Efficiency Analysis of Public Transport Systems: Lessons for Institutional Planning

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ABSTRACT: The Transport System of the Recife Metropolitan Area is under change. As a subsidy to its change an efficiency analysis is done with the purpose of highlighting characteristics of the efficient systems. Nineteen transport systems are analyzed, twelve from several countries in Europe and seven from Brazil: nine from Europe and only one from Brazil were found efficient. These systems are characterized by very different power structure and tariff structure. Efficient ones adopted a more democratic power partition among communalities and established a more broad system of tariffs. Among other lessons it is suggested that RMR adopts a structure that allows a more equal partition of the several municipalities comprising the Metro Area including representatives of users groups like workers associations and syndicates. Also it should adopt a more flexible tariff systems giving advantages to usual users at the same time that decreases costs and improves the operational efficiency.

INTRODUCTION

Metropolitan areas have experienced in the last decades an increasing expansion bringing, as a consequence, several socio-economic problems such as an unequal spatial urban development, a high pressure on disposable infrastructure, land and housing shortages and, with emphasis, lack of urban services. These problems, in addition to low income and unemployment, expel poorer people to urban peripheries where housing costs are lower. But these peripheries are diploid of public services and increase the cost of providing urban infrastructure. Public transport, in particular, planned to operate in more density populated areas, offer a lower frequency and quality service, due in part to larger distances and a precarious road system. Unorganized urban expansion leads to an unorganized and irrational transport system in which superimposition of routes is one of its characteristics. In addition, municipal system if not centrally coordinated results in superimposition and low coordination of routes and irrationality of the whole system.

Urban expansion, a conurbation phenomenon in which city limits loose expression bring planning difficulties. Notwithstanding the difficulties, people require in each area an adequate public transport that allows easy moves to work, shopping, educational, health and cultural centers. Thus, a metropolitan public transport system needs to assure mobility and accessibility through a fast, secure, regular and trustable transport at a reasonable cost. Unfortunately it is not easy to assure all these characteristics due to complex institutional arrangements between state and several municipalities. Thus, a first step consists of working an agreement among all political institutions involved. In particular, questions such as power division among them, administrative coordination, financing and selection and operation of all concession to operate the several services involved (bus, metro, vans, and so).

The main objective of this paper consists of directive propositions to a new institutional arrangement to the Recife Metropolitan Area - RMA based on efficiency analysis of several transport systems. A Data Envelopment Analysis – DEA is adopted to select efficiency systems and their characteristics are analyzed to highlight key propositions that may help the improvement of RMA transport system.

In the next section questions related to quality and efficiency in public transport systems are revised. In the third section efficiency analysis and the DEA method are presented. In the fourth section, prior efficiency studies of transport systems are briefly revised. In the fifth section the systems analyzed, data basis and selected variables are presented. In the sixth section the Recife Metropolitan Area Transport Agency and the Metropolitan Transport Consortium are described. The following two sections bring the results and a discussion of its consequences. Finally, in the last section, proposals for the institutional re-organization of RMA are shown.

QUALITY AND EFFICIENCY IN PUBLIC TRANSPORT

Quality and efficiency of public transport systems may be analyzed based on several factors relating to the quality of the service that is offered – service performance - and to the performance of the agencies and companies in charge of it. As an example, Santos (2000) points several characteristics required for a good performance:

(a) System accessibility, determined by the distance between users origin and the initial station and between the last station and the final destination. The shorter this distance higher is route availability and, as a consequence, geographical coverage increases, making it easy and better to people to move from one place to the other.

(b) Travel time, determined by velocity and geometry of routes. Velocity is a function of distances, of traffic conditions and road quality. The geometry of routes is a function of the development of a complex connection of more direct and subsidiary routes.

(c) Trustworthiness, determined by uncertainty of time schedules. It can be measured by the number of trips on time in relation to the other with delay and how much are the delay. Punctuality bring users trust and fidelity.

(d) Frequency, determined by the time interval between each trip. Users must know the timetables, and its changes along the day, during weekends and other special occasions.

(e) Maximum load, determined by the number of passengers in rush hours in relation to vehicle capacity.

(f) Vehicle characteristics, including age, conservation and technology all bringing users comfort. Conservation requires general maintenance, and noise and temperature control. By technology one also understands door size, steps and adoptions required by special passengers.

(g) Adequate information and support facilities, such as covered stations, schedule and timetable information, clear indications of stations and vehicles.

(h) Mobility in accordance with necessities, that is, routes must be planned to cover the whole area and allow flexibility in choosing an appropriate route. In addition, adaptations are required to attend passengers with motion restrictions.

Besides quality requirements, efficiency is related to performance indicators, such as low operational cost to users, minimum number of vehicles and personnel but without a decrease in the quality of service provided. And efficacy is related to the number of users of public transport in relation to population, kilometers of routes provided in relation to area, and the satisfaction level, all represent in a high quality service for the lowest fare as possible.

