Evaluating the Technical Efficiency of Trolley Buses in Athens, Greece

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Abstract

Efficiency measurement traditionally has been an important approach of evaluating public firm performance. The purpose of this paper is to estimate the technical efficiency of Trolley Buses of the Athens and Piraeus Area (TBAPA) in Greece for the year 2003. The estimation of technical efficiency is based on the Stochastic Frontier Analysis (SFA) and employs the Cobb-Douglas specification of the production function. Meanwhile, an attempt is made to investigate the explanatory power of other factors on the organization's technical efficiency, such as the impact of other competitive means of transportation and the distance of the areas that each line connects. The panel data set consists of the monthly observations of the 20 lines of TBAPA for the year 2003. Finally, our findings are compared with those from Data Envelopment Analysis (DEA), a popular approach in the literature, providing, in general terms, consistent results.

Introduction

TBAPA (Trolley Buses of the Athens and Piraeus Area) was founded in 1970. It is a public Greek company, part of the general Athens Urban Transit Organization (AUTO), responsible for the operation of the trolley bus network. Its main task is to deliver transportation services via electric buses according to schedules and programs that are drafted by AUTO. In 2008, TBAPA had 22 trolley bus lines, which covered more than 350 kilometers in Athens and Piraeus. The fleet consisted of 366 trolley buses, 51 of which were articulated. A total of 12 million passengers use them every year. According to the official TBAPA site, the company has approximately 1,600 employees.

The area of greater Athens, situated on the southern coast of mainland Greece, is 3,200 square kilometers, including the port of Piraeus. It concentrates one third of the population of Greece in about 2.8 percent of the country's total area and is the main urban center of Greece. Athens scores well in almost all "social" indicators, has a very low crime rate in Europe, and has a low income disparity. Business is mainly composed of small- and medium-size enterprises, and the educational level of the Athenian labor force is high (OECD 2004).

Since the late 1990s, the Athens region has benefited from a period of exceptional financing and promotion related to the Olympic Games of 2004 and the EU (European Union) Support Funds (MoF 1998), which boosted investment in infrastructure and a modern region-wide transport network. This included a brand-new international airport; urban highways and ring roads to decrease congestion; upgraded rail links; a new metro; a non-polluting bus fleet; and tramway lines that connect the city center and the suburbs (OECD 2004).

However, Athens still has considerable potential for growth. It needs clear strategic planning to take advantage of the opportunities that globalisation is bringing. In fact, Athens has considerable potential for development in its role as international gateway to Greece, the eastern part of the enlarged European Union, and the Middle East. However, fulfilling this role will require strategic responses from the Greek government and the authorities of Athens and the surrounding region of Attica to a number of specific challenges (OECD 2004).

In this context, it is an important challenge for the economy's authorities to estimate the technical efficiency of TBAPA for each one of its 20 lines for the year 2003. This is a particularly appealing topic for many reasons: (1) Athens is one of the very few European capitals in which trolley buses are used, and (2) trolley buses were one of the main means of transportation in Athens in 2003, when the Athens metro network was still very limited. Besides, in the early 2000s, the Greek Department of Transportation (GDT), in collaboration with the Athens Urban Transit Organization (AUTO), introduced certain reforms in order to promote competition and thus increase efficiency and productivity. One of these reforms was the implementation of Exclusive Bus Lanes.

Review of the Literature

Asensio and Trillas (2006) measured technical efficiency in the Spanish suburban railway for 11 cities in Spain for the 2000-2004 time span, by means of DEA. Furthermore, they measured Total Factor Productivity (TFP) change with a Malmquist index and decomposed it into its various sources. The results indicated the importance that technical change has had as determinant of productivity improvements. While all cities in the sample experienced positive technical change, technical efficiency, on average, decreased in the period under investigation.

Roy and Yvrande-Billon (2007), using a panel data set consisting of 135 different French urban transport networks over the 1995-2002 time span, investigated the impact of ownership structure and contractual choices on technical efficiency in the French urban public transport sector by means of SFA. The empirical results showed that technical efficiency depended on ownership structure and the type of contract governing their transactions. Specifically, private operators outperformed public ones, and operators under cost-plus contracts exhibited a higher level of technical efficiency than operators under fixed-price agreements.

