ANALYSIS OF EFFICIENCY OVER TIME USING DATA ENVELOPMENT ANALYSIS TECHNIQUES: THE CASE OF INTERSTATE PASSENGER COACH TRANSPORT COMPANIES IN BRAZIL

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ABSTRACT

The present work uses Data Envelopment Analysis - DEA to evaluate the technical and operational efficiency of companies engaged in interstate passenger coach services in Brazil. The evaluation encompasses the years 2004, 2005 and 2006 and involves 102 coach companies that only operate interstate routes over distances greater than 75 km in Brazil. The variables selected are: i) product: passenger-kilometers (turnover); ii) inputs: distance traveled in kilometers (representing fuel consumption), fleet of vehicles (invested capital) and drivers (labor). The study employed the BCC optimization model to compensate for the varied sizes of the transport companies analyzed, with an orientation directed at reduction of inputs.

The result was the identification of groups of efficient companies both large and small that can serve as benchmarks for the inefficient companies. Its could assist the regulating authority in

determining the targets to be achieved by the inefficient companies in order to place themselves as near as possible to the efficiency frontier or even become part of it. The regulatory authority could also use them as an indicator to define a yardstick competition for regulation purposes.

1. INTRODUCTION

The 1988 Brazilian Federal Constitution defined the activity of interstate passenger coach transportation (TRIP) as a public service, whereas the general guidelines about the conditions for the offer of services were established by the law 8.987/1995, by the enactment 2.521/1988 and by the law 10.233/2001 which created the National Agency of Overland Transportation (ANTT), responsible for the elaboration and edition of norms and regulations about these services. According to ANTT (2004), the TRIP represents the main modality of collective handling of users, with 95% of the total of displacements accomplished in relation to the other means of transportation.

The TRIP services in Brazil have always been offered by private companies, in a regime of public service, through an permission to operate the routes, but submitted to a strong intervention from the State due to the relevance of activity to the social and economical relationships and to the development and regional integration of the country. The remuneration of the service is accomplished directly by the receipt coming from the fares charged to the users, with no tariff freedom, but strong economical regulation. The remuneration is based on the cost of the transportation offered in regime of economical efficiency (allocative and productive) associated to a margin of profitability affecting the immobilized capital stock (Orrico Filho & Santos, 1996), prudently invested and still not depreciated.

The theme about efficiency and productivity of companies in a regulated environment has been widely discussed in the literature and with a broad and diverse methodological approach (Coelli *et al.*, 2003). Especially, the applications in the bus passengers transportation area has many approachs such as: Merewitz (1977); Hensher (1987). Others adopted the Data Envelopment Analysis – DEA method, such as Viton (1998) and Odeck and Alkadi (2001).

The DEA technique has been applied in Brazil in different transportation modes, being of interest of the present work Noaves and Medeiros's (2008) and Araújo, Martins and Silva's (2008) studies, who analyzed the efficiency and productivity of TRIP companies in Brazil during 2006.

Despite this diversity concerning research, there are few studies of national range on the analysis of efficiency and productivity of TRIP companies in Brazil utilizing the DEA technique.

The present study, under this scope, has the goal of evaluating the productive efficiency of companies which offer the TRIP services in Brazil, utilizing a non-parametric method based on the DEA technique, during the years of 2004, 2005 and 2006. In order to do so, this work was elaborated into five sections, including this introduction. The second section presents a theoretical background about the DEA technique and about the regulation of TRIP observing the structure of its market and a possible way of production to be adopted in the DEA modelling for the Brazilian case. The third section is about the methodology and its application. The fourth section concerns the analysis of the results obtained based on the adopted model and on the information related to the production of 102 TRIP companies. The fifth section conveys the final considerations.

2. THEORETICAL BACKGROUND

In this section, we discuss concepts related to the evaluation of productive, operational efficiency and the economical regulation.

2.1 Concepts Inherent to the Economical Efficiency

The evaluation of economical efficiency, with allocative, distributive and productive origins, has been focused on static aspects, which conduced to a wider analysis search from the concept of dynamic efficiency, which includes investments and the capacity of technological innovation and also the conditions of time duration or the criteria of Pareto allocation efficiency of an optima choice among the allocations of resources which are limited to technologies and given institutions. In this context, the term productivity comes, which represents, according to Coelli, Rao and Battese (1997), several nuances in its way of measurement, which requires, thus, to describe definitions commonly utilized, such as: productivity, productive or technical efficiency; allocative efficiency, technical changes; scale economy; Total Productivity of Factors (PTF); production frontier; and feasible set of production.

Productivity is defined as the relationship between the produced and the necessary input for production. In the case of multiple inputs and products, the concept of productivity is equivalent to TFP. The production frontier represents the maximum production for each level of input and reveals the state of technology in industry. The company is technically efficient if it is in the production frontier, being inefficient if it is under the graph. All the points under the graph are feasible, since they require only a given combination of production factors available, starting from the technology adopted. However, the points above the graph are not reachable to the production factors existent and the current technology, since it would exceed the production frontier in industry.

The time passing implies a change of turnover in the production frontier with enlargement or reduction in the production set. In this sense, two efficiencies can be distinguished: the momentary and the one which comes from technical changes. The first one will be call partial efficiency and the second one time efficiency. According to Coelli, Rao and Battese (1999&0, the increase in productivity is a consequence of the improvements in efficiency via technical changes or scale economy, being a result of a combination of these factors. Finally, Farrell

(1957) indicates that the technical efficiency reflects the ability that firms have to obtain maximum production with the given inputs, whereas the allocative efficiency reflects the ability that firms have to utilize the inputs in optima proportions, in Pareto's sense, given their prices.

2.2 Analysis of Efficiency via DEA

Although there are several techniques available to measure the productive efficiency which reliably simulates the behavior described in section 2.1, such as econometric models of production functions, TFP indexes, Data Envelopment Analysis and stochastic frontier (Silva *et. al.,* 2010), this work focuses on the DEA method. Thus, this section describes this method and discusses the models which are usually adopted.

2.2.1 History of the DEA method

Based on the theoretical studies on efficiency, the DEA concept emerged as a study published by M. J. Farrell in 1957, motivated by the necessity to develop better methods which enabled to evaluate productivity. According to Cooper *et. al.* (2004), Farrell argued that the obtaining of productivity measures were very restrict and failed when it was desired to obtain a global measure of efficiency, utilizing multiple inputs and multiple outputs. Charnes, Cooper and Rhodes in 1978, continued the work developed by Farrell (1957), becoming this approach popular and using a model of mathematical programming (CCR model) which was entitled Data Envelopment Analysis, for the definition of an efficient frontier function related to the productive units which were being evaluated. These productive units were called Decision Making Units (DMU), which according to Cooper *et al.* (2004) are entities capable of turning multiple inputs into multiple outputs.

In 1984, the research agenda of DEA model develops the BCC model (abbreviation for the last name of the authors Baker, Charnes and Cooper), the model distinguishes the technical or scale inefficiencies estimating the technical efficiency in a given operational plan and identifying scales plans. This way, the model relaxes the condition of constant scale return, typical of the CCR, enabling the local investigation of the scale return type.

