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EFFICIENCY ANALYSIS OF PUBLIC TRANSPORT IN LAHORE, PAKISTAN

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Abstract

Public transport has been a focus of financial allocations in Pakistan for which the efficiency of performance of these projects should also be brought under consideration. Accordingly, this study focus on resource allocation and its impact on transport system of the city of Lahore, by estimating the efficiency and productivity of franchise based bus service on 15 selected urban public routes of the city. Data of input and output is used from July 2013 to March 2014. Using the data envelopment analysis (DEA) the study finds relative technical efficiency scores of different routes and total factor productivity (TFP) under the first stage DEA. Further, under the second stage DEA analysis, the route-wise targets and slacks of inputs and outputs are examined. The results imply that the public transport sector of Lahore is performing satisfactorily, mainly due to the improved managerial efficiency. Based on this empirical work, recommendations have been made at the end of the study.

Key Words: Technical Efficiency, DEA, VRS, CRS, 2nd Stage DEA, Malmquist Productivity Index.
JEL Classification: C61, C67, D24, D61, H42.

I. Introduction

A competent and well performed urban public transport is a need of the day in Lahore city, which is a second largest metropolitan city of Pakistan, and also a capital of the province of Punjab. According to the current popular estimates its population has increased from 6.3 million in 1998[1] to about 10 million. Its boundaries have extended up to an area of 1,772 square km.[2] Owing to an industrial and commercial importance of the city people from the surrounding areas/towns come here in large number, for the sake of education and for earning their livelihood. Urban public transport facilitates

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[1] As per the last National Census (2017).

[2] Worldpopulationreview.com

the movement of people, stimulate employment, create wealth and allow development. It also plays its role in developing and enhancing the regional, social and cultural characteristics by supporting their mutual interaction and collaboration. It contribute in pro-poor policies by providing low price travelling for its citizens, specifically those who cannot afford to live in the expensive heart areas of the city and are compelled to live at the far flung cheaper areas.

Public transport has been a focus of governments' financial allocations in order to accommodate its continually rising demand. Presently, with the government designated rights, the well organized large buses owned by various private bus operators[3] are providing the public transport service on 27 operational high occupancy vehicle (HOV) routes of Lahore.[4] It may be mentioned that all large buses in operation, mazdas and mini-vans are owned by private owners; and the Lahore Transport Company (LTC) is functioning as a regulatory authority only. This study conducts a performance evaluation of large buses on their designated 15 selected HOV routes. Instead of mini-vans, the large buses provide a comfortable and safe travelling mode. Meanwhile, large buses can distinctively carry a greater number of passengers. It is anticipated that this performance evaluation will provide decision-makers with operational insights as to how to improve the performance of the network as a whole.

1. Objective of the Study

This research work provides insight on two aspects of performance, i.e., technical efficiency and productivity growth evaluations for large bus service on different operational HOV routes of the Lahore city. Meanwhile, by identifying targets and slacks, the study also explores the extent of deficiency or excess of the input and output variables over the period of nine months. Rest of the paper is organized in the following way. Section II briefly review the related literature. Section III explains the selected input and output variables. Section IV presents input-oriented DEA model, two-stage DEA slack model, Malmquist Productivity Index equation that are used in the present study. Results and interpretations are presented in Section V. The final section VI concludes the findings and recommendations of the study.

II. Literature Review

Efficiency related aspects of transport sector, like transit agencies, bus routes and regional transit setups have been analyzed by many countries. On the other side, transport studies in Lahore are very few and mostly capture the confronted challenges, like

[3] These are 11 different private bus operators out of which 5 are foreign operators, i.e., Platform Turizm, PakOz, Foton, Daewoo Express and Pak or Global. Remaining are local bus operators, i.e., Bajwa Brothers, First Bus, Shaheen Ways, Bandial Transport, Askar Metro, etc.

[4] Lahore Transport Company (LTC).

congestion and environmental aspect in a theoretical manner. A brief insight related to these studies is presented here. Karne and Venkatesh (2003) analyze the efficiency, financial performance and productivity of the state transport setups of an Indian city Maharashtra, by dividing it into six regions. The study concludes that under technical efficiency analysis four regions have shown improvement in the year of 2001-02 and also found that during this time span, increasing return to scale situation existed in most of the regions. Besides, under the evaluation of total factor productivity change, it found only 1.1 per cent improvement over the considered time span of 1995 to 2002. Karlaftis (2004) analyzed 256 urban transit systems of USA over the period of four years 1990 to 1994. His efficiency based estimations suggested that the system of approximately 550 vehicles was of optimal size, while effectiveness based estimation indicated that the system of 150 vehicles was of optimal size. All remaining groups of system appeared to be operating under varying degrees of increasing returns to scale. He concluded that economies of scale greatly depended on the output specification. Agarwal (2009) investigated the efficiency aspects of public transport zone of rural, urban and hill areas of India in the time period of 2004-05 to 2007-08. Results of the study depicted that among the efficiency scores of 29 STUs, there existed a large variation and disparities. In the performance realm, these STUs had a declining trend in the former three years and then reflected an increasing trend in the last year of calculation. Besides, only 3 STUs showed high productivity and the remaining STUs had potentials for improvement.

