresponding P-value
Constant	3042.128	0.000
$x1$	54.39326	0.001
$x2$	-352.0908	0.000
$x3$	.876926	0.045
$x4$	1.143187	0.000
$x5$	1.177024	0.170
$x6$	40.62439	0.000
$x7$	1.142984	0.000
$x8$	-3.053885	0.017

3. Efficiency Analysis

In this section at first we demonstrate the DEA model. Subsequently, we present the efficiency result determined by the DEA model

3.1 Data Envelopment Analysis (DEA) Model

In this section, at first we present the proposed DEA model to measure efficiency of different routes. DEA can be defined as a non- parametric mathematical technique for computing the relative efficiency of decision making units (DMUs) in a peer group. These DMUs employ one or multiple inputs for producing one or multiple outputs. Examples of DMUs are organizations, hospitals, business units, individuals etc. The efficiency of a DMU can be determined with the help of appropriate input-output ratio. The DMUs with highest efficiencies are considered as benchmark and form the efficient frontier. All other DMUs are evaluated against this efficient frontier. Charnes et al. (1978) first brought the idea of DEA in the context of engineering field. Scholars like Farahmand et al. (2014) and Farahmand et al. (2015) have performed comparative study of CCR models and adopted mixed approach of regression and DEA analysis, respectively. Exploration of literature related to transportation reveals the presence of significant number scholarly works that involve application DEA for efficiency measurement for urban public bus transport system in different country context like US, Malaysia, Spain etc. (Pina and Torres, 2001; Karlaftis, 2004). To measure the performance of the bus routes from

An International Journal JSCDSS E-ISSN: 2289-8603

financial perspective, we have taken following output and input measures in our DEA model, listed in table 5.

Table 5
Description of Input and Output variables.

	Routes
Input measures	1. Office running cost 2. Stationary cost 3. Driver wage 4. Conductor wage 5. Servicing cost 6. Fuel cost 7. Tyre Cost
Output measures	1. Net revenue per bus per day

Next we present the general DEA framework. We have designed it in all possible approaches i.e. fractional programming (FP), Linear Programming (LP), and dual of this Linear Programming (LP). The fractional programming approach is described in the following manner:

Let, there be n DMUs (i.e., n routes) each having m inputs to produce s outputs. Let, x_{ij} denotes the value of the i^{th} $(i=1, 2, 3,.., m)$ input for the j^{th} DMU $(j=1, 2, 3,.., n)$ and similarly, let y_{rj} denotes the value of the r^{th} $(r=1, 2, 3,.., s)$ output for the j^{th} DMU $(j=1, 2, 3,.., n)$. Let, the DMU_j being evaluated on any trial is designated as DMU_{jo}. To determine the relative efficiency θ_0 of DMU_{jo}, we need to solve the DEA model (FP) with the help of one comparative set of weights of inputs $(v_i, i=1, 2, 3, \ldots, m)$ and another comparative set of weights of outputs $(u_r, r=1, 2, 3,.., s)$. To avoid the appearance of zero weights, a positive Archimedean infinitesimal constant $\in$ is used. With the help of these, DEA model (FP) can be formulated as follows:

Model1 (FP)

$$\max \theta_0 = \left(\frac{\sum_{r=1}^{s} y_{r0} u_r}{\sum_{i=1}^{m} x_{i0} v_i} \right)$$

Subject to

$$\frac{\sum_{r=1}^{s} y_{rj} u_r}{\sum_{i=1}^{m} x_{ij} v_i} \le 1 \qquad j=1, 2, 3, \ldots, n,$$

$$u_r \ge \in \quad r=1, 2, 3, \ldots, s,$$

$$v_i \ge \in \quad i=1, 2, 3, \ldots, m.$$

Now, this model 1(FP) can be transformed into a linear programming problem (LP) using some algebraic manipulations:

Model 2 (LP)

$$\max \theta_0 = \sum_{r=1}^{s} y_{r0} u_r$$

Subject to

$$\sum_{r=1}^{s} y_{rj} u_r - \sum_{i=1}^{m} x_{ij} v_i \le 0 \qquad j=1, 2, 3, \ldots, n,$$

$$\sum_{i=1}^{m} x_{i0} v_i = 1$$

$$u_r \ge \in \quad r=1, 2, 3, \ldots, s,$$

$$v_i \ge \in \quad i=1, 2, 3, \ldots, m.$$

Now, dual form of this LP is expressed in model 3, where λ_j denotes the corresponding weight of DMU_j

Model 3 (Dual-LP)

$$\min \theta_0$$

Subject to

$$\sum_{i=1}^{m} x_{ij} \lambda_j \le \theta\, x_{i0} \qquad i=1, 2, 3, \ldots, m,$$

$$\sum_{i=1}^{m} y_{rj} \lambda_j \le y_{r0} \qquad r=1, 2, 3, \ldots, s,$$

$$\lambda_j \ge 0$$

3.2 Result of efficiency analysis

To determine the efficiency of different routes in Kolkata, we have used DEAP V2.1, DEA software by Coelli (1996). Primarily, we have started our analysis by taking 23 routes have been under evaluation. Due to the presence of missing data and data inconsistency, we have to restrict our efficiency analysis up for 18 routes. The route description along with efficiency results are described in Table 6.