2,2,2 Properties and basic hypotheses of the DEA models

According to Golany and Roll (1989) apud Niderauer (2002), in order for the technical application of the DEA to succeed, it is necessary to guarantee that: (I) the units under analysis be comparable, which means, accomplish the same tasks and have similar goals; (ii) the units act under the same “market conditions” and (iii) the variables, in other words, the inputs and the outputs of the units be the same, except for intensity or magnitude.

Usually when making and DEA analysis, the following procedures are adopted: (I) coherence of the variables for input and output are verified, considering the basic hypothesis and accomplishing statistic tests; (ii) the “efficiency frontier” is determined from the calculation of the efficiency; and (iii) a "virtual" input and output value of each observation is created to measure how distant this point is from the "efficiency frontier".

The properties for one-dimensional statistics, according to Amaral (2000), can be adopted for the production function (f), in which f: K → R, where K, domain of the production function, is a compact, convex subset, from the non-negative octant of Rs, which is a vectorial space, and s is the number of inputs which belong to the set of integer non-negative numbers. R, counter-domain, is the set of real numbers. The production function used in the DEA model presents the properties of Table 1:

Table 1 – Properties of the production function in DEA molding

Property	Mathematical representation	Variables
Monotonicity	$\vec{x} > \bar{\vec{x}} \Rightarrow f(\vec{x}) > f(\bar{\vec{x}}), \forall \vec{x}, \bar{\vec{x}} \in K$	$\vec{x}$ Is the input vector and *f* is the production function
Concavidade	$\theta.f(\vec{x}) + (1-\theta).f(\bar{\vec{x}}) \leq f(\theta.\vec{x} + (1-\theta).\bar{\vec{x}}), \forall \vec{x}, \bar{\vec{x}} \in K$	θ is the efficiency
Data Envelopment Analysis	$f(\vec{x}_j) \geq y_j, j = 1,2,3,...,N, \forall \vec{x} \in K$	y_j is the value pf efficiency of the DMU_j
Minimum extrapolation	$g(\vec{x}) \geq f(\vec{x}); \forall \vec{x} \in K$	function *g* satisfies the three properties

Given the properties of Table 1, additional hypothesis are adopted to measure the maximum interrelation between the production function and its inputs, which are:

a) Non-negative errors, the errors Ej; j = 1, 2, 3,..., N are independent and identically distributed with density f(E) in a way that f(E) = 0 ∀ E<0;
b) monotonicity of the density function of error probability, if $0 \leq E' \leq E''$ so $f(E') \geq f(E'')$;
c) independence between errors and inputs of a DMU, the errors (Ej) are independent from the respective inputs (xj ; j = 1, 2, 3,...,N); and
d) independence between the DMU, represented by the pair $(y_i; \vec{x}_j)$.

2.2.3 Calculation of the Data Envelopment Analysis

The efficiency θ is calculated obtaining a relation between the outputs vector and the inputs vector, being situated between zero and one and it is represented by the equation (1):

$$\theta = \frac{u_0 + u_1 y_1 + ... + u_n y_n}{v_0 + v_1 x_1 + ... + v_n x_n} \leq 1,0 \qquad (1)$$

In which the inputs vector is $\vec{y}=(y_1,y_2,...y_n)$ and the outputs is $\vec{x}=(x_1,x_2,...x_n)$, u are the weights of the inputs and v_i of the outputs.

Among the several models which can be utilized for the DEA technique, the CRS model (Constant Return Scale) or CCR (abbreviation for the names of their creators Charnes, Cooper and Rhodes), and the VRS model (Variable Return Scale) or BCC (abbreviation for Banker, Charnes and Cooper) are the most relevant.

The measure of efficiency can be obtained by several ways: radial, additive; by the maximum average or by the minimum average. This last measure of efficiency pictures the relation of distance between the point where the DMU is and the efficiency frontier. Radial measures are utilized for the calculation of the technical efficiency (coefficient of utilization of resources). Through the concept of radial measure it is possible to search the maximum equally reduction of the inputs or the maximum equally expansion of the outputs (Debreu, 1951 apud DEA Home Page, 2004), according to what is represented at Figure 1.

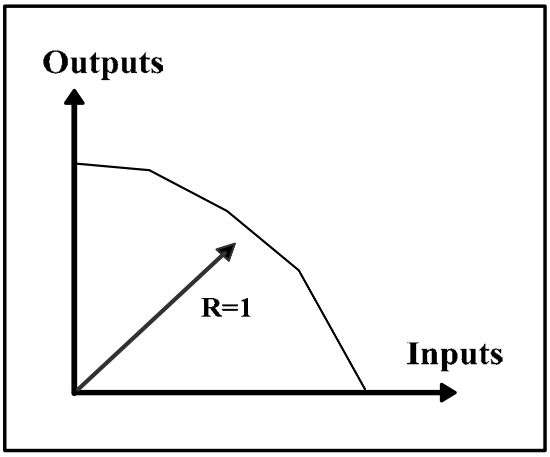


Figure 1 – Frontier of efficiency and radial distance (adapted from Amaral, 2000)

The calculation of the efficiency through the radial measure are obtained through the equations 2, 3 and 4.

Non-oriented: $\max\{\theta/[(1-\theta)\vec{X},(1+\theta)\vec{Y}]\in K\}$ (2)

Oriented to input: $\min\{\theta/(\theta\vec{X},\vec{Y})\in K\}$ (3)

Oriented to output: $\max\{\theta/(\vec{X},\theta\vec{Y})\in K\}$ (4)

Where $\vec{X}$ is the inputs vector, $\vec{Y}$ is the outputs', θ is the efficiency function and K is the domain of the production function, defined in 2.2.2.

2.3 Economic Regulation Concepts

The operation of the market according to its necessities of demand and offer can sometimes efficiently allocate the resources, but it can also present flaws identified through the comparison between the hypothesis of perfect occurrence, regarded as ideal market conditions, and other market structures. However, when presenting market imperfections, the economic theory suggests that the market necessities must give place to the economic regulation or to the operation of state companies.

The economic regulation, under this scope, according to Samuelson and Nordhaus (1983), refers to the diversity of products, to the establishment of service levels, to the entrance and exit conditions of the market and to the economic and operational conditions influenced by the services or activities, impacting especially over the amount produced, the area of actuation of each company and the prices of services or products. The *modus operandi* of the economic regulation aims at reaching several goals, among which, according to Pires and Piccinni (1999), are: (a) to enable economic efficiency in the services; (b) to avoid the abuse of monopoly power; (c) to assure the universal access and quality of the service; and (d) to stimulate innovation. Giambiagi and Além (2000) mentioned, among other goals: to promote welfare of the user and to guarantee the interconnection between different providers. The increase in the level of economic efficiency in the services for private companies has been mentioned in the literature as being the primary goal of the economic regulation.

Thus, the attainment of the goal of economy efficiency or total efficiency depends on the implementation of the roles to the sector by the regulator agents according to the regulatory mechanisms adopted in the sense of inducing the companies to search this efficiency in the services, which means, to present an efficient performance. In this sense, there are several mechanisms or methods of economic regulation applied to the service area according to how much encouragement is given to the companies.

3. METHODOLOGY, APPLICATION AND RESULTS

The methodology proposed in this work aims at identifying the companies which offer the TRIP services in Brazil with efficient operational patterns in terms of costs. Figure 2 presents the sequence of the stages mentioned and the respective stages and procedures.