Sheth, et al. (2007) evaluated performance under both the passengers and provider's perspective for 60 bus routes of Blacksburg transit, Virginia. It found that under VRS assumption the services of eight bus routes # 31, 33, 34, 35, 40, 42, 51 and 52 were inefficient. They concluded that higher efficiency results occurred under the VRS assumption as compared to CRS assumption in all 60 bus routes. Berhan, et al. (2013) investigates the performance of 93 bus routes of a government owned public transit system of Addis Ababa. This study assessed the financial and operational performance level at that time, by achieving both the secondary and primary data of nineteen months for the time period of 2010 to 2012. By comparing performance variables with the international standards, it found that all parameters were working significantly low. Besides, it also found that this transit system had a high operating cost as compared to its traffic revenues. This study suggests that in order to improve the ridership, dead mileage, fleet utilization and vehicle-kms, there should be a proper scheduling along with appropriate assignment of buses by considering the passenger demand of various routes and should also strategically devise ways to replace the old buses with the new ones.

JICA[5] (1991) presented a comprehensive study on Lahore transportation. Its main objectives were to present feasibility studies of the selected mass transit plans of that time and to make other transportation master plans up to the time of 2010 by delineat-

5 Japan International Cooperation Agency.

ing its intermediate action plans till 2000. Under these findings the study proposed various new roads, different road projects like parking measures, new bridges, flyovers and bus priority measures, etc. This study also presented the mass transit plan for both the rail and roads as well as by their specific mode interchange points. Imran and Nicholas (2003) examined the promotion of sustainable urban transport in the city of Lahore. On the basis of guided principles, indicators were selected in relation to the categories of environment, economic, social, transport activity and town planning. The study concludes that although efforts have been made in the realm of congestion reduction and environmental policy formulation, etc., but these steps did not cover all the credible aspects relating to sustainability. Jamal, et al. (2012) inspected compatibility and deficiency of transport arrangements in Lahore. They found that main issues ignored were the land-use planning and its integration with transport planning. Construction of roadways and traffic management was not being maintained with the increased mobility requirements of the society.

JICA (2012) final report is about Lahore Urban Transport Master Plan (LUTMP). According to its three main suggested strategies; firstly it proposed the Trunk Public Transport with three urban rail projects (RMTS[6]) and seven BRT lines over the core networks of Lahore. Along with these, the study clarifies that buses still serve as secondary and feeder service provider in the remaining areas of Lahore where MTS service remain inaccessible. Secondly, the study recommends the need to widen the capacity of existing roads to cope up the rapidly growing population and the GDP. Thirdly, the study strongly suggest an urgent need to get better the traffic management, especially in centrally located densely populated areas. In this realm the study presented a combination of various projects, like minor road improvement, parking management, pedestrian/bicycle path development, junction redesigning, etc. Javid, et al. (2013) evaluated the preferences and satisfaction of passengers through public transportation by comparing distinct modes, particularly considering the para-transit, i.e., wagon and mini buses as a case study in Lahore. They conducted a questionnaire survey and developed structural models for preferences to make use of public transport and satisfaction. Structural model of satisfaction reveals that travelers' satisfaction is positively related to enhancement of functional and symbolic factors. Functional factors include punctuality, convenience, service frequency and route coverage. Symbolic factors include vehicle physical condition, information and staff attitude, safety and comfort. The level of commuters' satisfaction have tendency to decrease with an increase in time factors and cost; they name it as time and cost factor. They concluded that focal steps are needed for wagon service to upgrade the service quality.

Anjum and Hameed (2013) analyzed the administration and operation of private bus companies in Lahore, under franchise plan of the government of Punjab and the environmental performance of these buses. They concluded that extreme rush of passengers, inadequate maintenance of system, insufficient training of bus drivers and

6 JICA recommended three RMTS projects, namely, the green line, orange line and blue line, upto the year of 2030.

outdated engine technology causes bus air pollution. Mirza, et al. (2013) evaluated the aspects of a sustainable road traffic patterns by considering two main junctions of Chouborji and Yateem Khana which are located on the key radial Multan road Lahore. They identified the type of traffic flow, its intensity, volume and different adjoining land use characteristics with the purpose to provide information for future policy formation. Javid, et al. (2014) examined the travel behavior patterns by considering relationship between socio-economic demographics (SEDs) and travel demand management (TDM) in Lahore city. By conducting a cross sectional analysis among the four different traffic mode shares; they found that the most influential factor which positively influence the usage of car ownership is higher education level, while other factors like gender, income and the current travel mode also affect TDM in different ways. The Lahore transport studies do not estimate the efficiency aspects and to fill the gap, this study evaluates the efficiency and productivity performance of Lahore urban transport to examine the operational flaws and in turn the extent of needed improvements.