MEASURING EFFICIENCY IN PUBLIC TRANSPORT – A DEA ANALYSIS

The efficiency of transport systems is determined by a Data Envelopment Analysis – DEA. Urban transport systems are considered decision making units – DMUs that relatively measured in relation to those that determine the efficiency frontier. There are two major approaches – a parametric and a non-parametric one. Parametric frontiers are characterized by a production function of constant parameters. This method was originally developed by Aigner and Chu (1968). A functional form is defined and usually it is estimated by econometric models. The specification of a functional form is the main limitation of the parametric approach, as efficiency measures vary according to the adopted function.

The non-parametric approach does not require the a priori specification of a function. The estimation of the frontier of the production set only requires that the production set satisfy some properties. The DEA method, a non-parametric approach, uses mathematical programming to estimate production frontiers and calculus efficiency scores. This method is based in the seminal paper by Farrell (1957) as later proposed by Charnes et al (1978).

In the DEA method, DMUs are assumed similar and differences results from input use and output obtained. It is assumed that the production set satisfy certain properties, as mentioned, but no assumption is made in relation to the frontier.

The production set is limited by a frontier that connects DMUs considered efficient. DMU efficiency determination results from estimation of a system of linear equation.

The model proposed by Charnes et al (1978), assuming constant returns to scale, may be represented by N firms or DMUs that use I input to obtain P products. Input and output quantities are represented by x_i and y_i and i refers to the ith DMU. The objective is to obtain a non-parametric frontier that envelopes the data in a manner that all united are placed on or under this frontier.

For each DMU the ratio between the weighted sum of inputs and the weighted sum of outputs is maximized, where u is a Px1 vector of weights associated to outputs and v a Ix1 vector of weights associated to inputs. The unknown vectors u and v are obtained as a result of the efficiency maximization of each DMU. For each DMU the following problem is solved:

$$\text{Max}_{u,v} \quad (u^t y_i / v^t x_i),$$
$$\text{Subject to} \quad (u^t y_j / v^t x_j) \leq 1, \quad j = 1, ..., N,$$
$$u \geq 0 \quad e \quad v \geq 0$$

The model presented obtains infinite solutions. If (u*, v*) is a solution, so (αu*, αv*) is also a possible solution. This problem was solved by Charnes (1978) imposing the condition $v^t x_i = 1$. Thus, the new programming model is:

$$\text{Max}_{u,v} \quad u^t y_i,$$
$$\text{subject to} \quad v^t x_i = 1,$$
$$u^t y_j - v^t x_j \leq 0, \quad j = 1, ..., N,$$
$$u \geq 0 \quad e \quad v \geq 0$$

This new model is known as a multiplicative model and presents a great number of restrictions. Using the linear programming dual property, the problem may be present in an equivalent form but with a smaller number of restrictions (I+P < N+1).

$$\text{Min}_{\theta,\lambda} \quad \theta,$$
$$\text{Subject to} \quad Y\lambda - y_i \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0.$$

Onde: θ – Efficiency Score;
λ – Nx1 constant vector;
X – Input Matrix (IxN);
Y – Output Matrix (PxN).

The linear programming model is solved N times, one for each DMU. The efficiency score θ might satisfy the condition $\theta \leq 1$.

Adopting the constant returns to scale assumption when not all DMUs are operating with optimal scale, may result in efficiency measures influenced by the scale efficiency. In this case, adopting variable returns to scale allows the measurement of efficiency independent of scale efficiency.

The model for variable returns was developed by Banker et al (1984), by addition of a convex restriction ($z^t\lambda = 1$):

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta, \\ &\text{Subject to } Y\lambda - y_i \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &z^t\lambda = 1, \\ &\lambda \geq 0 \end{aligned}$$

Where: z – N x 1 unitary vector.

One of the advantages of the DEA approach for measuring efficiency is that it produces automatically "target units" when inefficient units are found. These "target units" may be "virtual" and do not really need to correspond to a real DMU, that is, the "target unit" may be a linear combination of efficient units in relation to an inefficient DMU. Thus, at the same time that the DEA model identifies that a certain DMU is inefficient it also identifies the DMUs in relation to which this DMU is inefficient. It is determined a set λ weights, indicating a combination of efficient units and representing the output proportion that an inefficient unit could obtain using less inputs, in relation to "target units" (Régis, 2001).

BACKGROUND

Several studies have been carried out to analyze the efficiency of urban transport services, using non-parametric techniques. A brief review of some of these studies are presented.

Karlaftis (2004) presented a review of papers analyzing the performance of transport systems. Tomazinis (1977) specified a number of parameters to measure public transport systems and defined some basic concepts for the evaluation, such as efficiency, productivity and service quality. Fielding et al (1978, 1985a,b) presented an impressive number of parameters that could be used to evaluate performance, isolating three categories: efficiency, effectiveness and overall performance, this last one including the first two.

