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**Abstract:** Reliable measures of technical efficiency are of great interest because they can assist in addressing important issues. For instance, inefficient operation of firms - in the sense that if a firm is inefficient it does not produce at minimum cost - could lead to higher prices which could drive costumers to substitute away toward some other product or service. The purpose of this paper is the estimation of technical efficiency of Trolley Buses of Athens & Piraeus Area (T.B.A.P.A.), for each one of its twenty (20) lines for the year 2003. We apply the methodological framework of Stochastic Frontier Analysis (S.F.A.), by using the Cobb-Douglas specification of the production function. The dependent variable is the total kilometers that are covered by the vehicles of each line, while the independent variables include the fleet of the vehicles used, labor expanded and energy expanded. The data set consists of the monthly observations of the twenty (20) lines of the APTB. The results are compared to those from Data Envelopment Analysis (D.E.A.), a particularly widely used approach for efficiency measurement in the literature. Findings suggest that most lines were highly efficient, since technical efficiency ranged between 97% and 100%. The results obtained by means of the SFA approach are, in general terms, consistent with the DEA findings, despite the fact that DEA usually cannot discriminate between inefficiency and noise and tends to provide overestimated results.

# 1    Introduction

The purpose of this paper is to estimate the technical efficiency of Trolley Buses of Athens and Piraeus Area (T.B.A.P.A.), for each one of its twenty (20) lines for the year 2003. This is a particularly appealing subject for many reasons. At first, because Athens is one of the very few European capitals in which trolley buses are used. Moreover, trolley busses 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 (G.D.T.) in collaboration with the Athens Urban Transit Organization (A.U.T.O.), introduced certain reforms in order to promote competition and thus increase efficiency and productivity.

T.B.A.P.A. was found in 1970. It is a public Greek company, part of the general Athens Urban Transit Organization (A.U.T.O.), responsible for the operation of the Trolley Buses network. Its main task is to deliver transportation services via electrical buses, according to schedules and programs that are drafted by A.U.T.O. In 2008, T.B.A.P.A. had twenty-two (22) trolley bus lines which covered more than 350 kilometers in Athens and Piraeus. The fleet consisted of three hundred and sixty six (366) trolley buses, fifty one (51) of which were articulated. Twelve million (12,000,000) passengers use them every year. The company has one thousand and six hundred (1,600) employees, approximately (official T.B.A.B.A. site).

The estimation of technical efficiency is based on the so-called Stochastic Frontier Analysis (S.F.A.) and the results are compared to those form the deterministic approach of Data Envelopment Analysis (D.E.A.) The paper is structured as follows: section 2 presents previous and/or related studies on the topic; section 3 sets out the methodological framework; section 4 describes the data and the variables; section 5 presents the empirical results; section 6 compares them with DEA; finally, section 7 concludes the paper.

# 2    Previous Studies

In this section, we make an attempt to review previous studies dealing with the performance of urban transportation, mainly in Europe. Asensio and Trillas (2006) measured technical efficiency in the Spanish suburban railway for eleven 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 during 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 known 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 between 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 between operators. Fourth, the impact of the network's environmental variables and characteristics on performance was clearly highlighted in a number of studies. 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, as the public transport operators, taxis, private vehicle drivers and passengers, as well as society regarding energy and the environment. The *ex-ante* evaluation method is based on Cost Benefit Analysis (CBA) and is designed to assist any decision regarding implementation of EBL by determining whether it is beneficial. An empirical application was provided for Athens, Greece 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 benefit low-income travelers while imposing costs on high-income travelers.

Walter and Cullmann. (2008), aimed to analyze 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 must 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 further research is relevant.

## 3    Methodological Framework

### 3.1    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. However, 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 D.E.A. and productivity indices based on growth accounting and index theory principles (Coelli et *al.*, 1998). D.E.A. and S.F.A. are the most widely used methods for calculating the technical efficiency of a firm. The S.F.A. approach requires a functional form in order 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 D.E.A. 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:

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

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, $\beta$ 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, minor 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 (O.L.S.).

More specifically, equation (1) is written as:

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

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

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

The estimation of the S.P.F. by O.L.S. leads to consistent estimators for all the parameters, $\mu$ 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 stochastic specification assumptions.