III. Data of the Study

Data used for the empirical analysis consists of franchise based large bus services of HOV bus routes. Out of 27, data on 15 HOV bus routes was available for empirical testing. Few reasons for not including the remaining bus routes are: unavailability of computerized data, irregularity of the provided services, beginning of bus services by new operators, etc. The data was collected from the two sources, i.e., private operators[7] and LTC. Owing to some newly established bus operators, data had to be restricted for the time period of 9 months only, i.e., July 2013 to March 2014. This study intends to analyze the category of service efficiency from the provider's standpoint. In light of the reviewed literature, and as per availability of data, the list of selected inputs and output variables are as follows:

List of Inputs	
Operational Buses	*Average Headway (minutes)*
The total numbers of buses that run on a particular route are called operational buses. This variable also denotes the capital input provided by the respective private operators on a specific route.[8]	It is the time difference between two consecutive service vehicles on a route. Its reciprocal is a measure of the service frequency of the route. This variable is averaged over the entire route to accommodate different headways on different segments of the route.[9]

7 List of the selected bus routes and their corresponding operators is given in Appendix, Table A-1.
8 Hawas, et al. (2012), Agarwal, et al. (2010).
9 Sheth, ei al. (2007), Hahn, et al. (2011).

Total number of Bus Stops The bus stops on a particular route facilitate the passengers to ride in the bus with the nearest possible located bus stop.[10]	*Fuel Consumption* The total fuel consumed (either in the unit of CNG KG or diesel liters) in running the operational buses. This variable shows the material input.[11]
List of Outputs	
Vehicle-kilometer It is total of the kilometers traveled by all the operational buses on a specific route. So, this variable is a demonstration of the transit efficiency which gives the estimation of produced output.[12]	*Passenger ridership* This variable presents total number of passengers who travel through these bus services. It denotes the transit effectiveness by estimating service utilization which is a demand side indicator.[13]

Source: Authors' compilation.

IV. Methodology

Being a service business, the estimation of an accurate production function is not possible for urban public transport [Agarwal (2009)]. Since it does not demand any assumption about the parameters of production function, a non-parametric Data Envelopment Analysis (DEA) technique is suitable in this case. DEA deals with the decision making units (DMU) that can be a production process or entity, or a system that is urban public bus route in this analysis. Basically, DEA is a mathematical technique to measure the relative technical efficiency of similar DMU by allowing inclusion of multiple inputs and outputs through a linear programming analysis [Sheth, et al. 2007)].

Under the model formulation, the efficiency of bus routes is evaluated by using the goal of input minimization. This input-oriented view is used because demand or the quantity demanded of public transport is not controllable by the DMUs (bus routes). According to Banker, et al. (1984), the following mathematical model is an input-oriented model where inputs are minimized and outputs are kept at their current levels. The model is,

$$
\begin{aligned}
&\theta^* = \min \\
\text{Subject to}\quad &\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{io} && i = 1,2,\ldots,m; \\
&\sum_{j=1}^{n} \lambda_j x_{rj} \ge y_{ro} && r = 1,2,\ldots,s; \qquad (1) \\
&\lambda_j \ge 0 && j = 1,2,\ldots,n.
\end{aligned}
$$

10 Hahn, et al. (2009), Hahn, et al. (2011), Hawas, et al. (2012), Lao and Liu (2009).
11 Agarwal, et al. (2010), Contreras-Montoya, et al. (2001).
12 Karlaftis (2004), Agarwal, et al. (2010), Hahn, et al. (2011).
13 Barnum (2008), Agarwal, et al. (2010).

where DMU_o represents one of the *n* DMUs under evaluation and, x_{io} and y_{ro} are the *ith* input and *rth* output for DMU_o, respectively. λ_j are the weights. θ^* which represents the (input-oriented) efficiency score of DMU_o. If $\theta^* = 1$, then the current input levels cannot be reduced (proportionally), indicating that DMU_o is on the frontier; otherwise, if $\theta^* < 1$, then DMU_o is dominated by the frontier.

The output obtained from the 1st stage DEA is in turn used as an input estimate at the 2nd stage DEA. The 2nd stage DEA evaluates that input and output slacks which means an excess input or missing output which exist even after the proportional change in input or outputs [Hayes (2005)]. Resultantly, slacks improvements help in pushing a DMU towards efficient frontier [Zhu (2014), Zhang (2010)]. An input-oriented two-stage DEA model is as follow:

$$\begin{aligned} &\text{M} && \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{n} s_r^+\right) && \\ & && \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{io} && i = 1,2,\ldots,m; \\ &\text{s.t.} && \sum_{j=1}^{n} \lambda_j y_{rj} - s_i^+ = y_{ro} && r = 1,2,\ldots,s; \\ & && s_r^+ \geq 0;\ s_i^- \geq 0;\ \lambda_j \geq 0 && j = 1,2,\ldots,n. \end{aligned} \tag{2}$$

where coefficients of λ represents that weights and θ stands for an optimal efficiency score of first the stage, ε is an infinitesimal non-Archimedean constant smaller than any positive real number. In this model, DEA slack are s_i^- and s_i^+ which represents the input and output slacks, respectively. Negative signs in superscript of input slack represent the need to curtail down the input resources. Besides, positive sign in superscript of the output slack reflects that output level should be enhanced [Afsharian and Ahn (2014), Pastor and Lovell (2005), Färe, et al. (1994).