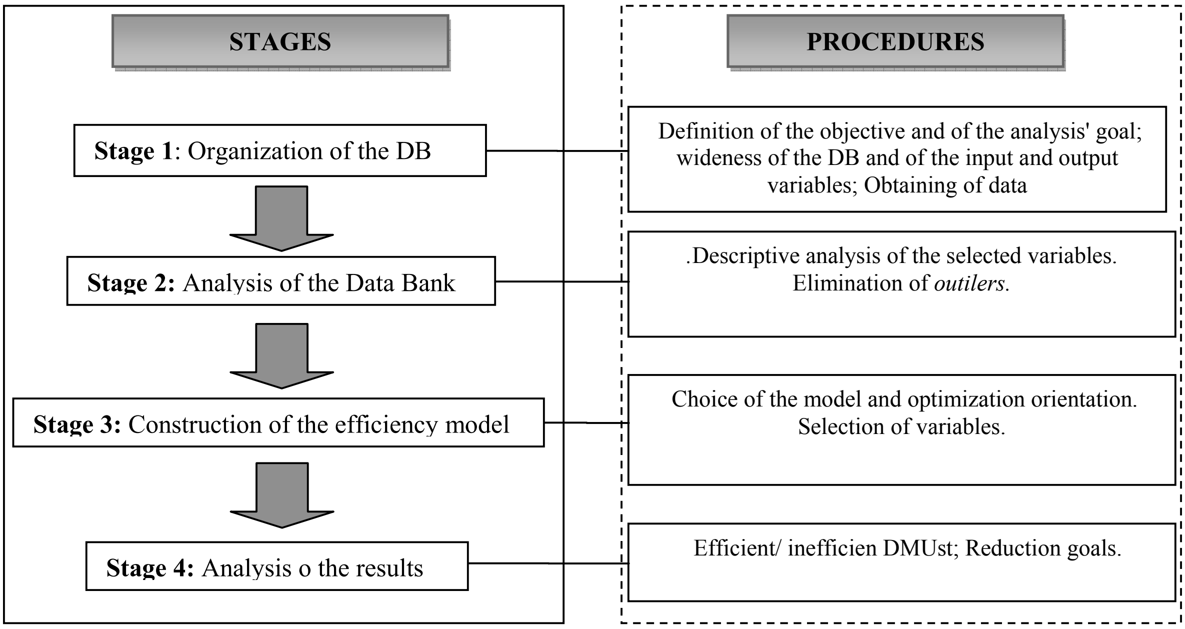


Figure 2 – Stages and methodological procedures

Stage 1 – Construction of the Data Bank (DB)

Before starting the collection and construction of the DB, we define the objective and the goal of the analysis accomplished. Thus, the objective of the present study are the companies which provide the service of Interstate Passengers Coach Transport (TRIP) and the goal is to analyze the evolution of productive efficiency of these companies in the period of 2004 and 2006 yearly.

Since these points were defined, the construction of the DB started. In order to do so, we utilize information about the production of 162 TRIP companies in Brazil which operate only in Brazilian interstate routes with a journey superior to 75 km, during the period 2004-2006. The information obtained about these companies composes input and output variables. The inputs were: quantity of buses (fleet); quantity of drivers; and yearly distance covered by the fleet in km. The output variables were: quantity of passengers transported; quantity of passengers-kilometer produced; and total of trips accomplished. The data was obtained in the electronic address of the ANTT and they are allocated by routes and by companies, so that they allow the aggregation of information in the entrepreneurial level.

Stage 2: Analysis of the Data Bank (DB)

After collecting the information to compose the DB, Stage 2 consists of accomplishing descriptive statistics (average, maximum and minimum values, median,quartiles, etc.) to know the behavior of units with relation to each variable. Complementarily, the box plot serves as an identification of outliers and a correlation of the DB variables, with the goal of verifying possible inconsistencies in the information obtained or even in the atypical behavior with relation to the sample

The procedure enables to eliminate the DMUs (units of analysis, in this case, the companies) and/or variables which can endanger the study. Besides, the representative variables for the study will be defined, restricting among the range of information, constants of the BD, those which do not exceed the assumptions of the DEA models, which are: accomplishment of the same tasks and similar objectives between the DMUs; the DMUs act under the same "market conditions", and the inputs and the outputs of the units be the same, except for intensity and magnitude. The descriptive statistics of the DB are represented in Table 2.