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

$$m_2(e) = [1/(N-k)] \cdot \Sigma \, e_i^2 \qquad \text{(3a)}$$

$$m_3(e) = [1/(N-k)] \cdot \Sigma \, e_i^3 \qquad \text{(3b)}$$

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

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

$$\sigma^2_v = m_2(e) - [(\pi-2)/\pi)] \, \sigma^2_u \qquad \text{(4b)}$$

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

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

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

$$M_i^* = (-\sigma_u^2 \varepsilon_i)(\sigma_u^2 + \sigma_v^2)^{-1} \qquad (6a)$$

$$\sigma^2 = \sigma_u^2 \, \sigma_v^2 \, (\sigma_u^2 + \sigma_v^2)^{-1} \qquad (6b)$$

## 3.2  *Data Envelopment Analysis*

According to Poitras et *al.* (1996), Data Envelopment Analysis (D.E.A.) is an efficiency evaluation model based on mathematical programming techniques. In contrast to parametric approaches, D.E.A. optimizes each individual observation with the objective of calculating a discrete piece-wise frontier determined by the set of Pareto efficient Decision Management Units (D.M.Us). D.E.A. is based on the idea that the efficiency of a D.M.U. is determined by its ability to transform inputs into desired outputs. D.E.A. 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 D.M.U.s which are most efficient in producing the virtual output from the virtual input. Because D.M.U.s on the efficient frontier have an efficiency score equal to 1, inefficient DMUs are measured relative to the efficient D.M.U.s.

More formally, assume that there are $n$ D.M.U.s to be evaluated. Each D.M.U.$_j$ consumes varying amounts of $m$ different inputs to produce $s$ different outputs. Specifically, DMUj consumes amounts Xj = {$x$ij} of inputs ($i = 1,.....,$ $m$) and produces amounts Yj = {$y$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 problem of evaluating the relative efficiency for any one of the n D.M.U.s, which will be identified as D.M.U.$_0$. Relative efficiency for D.M.U.$_0$ is calculated by forming the ratio of a weighted sum of outputs to a weighted sum of inputs, subject to the constraint that no D.M.U can have a relative efficiency score greater than unity. Symbolically:

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

where $u = (u_1,...,u_s)^T$, $v = (v_{1,...,}v_m)^T$
Subject to:

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

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

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 ($\theta$) to adjust the input and output weights:

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

Appropriate substitutions produce thelinear programming problem:

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

subject to:

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

where the value of $\Lambda_0$ is the relative efficiency of D.M.U.$_0$ and$\in$, is positive constant, called the non-Archimedian infinitesimal, which is introduced to facilitate solving of the linear programming problem. In D.E.A., this linear programming problem is known as the C.C.R.

## 4    Data

The data set consists of the monthly observations of the twenty (20) lines (see Table 1) of the T.B.A.P.A. in 2003. The numbering is not continuous because several lines were abolished and new ones created. Table 1 show that the Trolley Busses' network covers a large surface of Athens and Piraeus, serving areas from the centre of Athens to Eastern Western and North Suburbs, Piraeus and its surroundings. However, the network does not serve the South Suburbs of Athens, as those areas became important centers many years after the network was developed.

**Table 1**          T.B.A.P.A.' lines in 2003

| No. | Line | Rout 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 data set consists of four (4) variables. The single output is the total vehicle-kilometres. 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 of these variables reflects the operational characteristics of each line of the T.B.A.P.A.

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 the A.U.T.O. With regard to the independent variables of the model, the energy expanded is a crucial one, as it 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, with regard to the number of the vehicles of each line this is scheduled by the T.B.A.P.A. and the A.U.T.O.

## 5    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:

$$lnY = a_o + a_1 lnE + a_2 lnL + a_3 lnK + v - u$$

where: *Y* is a measure of output, *E* is a measure of energy spending, *L* a measure of labour, and *K* a measure the vehicles available. The regression results showed a very good fit to the data for almost all of the twenty (20) lines, while the *p*-values of the variables were particularly high, which are clear indications of mutlicollinearity. As a result, some variable(s) had to be removed from the model. In this spirit, first we note that with regard to the variable "labour", it is practically constant (at a monthly basis) for each line of the data and, thus, it does not affect the lines' level of output. Second, we exclude the variable ''vehicles'' from the model because of multicollinearity problems in the regression, as was easily confirmed. This was expected and easily interpretable because the number of vehicles is implicitly counted in the total amount of energy expanded. As a result, energy expanded is the only variable that we keep in the model and provides a very good fit to the data as can be inferred from Table 2.