This study also conducts the Malmquist Productivity Index (MPI) analysis that assesses the total factor productivity (TFP) change over the time. The MPI is estimated by incorporating 'distance function' for the two consecutive points of time period 't' and, period 't+1'. In order to avoid randomness in the benchmark selection the above two time intervals MPI equations can be combined as the following geometric mean [Halkos and Tzeremes (2006)].

$$M_I\,(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D_I^t(x^{t+1}, y^{t+1})}{D_I^t(x^t, y^t)} \times \frac{D_I^{t+1}(x^{t+1}, y^{t+1})}{D_I^{t+1}(x^t, y^t)}\right]^{1/2} \tag{3}$$

$$\Rightarrow MPI_I = \frac{D_I^{t+1}(x^{t+1}, y^{t+1})}{D_I^t(x^t, y^t)} = \left[\frac{D_I^t(x^t, y^t)}{D_I^{t+1}(x^t, y^t)} \cdot \frac{D_I^t(x^{t+1}, y^{t+1})}{D_I^{t+1}(x^{t+1}, y^{t+1})}\right]^{½} \quad (4)$$

where, *I* in subscript, presents input-orientation and D represents the input distance function, M is productivity of the most recent production point (x^{t+1}, y^{t+1}) 'using period $t+1$ technology' relative to the earlier production point (x^t, y^t) using period t technology. A value greater than unity, will indicate the positive total factor productivity growth between the two periods.

The MPI Equation (3) evaluate the two components of TFP separately becomes growth in productivity is usually defined as increase in these components of technical efficiency change (TEC) and technological change (TC) through which inputs are converted into outputs [Shen (2010)].

TFP Change = Technological Change (Frontier Effect) × Technical Efficiency Change (Catching up Effect).

Fare, et al. (1994) used the improve productivity equation by including the scale efficiency, which is one out of the two sub-components of the technical efficiency change, which is given as:

Technical Efficiency Change = Pure Efficiency change (PEC) × Scale Efficiency Change (SEC).

Pure efficiency change evaluates efficiency under VRS, in turn represents changes within the managerial efficiencies. Scale efficiency change provides an assessment of potential production gain achieved by extending the production up to an optimal level [Mehmood and Waseem (2014), Egilmez and McAvoy (2013)]. To estimate these analyses, acquired data of public buses has been evaluated with the help of a computer program DEAP 2.1.

V. Results and Discussion

Results of technical efficiency (TE) analysis of the Lahore public bus routes are presented in Table 1. Firstly, TE analysis evaluates efficiency under constant return to scale (CRS) which provides an overall technical efficiency (OTE) scores by providing a combined estimate of both the scale efficiency and pure technical efficiency. It finds that out of fifteen, six bus routes (B-1, B-8, B-10, B-12, B-16 and B-21) have worked as fully efficient with the same input level efficiency of score '1' i.e., at 100 per cent efficiency level. Alternatively, this route has the scope of producing 1.17 times (i.e., 1/0.855) as much as outputs from the same level of inputs. Secondly, TE analyzes efficiency under variable return to scale (VRS) which provides estimate of the pure technical efficiency (PTE) by separating it from the estimation of scale level [Agarwal, et al. (2010)]. It evaluates that 100 per cent efficiency performance have been attained by eight bus routes (B-1, B-5, B-8, B-10, B-12, B-16, B-21 and B-55). Conversely, lowest efficiency score of 0.917 existed in route B-28. This score represents that the existing scale level of this bus route has a potential to proportionally increase its output level up to 8.3 per cent by keeping the same input quantities.

Further, collectively under both the CRS and VRS evaluations, two bus routes (B-5 and B-55) have attained the highest VRS efficiency score but according to their CRS estimates their routes have worked relatively inefficiently. These results have pointed towards the situation that adopted the scale of production of these two bus routes which is not in accordance with their needed requirement and resultantly face decreasing return to scale that affects their OTE scores. Finally by dividing the CRS efficiency over VRS efficiency, the estimate of scale efficiency (SE), is attained. It evaluates that six bus routes (B-1, B-8, B-10, B-12, B-16 and B-21) exhibit the fully efficient production scale size by obtaining the efficiency score of '1'. Conversely, route B-12A with 0.872 least efficiency score presents that this relatively inefficient bus route diverges up to 12.8 per cent from the best production scale size.