Table 2 – Descriptie statistics, period 2004-2006, 162 companies

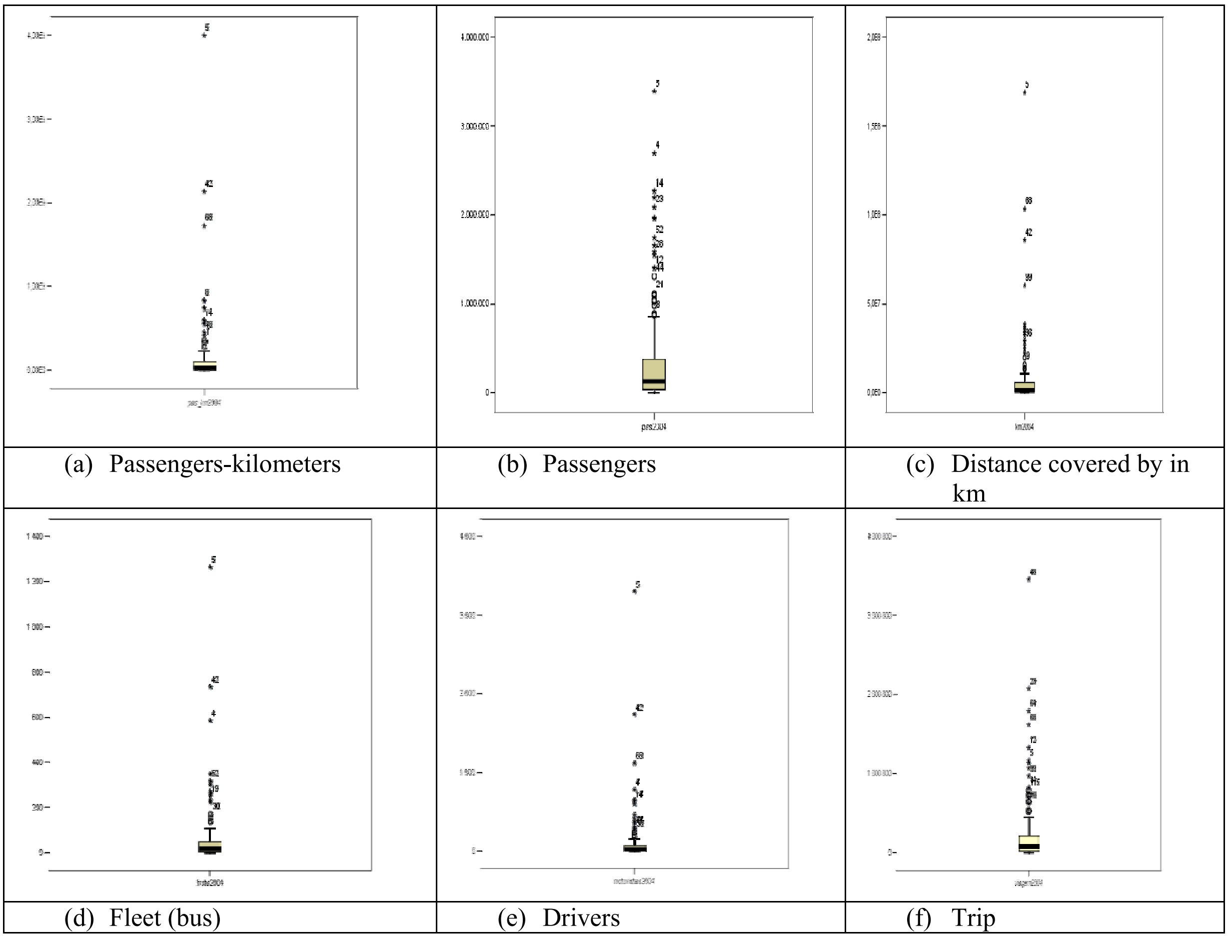
Year	Var.	Total	CV	Average	SD	Var	Min.	Max.	Med.	1º Quartil	3º Quartil
2004	pass-km	2,3E+10	7,5E-01	1,0E+08	7,7E+07	3,1E+16	1,5E+04	8,4E+08	3,6E+07	9,3E+06	1,2E+08
	pass	5,6E+07	4,8E-01	3,3E+05	1,6E+05	2,3E+11	2,3E+02	2,7E+06	1,5E+05	5,5E+04	3,8E+05
	km	1,2E+09	1,5E+00	5,3E+06	7,7E+06	6,9E+13	7,8E+02	3,7E+07	1,8E+06	6,7E+05	5,9E+06
	fleet	1,0E+04	1,0E+00	5,2E+01	5,4E+01	6,8E+03	1,0E+00	5,9E+02	2,8E+01	8,0E+00	5,6E+01
	driver	1,8E+04	1,7E+00	7,7E+01	1,3E+02	1,8E+04	1,0E+00	7,8E+02	2,8E+01	9,3E+00	7,4E+01
	trip	3,7E+07	8,3E-01	2,2E+05	1,9E+05	1,3E+11	1,3E+02	2,1E+06	8,8E+04	2,8E+04	2,5E+05
2005	pass-km	2,4E+10	2,1E+00	1,1E+08	2,4E+08	4,1E+16	1,2E+04	1,2E+09	3,2E+07	1,0E+07	1,3E+08
	pass	5,3E+07	1,1E+00	3,5E+05	4,0E+05	2,7E+11	1,6E+02	2,8E+06	1,6E+05	5,4E+04	3,8E+05
	km	1,2E+09	1,7E+00	5,6E+06	9,8E+06	7,6E+13	7,8E+02	4,8E+07	2,0E+06	6,2E+05	6,3E+06
	fleet	9,6E+03	8,3E-01	4,8E+01	4,0E+01	4,4E+03	1,0E+00	4,0E+02	2,5E+01	9,0E+00	5,2E+01
	driver	1,8E+04	2,0E+00	8,1E+01	1,6E+02	2,0E+04	1,0E+00	8,2E+02	3,1E+01	1,0E+01	7,6E+01
	trip	3,7E+07	8,3E-01	2,2E+05	1,9E+05	1,3E+11	1,3E+02	2,1E+06	8,8E+04	2,8E+04	2,5E+05
2006	pass-km	2,2E+10	2,5E+00	1,1E+08	2,7E+08	3,8E+16	1,1E+04	1,3E+09	3,6E+07	1,1E+07	1,2E+08
	pass	5,3E+07	1,2E+00	3,3E+05	4,0E+05	2,2E+11	1,2E+02	2,5E+06	1,5E+05	4,9E+04	3,8E+05
	km	1,2E+09	1,9E+00	5,6E+06	1,1E+07	8,3E+13	7,8E+02	5,2E+07	2,1E+06	6,3E+05	6,1E+06
	fleet	1,1E+04	9,4E-01	5,4E+01	5,1E+01	6,1E+03	1,0E+00	5,1E+02	2,8E+01	1,0E+01	6,2E+01
	driver	1,7E+04	2,0E+00	8,1E+01	1,6E+02	1,9E+04	1,0E+00	7,8E+02	3,2E+01	9,3E+00	7,7E+01
	trip	3,7E+07	7,4E-01	2,2E+05	1,6E+05	1,3E+11	1,3E+02	1,9E+06	8,8E+04	2,9E+04	2,1E+05

Var. = variables; CV = coefficient of variation; SD =standart deviation; Var = variancy; Min. = minimum; Max. = maximum; pass-km = passengers-kilometers produced; pass = passengerstransported; km = distance yearly covered by the fleet; e driver. = drivers.

The constant information of Table 2 enables to verify that the production of pass-km, the number of passengers transported (pass) and the number of drivers registered insignificant increases in 2005 in percentage points, respectively from 0,54, 0,70 and 1,58 with relation to 2004, as well as a reduction in 2006 in percentage points, respectively from 5,46, 4,89 and 2,24 in relation to 2004. On its turn, the distances yearly covered by the fleet (km) presented reductions in 2005 and 2006 in relation to 2004, respectively from 2,64 and 3,28 percentage points. On the other hand, the fleet was reduced in 2005 into 6,88 percentage points and increased in 2006 in 4,08% relation to 2004.

The elevated values correspondent to the variance and standard deviation, for each one of the variables represented in Table 2, indicate the differentiation between the companies in terms of quantity, relevance and materiality of markets served, and in terms of the size of the firms according to the fleet and to the number of employed drivers. This data points out that the information of some firms can cause an obliquity in the intended analysis, since it might not be considered that large companies have differences in scale with relation to small companies. The difference in scale suggests a possible grouping for small, medium and big companies in order to satisfy the prerequisites that the DMUs are supposed to accomplish in a DEA model. They must accomplish the same tasks and have similar goals, and also, they must have similar "market conditions".

According to this, the box plot of the variables for the identification of possible outliers was elaborated. The results for 2004 are expressed in Figure 3.



(a) Passengers-kilometers

(b) Passengers

(c) Distance covered by in km

(d) Fleet (bus)

(e) Drivers

(f) Trip

Figure 3 – Box plot of the variables referent to 2004

The result in Figure 3 indicates the existence of companies with a behavior different from the sample of 162 firms in 2004, fact which was observed for 2005 and also for 2006. It was noticed that, in the selected period, 60 companies presented an atypical behavior, being eliminated from the DB in order to avoid some obliquity in the final results.