De Borger and Kerstens (2006) provided a theoretical analysis of the performance of bus-transit operators. In fact, they summarized the results about the economic performance of bus-transit operators by focusing on productivity growth and efficiency. More importantly, they reviewed the most relevant technological, environmental, and regulatory determinants of productivity growth and differences in efficiency levels between operators. A first conclusion was that productivity growth of bus-transit operators was either negative or mildly positive. Second, substantial inefficiencies remained among bus operators, although there were huge differences over time and across the countries. Third, an important conclusion was that the ownership structure was not so crucial in explaining differences in efficiency among operators. Finally, although many uncertainties remain, deregulation was likely to improve performance in a number of different respects.

Tsamboulas (2006) presented a comprehensive approach for the ex-ante evaluation and identification of relevant impacts related to the implementation of Exclusive Bus Lanes (EBL). He proposed relevant indicators to measure the impacts related to key stakeholders–public transport operators, taxis, private vehicle drivers, and passengers, as well as society–regarding energy and the environment. The ex-ante evaluation method was based on Cost Benefit Analysis (CBA) and was designed to assist any decision regarding implementation of EBL by determining whether it is beneficial. An empirical application was provided for Athens, where

EBLs were introduced to accommodate traffic for the Olympic Games of 2004. The findings of the study showed that the costs and benefits depend on an area's situation. Also, EBL facilities were found to benefit low-income travelers while imposing costs on high-income travelers.

Walter and Cullmann (2008) analyzed potential gains from hypothetical mergers in local public transport, using DEA with bias corrections by means of bootstrapping in a sample of 41 public transport companies from North Rhine-Westphalia, the most densely populated region in Germany. The mergers were into geographically-meaningful larger units that operated partially on a joint tram network. Merger gains were then decomposed into individual technical efficiency, synergy, and size effects. The findings suggested that the incorporation in rail-bound local public services was necessary, although they would better be analyzed on a case-by-case basis. The impact on the population and network density is not substantial in an already densely populated area. Regarding the merger gains, they must be expected for bus, tram, and light railway mergers and smaller bus mergers, but for larger bus mergers.

Methodological Framework

Stochastic Frontier Analysis

In 1957, Farrell (1957) provided us with the definition of technical efficiency and, until the late 1970s, its empirical application was relatively limited. Aigner et al. (1977), introduced the stochastic frontier production function, and Meeusen and van den Broeck (1977) presented the Cobb-Douglas production function with a composed multiplicative disturbance term. Since then, Farrell's idea became a useful tool for estimating technical (in)efficiency.

There are three main approaches for measuring technical efficiency: parametric (deterministic and stochastic), non-parametric based on Data Envelopment Analysis (DEA), and productivity indices based on growth accounting and index theory principles (Coelli et al. 1998). DEA and SFA are the most widely used methods for calculating the technical efficiency of a firm. The SFA approach requires a functional form to estimate the frontier production function and is based on the idea that the data are contaminated with measurement errors and other noise (Bauer 1990). The DEA approach uses linear programming techniques to estimate a piece-wise frontier that envelops the observations and requires no specific functional form for the production function (Fried et al. 1993).

The specification of the adopted model starts with the assumption that the technology applied in the production process can be described by a twice differentiable production function which relates the flow of output with various inputs of production. In algebraic terms, the stochastic production frontier (SPF) can be expressed as:

$$y = f(X,\beta)exp(\varepsilon),\ \varepsilon = (v\text{-}u),\ u>0 \qquad (1)$$

where: y is the observed output quantity; f is the deterministic part of the frontier production function, X is a vector of the input quantities used by the firm, β is a vector of parameters to be estimated, v is a symmetrical random error, and u is a one-sided non-negative random error term representing technical efficiency. It is assumed that f is finite for every X, and continuous for all nonnegative y and X. The elements of v represent the conventional normal distribution of random elements including measurement errors, omitted variables, and other exogenous factors beyond the firm's control. The elements of u indicate shortfalls of the firm's production units from the efficient frontier.

Thus, technical efficiency is measured by the ratio:

$$TE = y / [f(X)exp(v)] = exp(-u)$$

and has a value between 0 and 1, with 1 defining a technically efficient firm. Given a parametric functional form for f and distributional assumptions about u and v, equation (1) can be estimated by Ordinary Least Squares (OLS).

More specifically, equation (1) is written as:

$$ln(y) = ln[f(X)] + v - u \qquad (2a)$$

$$ln(y) = -\mu + ln[f(X)] + (v\text{-}u+\mu) \qquad (2b)$$

where: $\mu = E(u)>0$.