TABLE 1

Technical Efficiency Analysis of Bus Routes Averages

Route No.	Units (Bus Routes)	Technical Efficiency (TE) Scores		
		CRS (TE)	VRS (TE)	Scale Efficiency (SE)
1.	Route # B-1	1.000	1.000	1.000
2.	Route # B-2	0.970	0.978	0.991
3.	Route # B-5	0.939	1.000	0.939
4.	Route # B-8	1.000	1.000	1.000
5.	Route # B-10	1.000	1.000	1.000
6.	Route # B-11	0.888	0.984	0.903
7.	Route # B-12	1.000	1.000	1.000
8.	Route # B-12A	0.855	0.981	0.872
9.	Route # B-16	1.000	1.000	1.000
10.	Route # B-19	0.991	0.997	0.994
11.	Route # B-21	1.000	1.000	1.000
12.	Route # B-26	0.897	0.978	0.918
13.	Route # B-28	0.901	0.917	0.983
14.	Route # B-41	0.937	0.965	0.971
15.	Route # B-55	0.892	1.000	0.892

Source: Authors' calculations.

Table 2 shows the summary results related to technical efficiency (TE) of Lahore public bus routes. This TE analysis evaluate that relatively inefficient bus routes constitute a larger share of the considered sample set and these percentage shares are 60 per cent under CRS, 46.7 per cent under VRS and 60 per cent under SE. These inefficient bus routes can be improved by following production patterns presented by the remaining efficient bus routes which are 6 routes under CRS evaluation, 8 routes under VRS evaluation and 6 routes under SE estimation. Besides, best efficiency score is of one under all the three TE components which reflects 100 per cent efficiency level. On the other hand, minimum efficiency in all 15 DMUs is 85.5 per cent (B-12A), 91.7 per cent (B-28) and 87.2 per cent (B-12A) in the domain of CRS, VRS and SE, respectively. In this regard lessen the TE scores, greater will be the potential to bring improvements in resource utilization of the respective bus routes services. Further, average TE scores exhibit that bus services on routes have 1.3 per cent deficiency under VRS (TE), whereas CRS (TE) evaluates underutilize up to a larger extent of 4.8 per cent. In the realm of average scale efficiency (SE), 3.5 per cent scale inadequacy has been encountered on the bus services provided on these routes.

By using the 2nd stage-DEA technique, Table 3 highlights the input targets for achieving the aim of minimization of input. According to these results the input targets of Bus Operations and Arg. Headway are high for two HOV routes (B-22 and B-21). Among the selected routes, these two routes are those which comparatively have a longer route length. In the remaining input parameters the highest target for the parameter of Bus Stop exist in the route of B-16, which is targetted for the input of Fuel Consumption and is high for the B-2 HOV route.

Meanwhile the 2nd stage-DEA also highlights those confronted inputs slacks that need to be rectified in order to convert an inefficient bus routes into an efficient one. Such input slack exist in eight routes: # B-5, B-11, B-12A, B-19, B-26, B-28, B-41 and B-55. Input issue of fuel wastage has been found in the HOV routes # B-12A, B-19, B-26 and B-28. The reason of fuel wastage might be the presence of dead

TABLE 2

Summary of Technical Efficiency

Efficiency Aggregates	Under CRS or (OTE)	Under VRS or (PTE)	SE
Number of efficient routes	6	8	6
Number of inefficient routes	9	7	9
Maximum efficiency (%)	100	100	100
Minimum efficiency (%)	85.5	91.7	87.2
Average efficiency (%)	0.952	0.987	0.965

Source: Authors' calculations.

mileages[14] or excessive brakes due to traffic-jam on these busy routes which pass through the hotspot areas. Another input issue of excessive bus operations exists in

TABLE 3

Summary of Input Targets and Slacks

Routes	Bus Operations	Average Headway	Number of Stops	Fuel Consumption
	Targets Slacks	Targets	Targets Slacks	Targets Slacks
Route # B-1	362.000	13.000	20.000	30699.892
	0.000	0.000	0.000	0.000
Route # B-2	674.000	18.000	38.000	62484.000
	0.000	0.000	0.000	0.000
Route # B-5	266.849	8.257	35.071	27390.359
	0.000	1.796	5.139	0.000
Route # B-8	567.000	11.000	33.000	53197.535
	0.000	0.000	0.000	0.000
Route # B-10	410.000	12.000	55.000	49037.000
	0.000	0.000	0.000	0.000
Route # B-11	269.835	8.136	29.680	26166.052
	0.000	5.091	10.002	0.000
Route # B-12	512.000	16.000	41.000	35298.000
	0.000	0.000	0.000	0.000
Route # B-12A	264.724	8.498	19.815	19062.715
	0.000	5.769	0.000	3914.369
Route # B-16	312.000	10.000	60.000	40286.000
	0.000	0.000	0.000	0.000
Route # B-19	457.737	14.631	35.882	33943.248
	0.000	1.855	0.000	9997.575
Route # B-21	680.000	22.000	16.000	58089.825
	0.000	0.000	0.000	0.000
Route # B-26	300.789	9.454	31.707	24823.151
	0.000	11.113	0.000	1145.688
Route # B-28	444.578	13.927	40.416	33231.847
	0.000	9.570	0.000	9801.565
Route # B-41	414.581	10.502	31.257	35819.732
	20.031	0.000	1.056	0.000
Route # B-55	186.611	5.910	25.945	18764.621
	0.000	5.924	4.095	0.000

Source: Authors' calculations.