Thus, the Cobb-Douglas production function after the exclusion of these two variables takes the form of equation:

$$lnY = alnE + v - u$$

The results of the regression analysis are illustrated in Table 2. It can be inferred that the model provides a very good fit to the data and of course the variable "energy" is highly significant in almost all the regressions.

**Table 2**         Regression analysis results (*p*-value in parenthesis)

| Line | Const | lnE | R-Sq (%) |
|------|-------|-----|----------|
| 1 | 10.661 (0.00) | 0.943 (0.00) | 89.0 |
| 2 | 10.026 (0.00) | 0.970 (0.00) | 94.1 |
| 3 | 10.547 (0.00) | 0.988 (0.00) | 97.6 |
| 4 | 10.225 (0.00) | 0.962 (0.00) | 92.6 |
| 5 | 10.431 (0.00) | 0.962 (0.00) | 92.5 |
| 6 | 10.361 (0.00) | 0.981 (0.00) | 96.2 |
| 7 | 9.095 (0.00) | 0.558 (0.06) | 31.1 |
| 8 | 9.183 (0.00) | 0.911 (0.00) | 83.0 |
| 9 | 9.268 (0.00) | 0.913 (0.00) | 83.4 |
| 11 | 10.242 (0.00) | 0.984 (0.00) | 96.8 |
| 12 | 10.461 (0.00) | 0.892 (0.00) | 79.6 |
| 13 | 10.551 (0.00) | 0.991 (0.00) | 98.3 |
| 14 | 10.023 (0.00) | 0.981 (0.00) | 96.1 |
| 15 | 9.636 (0.00) | 0.900 (0.00) | 81.0 |
| 16 | 9.601 (0.00) | 0.913 (0.00) | 83.3 |
| 17 | 9.960 (0.00) | 0.978 (0.00) | 95.7 |
| 20 | 10.017 (0.00) | 0.884 (0.00) | 78.1 |
| 21 | 10.654 (0.00) | 0.666 (0.08) | 44.3 |
| 24 | 9.883 (0.00) | 0.668 (0.08) | 44.6 |
| 25 | 10.063 (0.00) | 0.849 (0.00) | 72.0 |

The next step is, through equations (3a, 3b, 4a, 4b), to estimate the second and third central moments, $\sigma^2_u$ and $\sigma^2_v$ of each line. After measuring the second and third central moments, $\sigma^2_u$ and $\sigma^2_v$, we are able to estimate the technical efficiency of each line. Table 3 presents the measures of technical efficiency (T.E.).

**Table 3**    Technical efficiency measures % (ranking in parenthesis)

| Line | T.E.% |
|------|-------|
| 1 | 99.17 (11) |
| 2 | 98.89 (14) |
| 3 | 99.34 (9) |
| 4 | 99.46 (6) |
| 5 | 99.47 (5) |
| 6 | 99.44 (7) |
| 7 | 99.72 (2) |
| 8 | 99.01 (13) |
| 9 | 97.85 (17) |
| 11 | 100.00 (1) |
| 12 | 98.13 (16) |
| 13 | 99.52 (3) |
| 14 | 99.26 (10) |
| 15 | 99.42 (8) |
| 16 | 99.07 (12) |
| 17 | 99.52 (4) |
| 20 | 98.23 (15) |
| 21 | 97.41 (19) |
| 24 | 97.01 (20) |
| 25 | 97.82 (18) |

The results after the removal of several unusual observations range between 97% and 100% with an average equal to 98.8% approximately. This result implies that the lines appear to be highly efficient in terms of technical efficiency. Line 11 is the most technically efficient while line 24 is the least efficient line in our dataset.

After a closer look at the empirical results, namely the technical efficiency measures and the characteristics of each line, it seems that a combination of the length of each line and the areas that it connects are the factors which define each line's technical efficiency. More precisely, the lines which serve areas that are distanced and not connected directly with other "competitive" means of transportation, seem to be more technical efficient.