An International Journal JSCDSS E-ISSN: 2289-8603

Table 6
Route description and corresponding efficiency result.

No	Route name	Distance (in kms)	From	To	Efficiency
1	L3E	21	Esplanade	Amtala	1
2	C-16	16	Gallif Street	Garia Station	1
3	C-4	16	Joka	Patuli	0.96
4	101	12	Garia	B.B.D Bag	0.989
5	13 B	40	Rabindra Nagar	Salt Lake	1
6	77B	44	Esplanade	Batanagar	1
7	12C	31	Howrah Station	Pailan	0.993
8	77	35	Esplanade	Achipur	1
9	77A	52	Esplanade	Birlapur	1
10	257	12	Thakurpukur	Dharmatala	1
11	S-8	26	Thakurpukur	Howrah Station	0.963
12	S-4	22	Taratala State Bus Depot	Howrah Station	0.942
13	S-3	11	Nagerbazar	Esplanade	0.928
14	45	31	Dum Dum Airport	Padmasree Cinema	0.995
15	45A	45	Dum Dum Airport	Garia Station	0.996
16	45B	14	Sealdah	Garia Station	0.997
17	219	17	Nagerbazar	Howrah Fire Station	1
18	28	29	Amdanga	Khanna Cinema	0.981

As per the result, 8 among the 18 routes under evaluation are efficient whereas other routes come out as inefficient ones. High fuel consumption due to congested roads, poor maintenance, and presence of higher number of buses compared to the demand often affects the profitability of the buses, which, in turn, bring down the efficiency of the routes.

4. Conclusion

The paper ends with this section by discussing the contribution, limitations, and future research avenues.

4.1 Contribution

In case of efficiency analysis, often input parameters are chosen without giving any proper rationale. Our method presents a regression based proper scientific method to select cost input parameters. It improves the robustness of overall performance assessment procedure. In addition, this model involves less complexity in efficiency computation.

4.2 Limitation

In this paper, we have employed Multi Linear Regression for daily cost structure whereas incorporation of translog cost function in case of yearly statistics can yield to better result. Also, application of advanced DEA approaches like Semi Oriented Radial Measure, Modified Slack based measure, and Translation Invariant model can enhance the rigour of the proposed method.

4.3 Future research avenues

From future research opportunities point of view, it will be a matter of interest for scholars to capture financial, operational and service efficiency with the help of modified DEA model. Also, long term impact of fixed costs, bus routes performance measurement for longer time span, measurement of environmental performance through emission factor can be other research avenues.

References

Agarwal, P. and Singh, A. (2010).Performance improvement of urban bus system: issues and solution. International Journal of Engineering Science and Technology, 2(9), pp. 4759–4766.

Charnes, A., Cooper, W W. and Rhodes, E. (1978).Measuring the efficiency of decision making units. European journal of Operational research, 2(6), pp. 429-444.

Coelli, T. (1996). A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. Centre for Efficiency and Productivity Analysis, University of New England, Australia.

Farahmand, M., Desa, M. I. and Nilashi, M. (2014).A Combined Data Envelopment Analysis and Support Vector Regression for Efficiency Evaluation of Large Decision Making Units. International Journal of Engineering & Technology, 6(5), pp. 2310-2321.

Farahmand, M., Desa, M. I. and Nilashi, M. (2015). A Comparative Study of CCR-(ε-SVR) and CCR-(ν-SVR) Models for Efficiency Prediction of Large Decision Making Units. Journal of Soft Computing and Decision Support Systems, 2(1), pp. 8-17.

Karlaftis, M. (2004). A DEA approach for evaluating the efficiency and effectiveness of urban transit systems. European Journal of Operational Research, 152(2), pp. 354–364.

Phanikumar, C. and Maitra, B. (2006).Valuing urban bus attributes: an experience in Kolkata. Journal of Public Transportation, 9(2), pp. 383-389.

Pina, V. and Torres, L. (2001). Analysis of the efficiency of local government services delivery. An application to urban public transport. Transportation Research Part A: Policy and Practice, 35(10), pp. 929–944.

PTI. Kolkata: Private bus operators on strike; fare hike demanded. http://www.ndtv.com/kolkata-news/kolkata-private-bus-operators-on-strike-fare-hike-demanded-546935[14 April, 2015].

An International Journal JSCDSS E-ISSN: 2289-8603