[14] Dead mileage represents that travelled distance which a bus covers consciously or unconsciously in addition to the original designated path of a route.

route # B-41. Therefore, in order to serve efficiently on this HOV route, its operators should reduce such round trips among the total bus operations that bring only insufficient number of passengers. Besides, routes # B-5, B-11, B-12A, B-19, B-26, B-28 and B-55 are confronted with the problem of excessive headway which means that passengers have to wait more for each next bus. So the number of operational buses should be increased which can improve efficiency by providing timely bus services. Further, the issue of excessive bus stops has also caused a declining technical efficiency in routes # B-5, B-11, B-41 and B-55.

With the help of 2nd stage-DEA, Table 4 highlights that among the selected bus services, issues (slacks) exist in routes # B-26, B-28 and B-55 under the output of passenger ridership that highlights the need to overcoming the passengers shortage in order to operate on the efficient frontier. Under the other output goal of travelled vehicle-km, slack exists in route # B-11 that reflects its deficiency and extent of needed augmentation of traveled vehicle-km. to provide an overall technically efficient bus services on this route.

To examine the trends in productivity growth, analysis of Malmquist Productivity Index (MPI) evaluates productivity performance of bus routes from July 13 to March 14. This analysis clarifies dimensions of productivity change by decomposing into the indices of TEC, PEC, SEC, TC and TFP. Average values of these indices over the pe-

TABLE 4

Detected Issues in Output

Routes	Issues in Output
Route # B-1	
Route # B-2	
Route # B-5	
Route # B-8	
Route # B-10	
Route # B-11	Deficiency in traveled vehicle-km
Route # B-12	
Route # B-12A	
Route # B-16	
Route # B-19	
Route # B-21	
Route # B-26	Shortage of passenger ridership
Route # B-28	Shortage of passenger ridership
Route # B-41	
Route # B-55	Shortage of passenger ridership

Source: Authors' calculations.

riod of time are shown in Table 5. The first evaluation under the total factor productivity (TFP) is of technical efficiency change (TEC) that assessess the betterment in efficiency which is also known as 'catching up' effect. It is realized by achieving the goal of maximization of the output quantities[15] on the bases of given set of inputs[16] by using the same technology. With the operational perspective, this goal can be realized by enhancing management practices (PEC), for instance, improvement in service by offering a better punctuality of buses or by bringing betterment in scale efficiency (SEC), e.g., by running all the available bus fleets according to the schedule, etc. Secondly, the other mutually exclusive aim is related to bring in such a technological change (TC) that increases the maximum quantities of output by using particular set of inputs or in other words improvement in production capacity, i.e., known as 'frontier shift' effect [Wang (2013)].

Under the TEC six routes (B-5, B-11, B-12A, B-19, B-26, and B-41) have greater than one score that represents their improved efficiency performance mainly due to their better scale efficiencies. Three routes (B-2, B-28, and B-55) have a declining efficiency growth by attaining less than one score whereas, six routes (B-1, B-8, B-10,

TABLE 5

Productivity Performance of Bus Routes by Decomposing MPI

Units (Bus Routes)	TEC	SEC	PEC	TC	TFP
Route # B-1	1.000	1.000	1.000	1.010	1.010
Route # B-2	0.995	0.998	0.997	0.987	0.982
Route # B-5	1.005	1.005	1.000	1.009	1.014
Route # B-8	1.000	1.000	1.000	0.984	0.984
Route # B-10	1.000	1.000	1.000	1.018	1.018
Route # B-11	1.002	1.007	0.995	1.021	1.023
Route # B-12	1.000	1.000	1.000	0.999	0.999
Route # B-12A	1.015	1.010	1.005	0.997	1.013
Route # B-16	1.000	1.000	1.000	0.987	0.987
Route # B-19	1.003	1.001	1.003	0.999	1.003
Route # B-21	1.000	1.000	1.000	1.007	1.007
Route # B-26	1.017	1.008	1.009	0.992	1.009
Route # B-28	0.998	0.001	0.997	0.992	0.990
Route # B-41	1.026	1.014	1.012	0.991	1.017
Route # B-55	0.993	0.993	1.000	0.992	0.985

Source: Authors' calculations.

[15] Vehicle-km and passenger ridership.

[16] Number of operational buses, number of bus stops, fuel consumption and headway.

B-12, B-16, and B-21) have a score of one that reflects similar efficiency growth of these DMUs over the time. On the other hand under TC index only five routes (B-1, B-5, B-10, B-11 and B-21) have greater than one score that reflects betterment in the productivity capacity or attainment of frontier shift effect. According to overall results of TFP, nine routes (B-1, B-5, B-10, B-11, B-12A, B-19, B-21, B-26, and B-41) out of fifteen denote an increasing productivity growth, mainly because of better utilization of available input resources over the period of July 13 to March 14.