For instance, line 11 connects areas around the center of Athens that are served neither by the metro nor by bus or electric railway. More characteristic is the case of line 7, the second most efficient line of the sample. This line serves areas near the centre of the city, which are served by metro and buses. However, this line is highly efficient because its connection with these "competitive" means is not direct. The same is in force for line 13, which is the longest (25km) line of the sample and the third most efficient. This line connects many areas around Athens via big avenues in which the bus network is very extensive. Passengers seem to prefer trolley buses because they offer a direct way to their destination. Contrarily, lines which serve areas that are served by metro (line 8), or the electric railway (lines 20, 21) are among the least efficient lines.

## 6    Comparison with D.E.A.

In this section, we compare the SFA technical efficiency estimates with the D.E.A. respective results (Kagiantalides, 2004). See Table 4. It is not a strict comparison, because the variables in the two approaches are different given that DEA is a non-parametric technique which does not specify a production function for the estimation of technical efficiency.

**Table 4**        S.F.A. and D.E.A. technical efficiency measures

| Ranking | S.F.A. | D.E.A. |
|---------|--------|--------|
| 1 | 99.17 | 95.79 |
| 2 | 98.89 | 95.31 |
| 3 | 99.34 | 98.18 |
| 4 | 99.46 | 94.24 |
| 5 | 99.47 | 99.33 |
| 6 | 99.44 | 94.84 |
| 7 | 99.72 | 99.8 |
| 8 | 99.01 | 100 |
| 9 | 97.85 | 93.17 |
| 11 | 100 | 90.87 |
| 12 | 98.13 | 91.53 |
| 13 | 99.52 | 99.45 |
| 14 | 99.26 | 96.93 |
| 15 | 99.42 | 85.86 |
| 16 | 99.07 | 97.85 |
| 17 | 99.52 | 98.96 |
| 20 | 98.23 | 98.14 |
| 21 | 97.41 | 99.81 |
| 24 | 97.01 | 100 |
| 25 | 97.82 | 99.97 |

Just like in S.F.A., D.E.A. technical efficiency measures range in relatively high levels, with an average equal to 96.5%, although the D.E.A. measures are, in general, lower than the ones estimated by S.F.A., as D.E.A. attributes the entire distance from the frontier to inefficiency as it does not discriminate between inefficiency and noise.

Another interesting issue is the comparison of the lines' ranking with both methodologies. As we can infer from Table 5, lines 3, 5, 7, 13, 17, ranked in the top 50%, regardless of the methodology used, while lines 1, 2, 16, are in the middle of the ranking, whereas lines 9 and 12 are among the least efficient with both methodologies.

**Table 5**      The ranking of with SFA and DEA

| Ranking | S.F.A. | D.E.A. |
|---------|--------|--------|
| 1 | 11 | 8 |
| 2 | 7 | 24 |
| 3 | 13 | 25 |
| 4 | 17 | 21 |
| 5 | 5 | 7 |
| 6 | 4 | 13 |
| 7 | 6 | 5 |
| 8 | 15 | 17 |
| 9 | 3 | 3 |
| 10 | 14 | 20 |
| 11 | 1 | 16 |
| 12 | 16 | 14 |
| 13 | 8 | 1 |
| 14 | 2 | 2 |
| 15 | 20 | 6 |
| 16 | 12 | 4 |
| 17 | 9 | 9 |
| 18 | 25 | 12 |
| 19 | 21 | 11 |
| 20 | 24 | 15 |

## 7    Conclusion

The main purpose of this paper was the estimation of technical efficiency of the Trolley Busses in Athens and Piraeus Area (T.B.A.P.A.), for each one of its twenty (20) lines for the year 2003, by means of S.F.A. Furthermore, a comparison between the S.F.A. estimates with the ones measured with the aid of the deterministic approach of D.E.A. was attempted.

With regard to the empirical results, the estimated technical efficiency measures range in high levels. More precisely, technical efficiency has an average equal to about 98.80% and 96.5% with the SFA and DEA methodologies, respectively. This is expected given the fact that conventional D.E.A. cannot discriminate between inefficiency and noise. The ranking of the lines is, in general terms, consistent when measured with the aid of the two respective methodologies. Finally, a closer look at the results and the characteristics of the route way of each line indicates that lines which connect areas that are distanced and not connected directly with other "competitive" means of transportation, seem to be more technically efficient, ranking very high in the list. We believe that our findings could be used for the formulation of policy rules. Clearly, future and more extended research is of great interest.

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