The estimation of the SPF by OLS leads to consistent estimators for all the parameters, μ included, under the assumption that v is normally and u is half-normally distributed. The rationale behind normality is simply convenience at the estimation stage, plus the fact that we lack information upon which to base alternative assumptions.

Estimation of equation (2) by OLS gives the residuals e_i, i = 1, 2, ..., N. The second and third central moments of the residuals, $m_2(e)$ *and* $m_3(e)$, respectively, are calculated, as follows:

$$m_2 (e) = [1/(N-k)] \cdot \Sigma e_i^2 \quad (3a)$$

$$m_3 (e) = [1/(N-k)] \cdot \Sigma e_i^3 \quad (3b)$$

where: N is the number of observations and k is the number of regressors, the constant term included. Then, we estimate σ^2_u and σ^2_v using the formulae (Georganta 1993):

$$\sigma^2_u = [(\pi/2)[(\pi/(\pi-4)]m_2(e)]^{2/3} \quad (4a)$$

$$\sigma^2_v = m_2 (e) - [(\pi-2)/\pi)] \sigma^2_u \quad (4b)$$

Following Battese and Coelli (1988), the point measure of technical efficiency is:

$$TE_i=E(exp\{-u_i\}/\varepsilon_i)=[[1-F[\sigma^{\cdot}-(M_i^*/\sigma^{\cdot})]/[1-F^{\cdot}(-M_i^*/\sigma^{\cdot})]exp[-M_i^* + (\sigma^{\cdot 2}/2)] \quad (5)$$

where: $F\cdot$ denotes the distribution function of the standard normal variable. Also:

$$M_i^* = (-\sigma^2_u\varepsilon_i)(\sigma^2_u + \sigma^2_v)\text{-}1 \quad (6a)$$

$$\sigma^{\cdot 2} = \sigma^2_u \sigma^2_v (\sigma^2_u + \sigma^2_v)\text{-}1 \quad (6b)$$

Data Envelopment Analysis

DEA is an efficiency evaluation method based on mathematical programming techniques (see, for instance, Poitras et al. 1996). In contrast to parametric approaches, DEA optimizes each individual observation with the objective of calculating a discrete piece-wise frontier determined by the set of Pareto efficient Decision Management Units (DMUs). DEA is based on the idea that the efficiency of a DMU is determined by its ability to transform inputs into desired outputs. DEA generalizes the single output/input technical efficiency measure to multiple outputs/inputs by constructing a relative efficiency measure based on a single "virtual" output and a single "virtual" input. The efficient frontier is then determined by selecting DMUs that are most efficient in producing the virtual output from the virtual input. Because DMUs on the efficient frontier have an efficiency score equal to 1, inefficient DMUs are measured relative to the efficient DMUs.

More formally, assume that there are n DMUs to be evaluated. Each DMU_j consumes varying amounts of m different inputs to produce s different outputs. Specifically, DMU_j consumes amounts $X_j = \{x_{ij}\}$ of inputs $(i = 1,..., m)$ and produces amounts $Y_j = \{y_{rj}\}$ of outputs $(r = 1,..., s)$. The $s \times n$ matrix of output measures is denoted by Y, and the $m \times n$ matrix of input measures is denoted by X. Also, assume that $x_{ij}>0$ and $y_{rj}>0$. Consider the problem of evaluating the relative efficiency for any one of the n DMUs, which will be identified as DMU_0. Relative efficiency for DMU_0 is calculated by forming the ratio of a weighted sum of outputs to a weighted sum of inputs, subject to the constraint that no DMU can have a relative efficiency score greater than unity. Algebraically:

$$\max_{u,v} \frac{\sum_r u_r y_{ro}}{\sum_t v_t x_{to}} = \frac{u^T Y_0}{v^T X_0} \tag{7a}$$

where: $u=(u_1,\dots u_s)^T$, $v=(v_1,\dots,v_m)^T$

subject to:

$$\frac{u^T Y_j}{v^T X_j} = \frac{\sum_r u_r y_{rj}}{\sum_t v_t x_{tj}} \le 1 \tag{7b}$$

for $j=1,2,\dots,n;\ u_r, v_i \ge 0$ *for* $r = 1,2,\dots,s,\ i = 1,2,\dots,n$

where: u_r and v_i are weights assigned to input r and output i, respectively.