Table 6 presents an overall productivity performance summary of Lahore public bus routes. Under the index of TEC maximum catching up productivity score existed at 1.026 (route B-41) which denotes 2.6 per cent improved efficiency growth. Contrarily, minimum TEC of 0.993 occurred in route B-55 that reflects its downturn efficiency growth up to 0.7 per cent. On the other hand, the second major component of technological change, estimates the effect of frontier shift under which maximum technological growth is 2.1 per cent in route B-11 and minimum growth is 0.1 per cent in route B-8.

Under the TFP index, an overall range of productivity growth in public bus routes subsists at 4.1 per cent, over the considered time span; besides, maximum productivity growth is up to 1.023 in route B-11. This trend shows its improved productivity growth up to 2.3 per cent, mainly due to pure efficiency and technological changes contribution up to 0.9 per cent and 2.1 per cent, respectively. Contrarily, route B-2 (that serves on important radial Multan road) shows the least TFP score as 0.982 with the declining productivity trend up to 1.8 per cent, on the account of diminishing pure efficiency, scale efficiency and technological changes up to the extent of 0.2, 0.4 and 1.3 per cents, respectively. This declining trend might be due to the reason that fleet of its operational buses was reduced from 25 to 20 buses within the months of October 13 to January 14. Another reason of declining the efficiency trend in route B-2 is comparatively the greater rush of other modes like mini-vans and qingqis on this route of important radial road, i.e., Multan road with the result passenger share of route B-2 stands reduced.

Average results of public bus routes have a slightly improved productivity growth 0.3 per cent, over the time. This result appeared due to slight progress in scale efficiency (SEC) and managerial efficiency (PEC) up to the volume of 0.1 and 0.3 per cents, re-

TABLE 6

The Overall Productivity Analysis

Type of Result	TEC	SEC	PEC	TC	TFP
LPT_max.	1.026	1.014	1.012	1.021	1.023
LPT_mean.	1.004	1.002	1.001	0.999	1.003
LPT_min.	0.993	0.993	0.995	0.984	0.982
per cent Growth	0.4 per cent	0.2 per cent	0.1 per cent	-0.1 per cent	0.3 per cent

Source: Authors' calculations.
LPT = Lahore Public Transport.

spectively. On the other hand, average TC displays a minute technological declining trend of -0.1 per cent. These results portray the situations of slight improvement in efficient usage of given input resources to produce maximum targeted output by employing better managerial efficiencies.

Table 7 and Figure 1 shows the trends in efficiency growth, technological growth, and productivity growth over time intervals from July 13 to March14. In this analysis July is the base period of which the index could not be calculated because MPI evaluates change of a time period as compared to previous time period. Over the time, values of these indices fluctuate and did not show any clear pattern. Under the index of TEC, efficiency growth appeared in four time periods Aug-13, Oct-13, Nov-13 and Feb-14 with the range between (0.3 to 2 per cent), whereas a declining efficiency trend

TABLE 7

Average Productivity Results

	July13-Aug13	Aug13-Sep13	Sept13-Oct13	Oct13-Nov13	Nov13-Dec13	Dec13-Jan14	Jan14-Feb14	Feb14-Mar14
TEC	1.017	0.984	1.003	1.017	0.997	0.993	1.020	0.998
TC	0.980	1.047	0.980	0.975	1.001	0.952	1.001	1.060
TFP	0.998	1.030	0.983	0.992	0.998	0.945	1.021	1.058

Source: Authors' calculations.

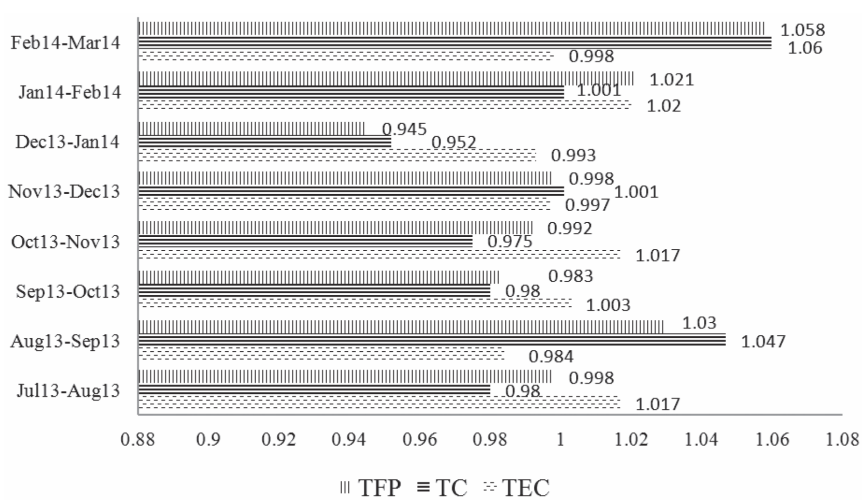

FIGURE 1

Average Productivity Analysis of
Lahore Public Bus Routes from July-13 to March-14

existed in the remaining time periods in the range of (-1.6 to -0.2 per cent). Besides, in TC index, technological growth takes place in four time periods Sep-13, Dec-13, Feb-14 and Mar-14 in range of (0.1 to 6 per cent), and the deficiency hold in other time intervals in the range of (-4.8 to -2.5 per cent).