Table 3 – Result of the correlation between the variables, period 2004-2006

Variables	pass-km2004	pas2004	km2004	Fleet 2004	Drivers 2004	Trip 2004
pass-km2004	1,00	-x-	-x-	-x-	-x-	-x-
pass2004	0,83	1,00	-x-	-x-	-x-	-x-
km2004	0,91	0,71	1,00	-x-	-x-	-x-
fleet2004	0,90	0,82	0,87	1,00	-x-	-x-
drivers2004	0,86	0,69	0,88	0,92	1,00	-x-
Trip 2004	0,71	0,76	0,70	0,63	0,56	1,00
Variáveis	pass-km2005	pass2005	km2005	Fleet 2005	Drivers 2005	Trip 2005
pass-km2005	1,00	-x-	-x-	-x-	-x-	-x-
pass2005	0,84	1,00	-x-	-x-	-x-	-x-
km2005	0,95	0,78	1,00	-x-	-x-	-x-
fleet 005	0,86	0,81	0,89	1,00	-x-	-x-
drivers2005	0,90	0,78	0,84	0,83	1,00	-x-
trip2005	0,67	0,74	0,72	0,68	0,52	1,00
Variáveis	pass-km2006	pass2006	km2006	fleet2006	drivers2006	trip2006
pass-km2006	1,00	-x-	-x-	-x-	-x-	-x-
pass2006	0,82	1,00	-x-	-x-	-x-	-x-
km2006	0,93	0,73	1,00	-x-	-x-	-x-
fleet2006	0,85	0,79	0,87	1,00	-x-	-x-
drivers2006	0,91	0,79	0,90	0,89	1,00	-x-
trip2006	0,58	0,65	0,66	0,62	0,58	1,00

pass-km = passengers-kilometers produced; pass = passengers transported; e km = distance yearly covered by the fleet.

It is observed in Table 3 that the representative production variable of passengers-kilometers (pass-km) registered a high positive correlation for the period of 2004-2006 in relation to the distance yearly covered by the fleet (km). This was expected, since one is a composition of the other. There was also a high positive correlation o pass-km in relation to fleet and number of drivers, and low positive correlation in relation to the number of trips accomplished. On its turn, the variable km presented a high positive correlation in relation to the number of drivers, especially in 2006, and low positive correlation in relation to trips accomplished.

According to the concepts of economy applied to transports (Hensher and Brewer, 2001; Rus, Campos and Nombela, 2003), the information referent to passengers-kilometers (pass-km) can be adopted as a proxy billing, whereas the yearly distance covered by the fleet (km) is a good approximation of fuel consumption, while fleet represents the immobilized capital and the number of drivers refers to the workforce utilized.

Thus, considering the constant result of Table 3 and the economy concepts applied to transports, the choice was to maintain in the DB the information referent to the variables pass-km, km, fleet and drivers. It is important to reinforce that the values of the output variables and input constants in the DB have been reported with operational information of the TRIP services offered by the companies and, based on this data, the analysis is going to indicate the degree of efficiency of a company in the offering of TRIP services in journeys superior to 75 km in Brazil.

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A the end of this process, the DB got composed of information of 102 companies (DMUs) and four variables, being three referent to inputs (fuel consumption – km, capital invested – fleet and workforce – drivers) and one relative to a product (billing – pass-km).

<u>Stage 3: DEA Modelling</u>

For the modeling of this work, the input-oriented BCC model was used, according to equation 5:

$$Efficiency = \frac{\beta_1 pass.km}{\beta_2 km + \beta_3 fleet + \beta_4 drivers} \quad (5)$$

In which *pass-km* represents the annual production of passengers-kilometers, *km* corresponds to the traveled distance annually by the fleet in kilometers, *frota* amounts to the total number of buses used by the companies, *motoristas* indicates the total number of drivers in each company, and β_n: refers to the coefficients to be estimated by the model.

The utilization of this model is due to the different sizes of the transportation companies analyzed. In other words, the BCC model prevents big companies, which present great values in the variables of the model, from being benefited in relation to small companies.

The BCC model makes it possible, considering all the care in selecting the variables, to identify, to isolate, and to analyze as many groups of companies as possible, according to their sizes. It allows to verify the company's efficiency, according to the input and/or output allocation inside the group in which the model has been inserted. Like this, the company with the best efficiency will be the *benchmarking* for all the inefficient companies that make part of the group. This will remove distortions by homogenizing the relative value to the company's size. In addition, works such as Merewitz (1977); Else (1985); Obeng (1985); Hensher (1987); White, Turner and Mbara (1992); Holvad *et al.* (2004); Novaes and Medeiros (2008) and Araújo, Martins and Silva (2008) used this modeling for the passenger's transportation, in which the last two works were developed for the Brazilian case.

<u>Stage 4: Model's Analysis</u>
Due to the importance of stage 4 in this work, it was decided to write in a specific section the analysis of the result, which does not interfere with the outline represented in Figure 2.

4. ANALYSIS OF THE MODEL'S RESULTS

4.1 Efficiency analysis 2004-2006

Before starting the analysis of the results is important to mention that for a sequential analysis over time, it is fundamental that the number of DMUs (companies) and the variables be the same year after year, because of the prerequisites for the DEA technique. Thus, according to the determined model, results for three years (2004, 2005 and 2006) were obtained, in accordance with Table 4.

Table 4 – Efficiency scores for 102 TRIP companies with the BCC model constructed

DMUs	Efficiency			DMUs	Efficiency			DMUs	Efficiency			DMUs	Efficiency		
	2004	2005	2006		2004	2005	2006		2004	2005	2006		2004	2005	2006
1	1,00	1,00	1,00	28	0,74	0,70	0,78	55	0,61	0,60	0,46	82	0,84	1,00	0,95
2	0,72	0,62	0,59	29	1,00	1,00	0,73	56	0,83	0,87	1,00	83	0,36	1,00	1,00
3	0,84	0,72	0,72	30	0,73	0,74	0,70	57	0,79	0,86	0,60	84	1,00	1,00	1,00
4	1,00	1,00	0,84	31	0,62	0,62	0,65	58	0,51	0,58	0,32	85	0,81	0,95	0,85
5	1,00	0,92	0,87	32	0,96	1,00	0,82	59	0,57	0,77	0,69	86	0,59	0,58	0,54
6	0,59	0,58	0,75	33	1,00	0,86	0,83	60	0,72	0,77	0,70	87	0,44	0,56	0,59
7	1,00	0,90	0,78	34	0,68	0,73	0,68	61	0,55	0,59	0,64	88	0,53	0,69	0,64
8	0,57	0,55	0,46	35	1,00	0,81	0,69	62	0,59	0,60	1,00	89	0,51	1,00	0,74
9	1,00	1,00	1,00	36	0,64	0,75	0,60	63	0,89	1,00	1,00	90	0,64	0,70	0,51
10	0,69	0,67	0,58	37	0,68	0,67	0,62	64	0,72	1,00	1,00	91	0,63	0,96	0,70
11	0,54	0,44	0,61	38	0,86	0,88	0,81	65	0,92	0,95	0,92	92	0,62	1,00	1,00
12	0,97	0,97	0,75	39	1,00	0,96	0,77	66	0,39	0,28	0,17	93	0,75	0,73	0,66
13	0,92	0,76	1,00	40	0,66	0,62	0,63	67	0,90	0,87	0,75	94	0,87	0,60	0,49
14	0,58	0,74	0,62	41	0,55	0,54	0,45	68	0,79	0,89	0,62	95	0,68	0,70	0,49
15	0,70	0,75	0,65	42	0,55	0,66	0,57	69	0,79	0,72	0,65	96	0,47	0,46	0,46
16	0,54	0,42	0,27	43	0,81	0,75	0,65	70	0,64	0,65	0,56	97	0,77	0,99	0,85
17	0,81	0,70	0,61	44	1,00	0,86	0,79	71	0,25	0,33	0,31	98	0,72	0,77	1,00
18	0,69	0,65	0,59	45	0,32	0,32	0,34	72	0,35	0,42	0,44	99	0,95	0,91	0,80
19	0,90	0,95	0,77	46	1,00	1,00	0,78	73	0,61	0,59	0,59	100	0,45	0,46	0,41
20	0,45	0,24	0,26	47	0,88	1,00	1,00	74	0,51	0,34	0,35	101	1,00	0,96	0,93
21	0,26	0,28	0,24	48	0,82	0,82	0,76	75	0,56	0,60	0,72	102	0,45	0,47	0,38
22	0,93	0,94	1,00	49	0,30	0,24	0,31	76	0,52	0,66	0,62	**AVERAGE**	**0,70**	**0,72**	**0,67**
23	0,44	0,39	0,52	50	0,75	0,76	0,54	77	0,75	1,00	0,86	**No. EF**	**13**	**15**	**13**
24	0,53	0,67	0,62	51	0,71	0,79	0,66	78	1,00	0,84	0,77				
25	0,56	0,46	0,61	52	0,74	0,70	0,68	79	0,75	0,41	0,35				
26	0,49	0,54	0,67	53	0,37	0,40	0,48	80	0,52	0,50	0,52				
27	0,64	0,71	0,55	54	1,00	0,90	0,84	81	0,64	0,50	0,55				