For this fractional programming problem with a potentially infinite number of optimal solutions, Charnes et al. (1978) were able to specify an equivalent linear programming problem. This requires introduction of a scalar quantity (θ) to adjust the input and output weights:

$$\theta = \frac{1}{v^T X_0},\ \mu^T = \theta u^T,\ \omega = \theta v^T$$

Appropriate substitutions produce the linear programming problem:

$$\max_{\mu,v} \Lambda_0 = \sum_r \mu_r y_{r0} = \mu^T Y_0 \tag{8a}$$

subject to:

$$\omega^T X_0 = \sum_t \omega_t x_{t0} = 1,\ \sum_r \mu_r y_{rj} - \sum_t \omega_t x_{tj} \le 0,\ \mu_r, \omega_t \ge \in \tag{8b}$$

where the value of Λ_0 is the relative efficiency of DMU_0 and $\in$ is positive constant, called the non-Archimedian infinitesimal, which is introduced to facilitate solving of the linear programming problem. In DEA, this linear programming problem is known as the CCR.

Data and Variables

The panel data set consists of the monthly observations of the 20 lines (see Table 1) of the TBAPA in 2003. The numbering is interrupted because several lines were abolished and new ones created. Table 1 shows that the trolley bus network covers a large surface of Athens and Piraeus, serving areas from the center of Athens to the eastern, western and northern suburbs and Piraeus and its surroundings. However, the network does not serve the southern suburbs of Athens, as those areas became important centers many years after the network was developed.

Table 1. TBAPA Lines in 2003

No.	Line	Route Way
1	Line 1	Attikis Sq.- Moshato
2	Line 2	Kipseli - Pagrati - Kesariani
3	Line 3	Patisia - Girokomio
4	Line 4	Ano Kipseli - St. Artemios
5	Line 5	Lamprini - Koukaki (Gigifies)
6	Line 6	Athens - Kokkinos Milos
7	Line 7	Panepistimiou - Alexandras Av.
8	Line 8	Alexandras Av. - Akadimia
9	Line 9	Ano Kipseli - Zappio
10	Line 11	Koliatsou - N. Pagrati - N. Helvetia
11	Line 12	Zappio - Peristeri - (St. Ierotheos)
12	Line 13	Lamprini - Papadiamantis Sq. - N. Psihiko
13	Line 14	Papadiamanti Sq. - Alexandras Av.- N.Psihiko
14	Line 15	El. Venizelou - Petralona
15	Line 16	Piraeus - St. Ioannis Rentis (ring route)
16	Line 17	Piraeus - St. Georgios (ring route)
17	Line 20	Athens - P. Ralli - Nikea
18	Line 21	Athens - P. Ralli - Nikea
19	Line 24	Zappio - Helion - Petroupoli
20	Line 25	Karaiskakis Sq. - Peristeri - Helion. - Kamatero

The available panel data set consists of four variables. The single output is the total vehicle-kilometers. The inputs are the total labour expanded, the total available vehicles, and the total energy expanded (electricity) by the fleet of the vehicles of each line. Each one of these variables reflects the operational characteristics of each line of the TBAPA.

More precisely, the output of our model reflects the kilometers that are covered by the fleet of the vehicles of each line in total. The total number of the vehicle-kilometers is estimated by the total number of the route ways multiplied with the length of each line. The number of the route ways of each line is scheduled by AUTO. With regard to the independent variables of the model, the energy expanded depends on several factors, such as the number of the passengers carried by the fleet of the vehicles, the number of the vehicles used, their average speed, the traffic situation, and the geographical characteristics of each route. The employees can be drivers, ticket collectors, or stationmasters. Finally, the number of the vehicles of each line is scheduled by the TBAPA and AUTO and depends on the number of the passengers each line serves and on the length of each line.

Moreover, to assess the impact of some other exogenous factors, two dummy variables were introduced (see Table 2). The first dummy variable (d_1) represents the influence of the Athens Metro, while the second dummy variable (d_2) expresses the distance of the areas that each line serves.

Table 2. Dummy Values

Line	Dummy I (d_1)	Dummy II (d_2)
1	1	1
2	1	0
3	1	1
4	1	0
5	1	1
6	1	1
7	0	0
8	0	0
9	1	0
11	1	1
12	1	1
13	1	1
14	1	1
15	1	0
16	1	0
17	1	0
20	1	1
21	1	1
24	1	1
25	1	1

More precisely, passengers prefer to use the Athens Metro, which offers a quicker and more comfortable trip to their destination, and, in this context, we make the assumption that the lines that serve areas directly connected with the Metro are negatively affected. In other words, the dummy takes the value zero (0) when the line connects areas that are served by the Metro, otherwise one (1).