An overall TFP index which is a product of both the catching up effect and frontier shift effect has a declining productivity trend in all months, except the three months, i.e., Sep-13, Feb-14 and Mar-14 which have better productivity growth up to 3, 2.1 and 5.8 per cents, respectively. These better productivity performance is attributed mainly to better technological growth. Conversely, the month of Jan-14 has lowest TFP change score of 0.945 which shows the down-turn of 5.5 per cent in consequence of a reduced technical efficiency and technological change scores up to the degree of 0.7 and 4.8 per cents, respectively. Along with the above mentioned operational features, the emerging productivity trend can also be explained with the help of collected field information of social life related events, e.g., the occurrences of the Holy month of Ramadan and summer vacations in the month of August reduced its passengers ratio, presence of Islamic month of Muharram in November has affected its basic output goal of ridership and a considerable shortage of CNG in the month of January had adversely affected its productivity performance.

VII. Conclusion and Recommendations

1. Conclusion

This study focuses on performance evaluation of large bus services provided on 15 selected franchises based urban public HOV routes in Lahore city. Average result of an overall technical efficiency scores under CRS shows that 4.8 per cent technical capacity is not in use. Besides, under an average SE score 3.5 per cent scale, inadequacy exists on the bus services provided on these routes. This TE analysis evaluates that relatively inefficient bus routes constitute a larger share of the considered sample set and these percentage shares are 60 per cent under CRS, 46.7 per cent under VRS, and 60 per cent under SE. According to the MPI results (on an average) 0.3 per cent improved the total factor productivity (TFP) scores hold across the considered bus routes over the period of Jul-13 to Mar-14. In the components of TFP, average scale efficiency and pure technical efficiency contributed in enhancing productivity of these bus services as compared to average technological change that has a light declining trend. The MPI analysis also finds that out of fifteen bus routes, nine routes (B-1, B-5, B-10, B-11, B-12A, B-19, B-21, B-26 and B-41) have shown increased productivity trend. Further, the 2nd stage DEA analysis highlights the confronted slacks (mostly related to excessive headway, fuel wastage, passenger shortage, etc.,) in the efficiency performance of the bus routes which needs to be rectified in order to improve the inefficient routes.

2. Recommendations

In order to maintain efficient public transport services, there is a need to enhance efficiency and productivity of the existing large bus operations at various bus routes. The private bus operators should try to use efficiently the limited available input resources to increase the overall technical efficiency. They also need to expand their existing scale of production for timely provision of bus services by maintaining a minimum headway. Further, special attention should be paid towards technological advancement to attain higher productivity growth in Lahore public bus routes performance, over the time. This goal can be achieved by establishing higher standard workshops for maintenance of the bus-fleet, by arranging training workshops for bus crew, by modernizing bus system like bus stops, ticketing, etc. Such improvements can provide an opportunity to maintain a public transport on sustainable basis.

Moreover, during the process of collecting data and field information by specifically visiting the depots of each private operator, the study recommends that the government should take responsibility to manage and channelize the other uninterrupted traffic modes, i.e., mini-vans and qingqis, especially on the main roads. In this realm, a proper regulatory system and long lasting polices should be implemented. Besides, the government should also provide equal incentives (like subsidies, availability of fuels on concessionary basis) to both the existing local and foreign bus operators with the aim to enhance their efficiency and productivity.

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APPENDIX

TABLE A-1

List of Selected Bus Routes

Sr. No.	Bus Operator Name	Route No.	Alignment
1.	Platform Turizm	B-1	R.A.Bazar to Secretariat
2.	Pakor Global	B-2	GBS to Maraka
3.	Daewoo	B-5	Railway Station to Defence
4.	Platform Turizm	B-8	Railway Station to Airport
5.	Daewoo	B-10	Railway Station to Wapda Town
6.	Daewoo	B-11	Railway Station to Green Town
7.	First Bus	B-12	Railway Station to Nishter Colony
8.	First Bus	B-12A	Bhatti to R.A.Bazar
9.	Daewoo	B-16	GBS to Township
10.	PakOz	B-19	Batti Chowk to Bagrian
11.	Platform Turizm	B-21	Railway Station to Sheikhupura
12.	First Bus	B-26	Chungi Wahga to Nishter
13.	Platform Turizm	B-28	Airport to Green Town
14.	Platform Turizm	B-41	Railway Station to Liaqatabad
15.	PakOz	B-55	Railway Station to Sabzazar