The constant result in Table 4 indicates that, in terms of medium values, the companies registered efficiency of 0,70 in 2004. In 2005, there was an increase in the average (0,72) of about 3 percentage points, while there was a reduction in the average (0,67) equals to 5% in 2006, being the variables considered in relation to 2004.

As to the number of efficient companies, that is, those with score equals to 1, it was observed the existence of 13 companies in 2004, 15 in 2005 – which corresponds to an increase of 15 percentage points, and 13 in 2006.

The Table 5 was created with the objective of comparing the average variations of the input and output variables in the period of 2004-2006 of the 102 companies analyzed.

Table 5 – Average variation of the input and output variables in the period of 2004-2006

Period	Km	drivers	Fleet	pass_km
Var 2004-2005 (%)	5,8	6,2	-7,2	10,4
Var 2004-2006 (%)	6,1	5,4	5,5	4,0

pass-km = passengers-kilometers produced; km = traveled distance anually by the fleet.

It is observed in Table 5 that the production of pass-km increased 10,4 and 4,0 percentage points, respectively, in 2005 and 2006, in relation to 2004, which registered a production of $10{,}49 \times 10^9$ pass-km in absolute values for the 102 companies analyzed. The increase in the production was accompanied by an increase in the input consumption related to the variables *km* and *drivers*, while *fleet* registered a reduction in 2005 and an increase in 2006.

The increase in the production verified in 2005 is related to an addition to the traveled distance by the fleet in kilometers and to a variable that was not adopted in the model that shows the quantity of passengers transported. This is due to the fact that *pass-km* corresponds to the sum of the product of passengers by the traveled distance. However, in 2006 the same is not applied wholly, because there was an irrelevant decrease in the quantity of passengers transported. In other words, the increase in the production reflects basically the addition of the traveled distance by the fleet in 2006.

The reduction of the fleet in 2005 may be considered strange due to the increase in the number of passengers transported as well as the traveled distance. However, this indicates a possible existence of idle capacity installed and a larger utilization of the fleet in 2005. It can be inferred that there was a better allocation of this input in 2005.

It is also important to mention that the fleet reduction does not exclude its renovation, considering the possibility that the companies might have transferred old buses and bought new ones, being the transferred quantity bigger than the acquired, which demonstrates, on the one hand, a better application of the money invested and, on the other hand, a reduction in the expenses on the maintenance of the fleet, favoring the companies' efficiency. In 2006, the increase in the fleet, considering the decrease in the number of passengers transported, points to the fact that the companies might have, in a first moment, overinvested. Yet, it should be mentioned that there are months of the year that are considered to be critical as to the offer of

TRIP services, specifically, those of high demand: December, January, February, and July. Thus, this increase required hiring of new drivers.

The increase of drivers in 2005 and 2006 can be considered strange, too. Nevertheless, it can be associated with the question of the security of the service's user in a way that the companies respected the labor rules, especially those regarding the maximum time of the driver's permanence driving the bus, as well as the increase in the fleet to supply months with a high demand.

In general terms, when analyzing the period of 2004-2006, the increase of production was accompanied by the quantity of input required, each one with its particularities, as shown above. This is reflected in an addition of almost 3 percentage points in the average efficiency registered in 2005. The reduction of almost 5 percentage points in the average efficiency in 2006, compared to 2004, thanks to a possible inefficiency in the input allocation, must be pondered based on the peculiarities mentioned above.

4.2 Benchmarks

The companies that form the surface of efficiency serve as reference (benchmarks) for inefficient ones so that these can be able to measure their inefficiency degree and look for solutions for input reduction and output expansion. It is worth mentioning that due to the fact that the TRIP is regulated, an output expansion might not occur. Because of that, strategies to reduce the input of the companies were searched.

Table 6 shows, year after year, the group of inefficient companies in relation to the efficient ones, and it also brings the number of how many times the efficient served as reference for the inefficient. However, it considers only those who had more than 20% of influence, that is, the importance of the efficient company so that an inefficient company can achieve this level of importance. This cut was made with the objective of eliminating from the counting those companies that had either a low or an insignificant level of importance.

Table 6 – Number of times in which efficient companies appear as reference year after year

2004															
E. E.	**1**	**4**	**5**	**7**	**9**	**29**	**33**	**39**	**44**	**46**	**54**	**84**	**101**		
NVR	18	3	57	24	44	37	2	32	10	5	5	55	20		
NVR>0,2P	2	1	10	2	12	27	1	13	7	4	1	52	16		
2005															
E. E.	**1**	**4**	**9**	**29**	**32**	**46**	**47**	**63**	**64**	**77**	**82**	**83**	**84**	**89**	**92**
NVR	30	1	36	27	8	58	4	11	23	11	7	22	63	26	6
NVR>0,2P	5	1	8	14	3	5	1	4	17	2	3	3	56	12	2
2006															
E. E.	**1**	**9**	**13**	**22**	**47**	**56**	**62**	**63**	**64**	**83**	**84**	**92**	**98**		
NVR	29	56	1	8	2	74	1	5	12	25	70	8	17		
NVR>0,2P	5	17	1	2	1	27	1	2	6	5	66	2	12		

E.C.=efficient company; NTR=number of times in which the company appears as reference; NTR>0,2P=number of times in which the company appears as reference with values over 29%.

It can be observed in Table 6 that companies 5, 9, 29, 39, and 84 were the ones that appeared as *benchmarks* for inefficient companies in 2004. Considering values over 20%, it can be verified that companies 29 and 84 stood out as reference for inefficient companies in 2004. However, companies 29, 23, 84, and 89 stood out as *benchmarks* in 2005 and by adopting the cut presented, company 84 can be seen as the one of most prominence. In 2006, companies 9, 56 and 84 were adopted as reference, with 56 and 84 over the cut of 20%.

Furthermore, it can be observed that the group of efficient companies changes year after year. Nevertheless, companies 1, 9, and 84 appeared in all three years of the study. In other words, these companies kept efficient along the time, while others appeared and/or disappeared of the level of efficiency along the time, that is, they did not follow the variations of the market during that period. It is important to mention that the highlighted companies are of different sizes, and they served as reference for inefficient companies of different sizes as well, in a way that inefficient companies stood out regardless their sizes in the edge (formed by the combination of 2 efficient companies) or in the surface, also called facet (formed by 3 or more efficient companies).