The second dummy variable expresses the distance of the areas connected by a certain line. The lines that connect areas that are both in the center of Athens or Piraeus take the value zero (0); otherwise, lines that connect the center of Athens or Piraeus with the suburbs or a suburban area to another suburban area take the value one (1). This is based on the assumption that the connection of distanced areas directly by one means of transportation, such as a trolley bus line, is expected to increase its passengers.

Empirical Results

From a methodological point of view the question of technical efficiency is examined by using the Cobb-Douglas specification of the production function. Thus, the adopted functional form, corresponding to equation (1), is:

$$lnY = a_o + a_1 lnE + a_2 lnL + a_3 lnK + a_4 d_1 + a_5 d_2 + v - u$$

where: Y is a measure of output, E is a measure of energy spending, L a measure of labour, K a measure of the available vehicles, d_1 is the first dummy variable which represents the impact of the Athens Metro, and d_2 is the second dummy variable that represents the impact of the distance between the areas that each line connects.

In the regression results, the variables K and E were statistically non-significant and had to be removed from the model. As a result, the model had to be re-estimated from scratch. Thus, the Cobb-Douglas production function finally took the form:

$$lnY = a_o + a_2 lnL + a_4 d_1 + a_5 d_2 + v - u$$

The regression results are illustrated in Tables 3 and 4. The R-squared statistic indicates that the model as fitted explains almost 80 percent of the variability in output, which means that the regression analysis provides a very good fit to the data and all the variables are highly significant. Moreover, the significance of the factors that are represented by the two dummy variables is confirmed.

Table 3. Regression Analysis Results

Parameter	Estimate	t-Statistic	P-Value
a_0	4.206	13.664	0.000
a_2	0.823	17.642	0.000
a_4	0.248	3.654	0.000
a_5	0.183	4.969	0.000

Table 4. Analysis of Variance

R-Squared	R-Squared (adj)	D.W.	F-Ratio	P-Value
79.9%	79.1%	1.83	312.33	0.0000

The next step is, through equations (3a, 3b, 4a, 4b), to estimate the second and third central moments, σ^2_u and σ^2_v. After measuring the second and third central moments, σ^2_u and σ^2_v, we are able to estimate the technical efficiency of each line. Table 5 presents the measures of technical efficiency (TE). The results range between 83.91 percent and 94.86 percent, with an average equal to 91.26 percent. Lines 17, 3, and 21 are the most technically efficient in our panel data set, while line 24 is the least efficient one. Lines 7 and 8, which are influenced by the operation of the Athens Metro, are not found to be among to the most efficient ones, a result that is consistent with our assumption expressed through the first dummy.

Table 5. Technical Efficiency Measures (%) and Line Rankings

Line	TE (%)	Ranking	Line
1	92.98	1	17
2	90.90	2	3
3	94.20	3	21
4	90.89	4	5
5	93.76	5	13
6	92.76	6	1
7	90.75	7	20
8	92.59	8	6
9	84.98	9	8
11	88.77	10	15
12	90.79	11	25
13	93.47	12	16
14	87.35	13	2
15	92.48	14	4
16	91.6	15	12
17	94.86	16	7
20	92.77	17	11
21	93.84	18	14
24	83.91	19	9
25	91.63	20	24

Comparison with DEA

In this section, we compare the SFA technical efficiency estimates with the DEA respective results (Kagiantalides 2004) (see Table 6). It is not a strict comparison, because the variables in the two approaches are different, given that DEA is a non-parametric technique that does not specify a production function for the estimation of technical efficiency.

Table 6. SFA and DEA Technical Efficiency Measures

Line	SFA	DEA
1	92.98	95.68
2	90.90	91.05
3	94.20	100.00
4	90.89	91.82
5	93.76	100.00
6	92.76	93.47
7	90.75	67.02
8	92.59	75.76
9	84.98	71.06
11	88.77	90.05
12	90.79	84.29
13	93.47	100.00
14	87.35	82.38
15	92.48	79.34
16	91.6	87.94
17	94.86	98.84
20	92.77	96.01
21	93.84	98.78
24	83.91	71.00
25	91.63	90.93

DEA technical efficiency measures range in relatively high levels, with an average equal to 88.27 percent. As can be inferred from DEA estimates, there are bigger gaps between the technical efficiency measures from line to line in comparison to their SFA counterparts. As we know, conventional DEA attributes the entire distance from the frontier to inefficiency as it cannot discriminate between inefficiency and noise.