The present work did not aim at presenting or discussing concepts related to the size of TRIP companies in Brazil, distributing companies by means of any attribute, such as size of the fleet or a classification in big, medium, or small company, since there is a variation among data of DB. However, the projection of the inefficient companies in the facets formed by efficient companies is extremely important for this research, and its comprehension becomes easier thanks to segregating the companies somehow, at least to highlight some relevant cases. With this objective and to give an example, the companies were selected in three groups according to the size of their fleets: (a) Type 1: 1 bus ≤ fleet ≤ 99 buses; (b) Type 2: 100 buses ≤ fleet ≤ 150 buses; and (c) Type 3: 151 buses ≤ fleet.

Thus, inefficient companies classified as type 2 and 3 as to the size of their fleets were identified in order to map the facets in which they stood out along the time and to verify the evolution through time. The results can be observed in Table 7.

Table 7 – Projection of inefficient companies in function of the size of the fleet to the facets of efficient companies by attribution of values in %.

DMU (Tipo)	DMU	2004 – Efficient Companies (types)													Total Wheight %	[redacted]
		1 (3)	4 (3)	5 (2)	7 (1)	9 (2)	29 (1)	33 (2)	39 (1)	44 (1)	46 (3)	54 (1)	84 (1)	101 (1)		
2	2	0	0	0	0	74	0	0	0	0	0	0	26	0	100	
	5	0	0	100	0	0	0	0	0	0	0	0	0	0	100	
	33	0	0	0	0	0	0	100	0	0	0	0	0	0	100	
	37	28	0	20	0	0	0	0	0	0	0	0	0	52	100	
3	4	0	100	0	0	0	0	0	0	0	0	0	0	0	100	
	13	0	5	20	0	0	0	0	0	0	75	0	0	0	100	
	17	0	11	58	0	0	0	0	0	0	31	0	0	0	100	
	22	0	0	2	15	0	0	0	0	0	83	0	0	0	100	
	23	0	0	50	0	0	0	0	9	0	0	0	0	41	100	
	46	0	0	0	0	0	0	0	0	0	100	0	0	0	100	

	83	0	0	48	0	0	0	15	37	0	0	0	0	0	100
n.º de facets		1	2	6	1	1	0	1	1	0	3	0	1	2	

DMU (Tipo)	DMU	2005 – Efficient Companies (types)															Total Wheight %
		1 (3)	4 (3)	9 (2)	29 (1)	32 (1)	46 (3)	47 (1)	63 (1)	64 (1)	77 (1)	82 (1)	83 (3)	84 (1)	89 (1)	92 (1)	
2	2	0	0	67	0	0	0	0	0	0	0	0	0	0	33	0	100
	5	18	0	0	0	0	1	0	0	0	0	0	28	53	0	0	100
	33	0	0	0	0	0	33	0	0	32	0	0	20	15	0	0	100
	37	39	0	47	0	0	0	0	14	0	0	0	0	0	0	0	100
3	4	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100
	13	51	0	0	0	0	48	0	0	0	0	0	1	0	0	0	100
	17	51	0	9	0	0	39	0	0	0	0	0	0	1	0	0	100
	22	0	0	0	4	10	86	0	0	0	0	0	0	0	0	0	100
	23	47	0	0	0	0	3	0	0	0	0	0	2	48	0	0	100
	46	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	100
	83	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	100
n.º de facets		5	0	3	1	1	6	0	1	1	0	0	4	4	1	0	

DMU (Tipo)	DMU	2006 – Efficient Companies (types)													Total Wheight %
		1 (3)	9 (2)	13 (3)	22 (3)	47 (1)	56 (1)	62 (1)	63 (1)	64 (1)	83 (3)	84 (1)	92 (1)	98 (1)	
2	2	0	44	0	0	0	0	0	0	0	0	56	0	0	100
	5	13	0	0	0	0	63	0	0	0	24	0	0	0	100
	33	0	16	0	17	0	41	0	0	0	26	0	0	0	100
	37	39	47	0	0	0	12	0	0	0	0	2	0	0	100
3	4	53	0	0	0	0	0	0	0	0	47	0	0	0	100
	13	0	0	100	0	0	0	0	0	0	0	0	0	0	100
	17	14	53	0	5	0	0	0	0	0	28	0	0	0	100
	22	0	0	0	100	0	0	0	0	0	0	0	0	0	100
	23	56	13	0	0	0	30	0	0	0	1	0	0	0	100
	46	52	9	0	39	0	0	0	0	0	0	0	0	0	100
	83	0	0	0	0	0	0	0	0	0	100	0	0	0	100
n.º de facets		6	6	0	3	0	4	0	0	0	5	2	0	0	

It can be observed in Table 7 that type 2 DMUs 5 and 33 (100 buses ≤ fleet ≤ 150 buses) were above the level of efficiency only in 2005, passing to the group of inefficient companies in 2005 and 2006. Among the type 3 DMUs (151 buses ≤ fleet), companies 4 and 46 left the level of production reached in 2004 and 2005, while 13 and 22 became efficient in 2006, and 83 in 2005 and 2006. It can be noted, therefore, that the standard of efficiency of some type 2 and 3 companies changed along the time, which was expected to happen.

Table 7 also shows the number of times, year after year, in which the efficient companies were *benchmarks* or appeared in any facet for type 2 and 3 inefficient companies. The efficient companies that registered zero as number of times in facets indicate that they were *benchmarks* for type 1 inefficient companies (1 bus ≤ fleet ≤ 99 buses), but they did not appear in the table. It can be perceived, therefore, that the number of times in which the efficient companies, year after year, served as reference varied in the period of 2004-2006, which was also expected. It is worth highlighting the situation of companies 1 and 9, which besides keeping efficiency along the three years, they also improved their participation in the formation of reference facets.

It can be seen that for cases represented in Table 7, there are 7 facets in 2004 and eight in 2005 and 2006. The constant facets in Table 7 are not formed by groups of companies of the same type, except one case in 2005 formed by companies 1, 46, and 83, all of them type 3 (151 buses ≤ fleet), and one case in 2006 formed by companies 1 and 83, also type 3. Thus, inefficient companies, year after year, stood up in the facets no matter the size of the fleets of the *benchmark* companies. Instead, proportionally to the value registered, they got closer to one or other reference company.

In terms of values, two projections stood out among those represented in Table 7 for the period of 2004-2006, that comprehends DMUs 13 and 22, both type 3 (151 buses ≤ fleet). This occurs due to the fact that DMU 13 stood out in the facet formed by the efficient companies 4, 5 and 46 in 2004, respectively with proportional values of 5%, 20% and 75%, which indicates that the DMU got closer to company 46, also a type 3. In 2004, DMU 22 stood out in the facet formed by the efficient companies 5, 7, and 46, respectively with proportional values of 2%, 15%, and 83%, which demonstrates that the DMU got closer to company 43, also a type 3. In 2005, DMU 22 stood out in the facet of companies 29, 32, and 46 with proportional values of 4%, 10% and 86%, respectively, pointing once again to an approximation to company 46. Finally, DMUs 13 and 22 reached the frontier of production in 2006, with the highest efficiency level, which allows saying that while company 46 was at the frontier of production, it represented a strong *benchmark* for those DMUs.