To compare the results from the two approaches, we examine the line rankings in both methodologies. The ranking correlation is 84.06 percent, which is particularly high. This implies that regardless of the differences in the estimates between the two approaches, the results are consistent. Indeed, lines 1, 3, 5, 13, 17, 20, and 21 are among the most efficient lines, regardless of the methodology used. Furthermore, lines 2, 4, 6, 16, and 25 ranked in the middle of the sample, while 7, 9, 14, and 24 are among the least efficient lines in both methodologies.

Table 7. Line Rankings

Ranking	SFA	DEA
1	92.98	95.68
1	17	3
2	3	5
3	21	13
4	5	17
5	13	21
6	1	20
7	20	1
8	6	6
9	8	4
10	15	2
11	25	25
12	16	11
13	2	16
14	4	12
15	12	14
16	7	15
17	11	8
18	14	9
19	9	24
20	24	7

Result Analysis and Discussion

As was mentioned before, in 2003, trolley buses were, apart from conventional buses and electric railway, the main public mean of transportation in Athens, since the Metro network was still very limited. The large surface that trolley buses covered, combined with the relatively cheap tickets due to the public character of the company, made this mean very popular among the middle and low income populations in Athens.

Moreover, another fact that affected this mean's performance was the implementation of Exclusive Bus Lanes (EBL). EBL eliminated crosses between public and private means and taxis, making the first faster with fewer delays. As a result, the implementation of EBL improved the reliability of the mean. A very important factor that is also closely related with trolley bus operational performance is the central management of this mean. TBAPA and AUTO allocate vehicles, energy, and labour centrally according to the demand of each line to minimize the waste of inputs. This is obviously reflected to the technical efficiency measures.

Since the operational management of the trolley buses is done by a central authority and the allocation of inputs (e.g., vehicles, energy, and labour) to each line is in accordance to its demand (which is directly connected with the output of our model), it is normal to expect very small differences among the line's technical efficiency measures.

The differences could be explained by several factors. A first factor is the length of each line and the areas that it connects. The SFA results indicated that the length of each line positively affects the line's technical efficiency. Lines 1, 3, 6, 13, 20 and 21, which are among the most efficient, are those that directly connect certain distanced areas. This result is also confirmed by the DEA results.

The second factor has to do with the question of whether (or not) the areas that are connected by trolley buses are also served by other competitive means of transportation, such as the Athens Metro. Our empirical findings indicated that line 7, which serves areas near the center of Athens, is among the least efficient lines in both methodologies.

These factors are crucial for the future performance of the organization. Since 2003, the Athens Metro network has expanded rapidly. In this context, a new strategic planning of the trolley buses network would be relevant, especially now that a tram network also is available in Athens.

Conclusion

The purpose of this paper was the estimation of technical efficiency of the trolley Buses in Athens and the Piraeus area for each of its 20 lines for the year 2003 by means of SFA using panel data. Also, we made an attempt to assess the explanatory power of other factors on the organization's technical efficiency, such as the effect of other competitive means of transportation and the distance of the areas that the trolley bus lines connect, by introducing relevant dummy variables into the model. Furthermore, a comparison between the SFA estimates with the ones measured with the aid of the deterministic approach of DEA was attempted.

The production function provided a very good fit to the data, and the variables included in the model were highly significant. Moreover, the significance of certain exogenous factors, which are represented by the two dummy variables, also was confirmed. As for the estimated technical efficiency measures, they range in high levels. More precisely, technical efficiency has an average equal to 91.26 percent and 88.27 percent with the SFA and DEA methodologies, respectively. The ranking of the lines is, in general terms, consistent when measured with the aid of the two respective methodologies, with the ranking correlation to be equal to 84.06 percent.

In explanation of the estimated technical efficiency measures, the implementation of Exclusive Bus Lanes and the central operational management of the trolley buses in Athens affected positively an already-popular public means of transportation. However, lines that connect directly-distanced areas seem to be more efficient than those that serve areas that are also connected with other competitive means, such as the Athens Metro. No doubt, clear strategic planning is needed to take advantage of the opportunities that the increasing transportation network in Athens is bringing.

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