4.3 Reduction goals

The projection of the inefficient companies in the efficiency frontier occurs in two ways. The first is only proportional, which is the result of the multiplication of the efficiency indicator calculated by the results of each unit. The second is a combination between proportional reduction and aggregation of breaks. The results of the projections are the global goals that each inefficient unit could reach to become efficient.

Figures 4, 5, and 6 present the possible proportional reductions (areas) or global goals in relation to 2004, with aggregation of breaks obtained by the model for the variables *km*, *drivers*, and *fleet*, respectively. For 2005 and 2006, we registered only comments on its proportional reductions.

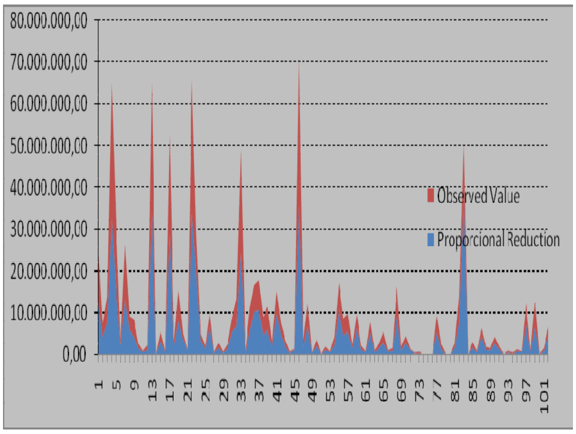

Figure 4 – Proportional reductions *km*2004

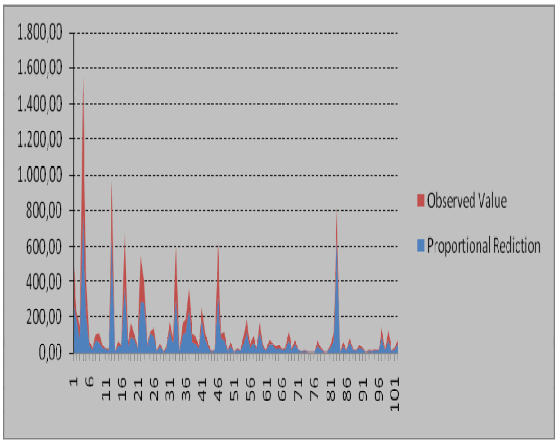

Figure 5 – Proportional reductions *driver*2004

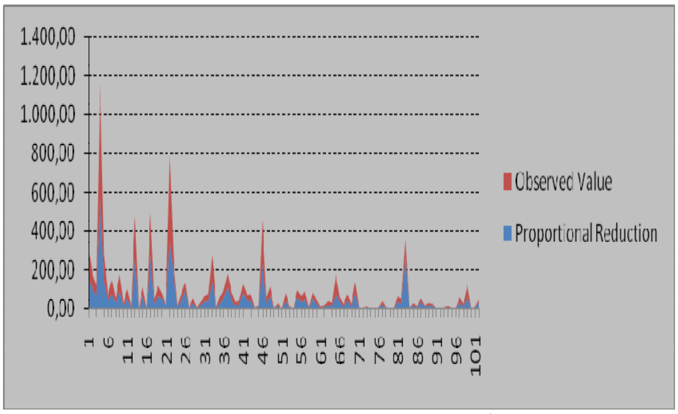

Figure 6 – Proportional reductions *fleet*2004

We can see in Figures 4, 5, and 6 that if the companies had reduced their inputs in 2004, then they could have achieved the frontier. This is a fact that could be also applied for 2005 and 2006. Table 8 shows the possible average reductions that the companies could have done in their input in order to become efficient.

Table 8 – Possible proportional average input reductions of the companies in the period of 2004-2006

	km	Motorista	Frota
2004	-22%	-34%	-17%
2005	-19%	-31%	-16%
2006	-26%	-37%	-21%

The model's result suggests that, in 2004, companies could have reduced the *km* input (Proxy for oil consumption) in 22%, manpower in 34%, and fixed assets in 17%. In 2005, these reductions could have been lessened due to a higher efficiency achieved by the companies in that year. In 2006, however, the contrary was observed since a higher level of inefficiency in relation to the previous years was verified.

It is important to mention that the reductions indicated in Table 8 are related to the breaks existing in the input. It means that besides proportional reduction, it could be possible to reduce more the input in order to reach a level even closer to efficiency. This occurred for the variables *km*, *drivers*, and *fleet* with about 8%, 25%, and 15% of the companies, respectively, during the three years of the study. As to the output breaks, which represented the company's capacity of extension even with the reduction of input, small values for the three years were observed, indicating that these companies had a higher production with less input.

The result indicates the possibility of a *yardstick* type regulation, because less rigid regulation of technical and operational parameters, such as minimum fleet and drivers' extra hours, could favor a better efficiency for the companies. This could also provide a change in the behavior among them and, possibly, a higher competition considering scale profits, and consequently, reductions in expenses and higher profits could be studied for sharing with tariff modicity.

5. FINAL CONSIDERATIONS

1. The efficiency analysis of companies engaged in interstate passenger coach services in Brazil, which operate interstate routes over distances greater than 75 km, observed in this study has a preliminary objective, but it represents an evolution in relation to the studies already carried out regarding this topic, considering the sample's size (102 companies), the period of the study (from 2004 to 2006), and the quantity of input/output variables adopted.

2. As to the present research, it is important to highlight that the Data Envelopment Analysis allowed building an efficiency frontier for the 102 TRIP companies studied in Brazil, based on the variables *km* (proxy for oil), *fleet* and *drivers* as input, and *passengers-kilometers* as output. As to this last variable, it was possible to identify companies that formed the frontier peaks, being considered efficient or examples of having good operational practices for the sample analyzed.

3. The model constructed for the three-year analysis showed that there was efficiency changes along the years and also showed that the last year presented the lowest efficiency level of all years. This efficiency was lower, probably, due to a market expansion from 2004 to 2005 and a significant increase in the fleet, which was decreased in the following year (according to Table 5), thus occurring an excess of capacity installed.

4. It was also observed that the *benchmarks*, that is, efficient companies that served as reference for inefficient companies, could be classified in small, medium, or big groups. Thus, big size efficient companies were reference for big size inefficient companies. The same occurred for medium and small companies. The findings might contribute to a more

detailed study of group-divided companies in order to better understand the operational behavior of efficient companies, trying to expand these finding to other companies. This stratified study can be applied in the different treatment of the companies, taking into consideration its characteristics.

5. Furthermore, there is a possibility of reduction of input to make the TRIP system more efficient. It was noted that the variables made possible an input reduction from 166% to 37%. The variable *driver* (proxy for manpower) was the one that required a higher reduction in the period of 2004-2006, indicating that it deserves special attention from the TRIP operators, because it strongly influences the companies' efficiency.

6. Finally, the DEA technique proves to be a possibility of tool for measuring the companies' efficiency towards services and policies such as fleet flexibility, expansion of productive capacity, extra hours for drivers, and others. besides, it is possible to identify patterns of efficient operation and establish performance goals to be achieved by the companies in each pre-determined period of time.

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