Viton (1997) studied the efficiency of the US bus system, applying DEA to a sample of 217 public and private companies, using the following parameters: vehicles / distance in miles and passengers transported (outputs) and average speed, fleet average age, miles traveled, gas used, personal employed in the transport service, maintenance personal, administrative personal, capital, and costs (inputs).

Chu et al. (1992) and Viton (1998) used a DEA model to develop a unique measure of performance and concluded that the US bus system improved its productivity between 1988 and 1992. Noted also that, in general, efficiency and effectiveness are negatively correlated.

Nolan (1996) studied technical efficiency in 29 average size US bus systems using a DEA model. As input used the number of buses, total number of employees and gas consumed and as output vehicles per mile.

Levaggi (1994) applied a DEA model to 55 urban transport companies in Italy. As output selected the number of kilometers traveled, average speed, capital represented by a proxy, the number of vehicles, and a coefficient of capacity defined by the ratio between passengers by kilometer and disposable seats per kilometer and population density. As input used employees cost, gas used, miles traveled, population density and number of vehicles. They concluded that companies operated with excess capital, excess bus capacity and that salaries represent a high percentage of total costs.

Karlaftis and McCarthy found that systems scoring highly on one attribute of performance (such as efficiency, effectiveness or overall performance) generally performed well on the remaining attributes, a finding that contradicts Chu et al. (1992).

Karlaftis (2004) applied a DEA model to 259 US systems, defining three different models according to parameters selected. The model differ on outputs: vehicles / distance in miles; passengers per mile or passengers transported; or both, jointly. As inputs, used: total number of employees, gas used and the number of vehicles. Concluded that efficiency is positively related to effectiveness and that the magnitude of the economies of scale depends on the output chosen.

Husain et al. (2000) also estimated a DEA to evaluate the efficiency of the public transportation service of Malaysia, a sample of 46 service units. As inputs used the number of employes and total labor costs. As output selected total service and companies gross revenue. They concluded that more efficient companies achieved higher revenues.

Pina and Torres (2001) used a DEA model to analyze the efficiency of public and private transport services in Spain. They choose as inputs: gas/ distance in kilometers; cost/km or cost/passenger; and subsidy/passenger. As output selected: bus number per kilometer per employee (bus-km/employee) a variable that provides information on urban transport performance in respect to total employees; number of buses per kilometer per year – a variable that shows average productivity and the bus utilization level; number of buses per kilometer per inhabitant, representing public transport offer in each city; and also as indicators of quality: the accident rate and frequency and agility of service provided.

SELECTED TRANSPORT SERVICES, VARIABLES AND DATA

It was decided to represent different systems to highlight diversities and similarities; from complex systems that combine several modalities such as tramways, metro and bus to very simple ones using only buses. The complexity partially reflects the dimension of the system: metropolitan areas serving several million or a few hundred thousand people. By combining several modalities and different city sizes efficiency analysis can be made more illustrative. In addition, developed countries are compared to Brazil.

Nineteen public metropolitan transport systems were analyzed (Table 1): seven Brazilian, five Spanish, two English, one French, one German, one Dutch, one Greek and one Lithuanian. The selection of different countries services is justified, even if public transport policies are different, because of proposals similarity, that is, all present the goal of decreasing inputs and increasing outputs, assuring the highest quality as possible. Data refers to 2001. Data analysis was applied only to systems showing consistency of the selected services; others systems that do not fulfill this condition were dropped out.

Five modalities are considered: urban bus, suburban bus, metro, suburban train and tramway. Only Bilbao and Valencia combine all five. Madrid and Barcelona do not offer tramway service. London, Manchester, Frankfurt and Amsterdam offer all but suburban bus. Seville offers urban and suburban bus and suburban train but do not have a metro and a tramway service. Lyon offers three modalities (urban bus, metro and tramway). Athens, Vilnius, Recife, Belo Horizonte and São Paulo offer only two: urban bus and metro with the exception of Vilnius that use tramway instead of metro. Fortaleza, João Pessoa, Salvador and Teresina offer only urban bus service. This diversity makes the analysis more consistent although policy implications must be draw carefully.

Four metropolitan areas represent more than five million inhabitants: São Paulo, London, Madrid and Frankfurt. Seven house from two to five million: Barcelona, Athens, Recife, Manchester, Salvador, Belo Horizonte and Fortaleza. Five represent from one to two million and three have below one million inhabitants: Teresina, Vilnius and João Pessoa. Modalities can be associated to dimension or to the quality of the provided service.

Table 1: Selected Metropolitan Services

Brazil[1]	European Systems[2]	
Cities	Cities	Country
Recife	Seville	Spain
Belo Horizonte	Madri	Spain
Fortaleza	Barcelona	Spain
João Pessoa	Bilbao	Spain
Salvador	Valencia	Spain
São Paulo	Londres	England
Teresina	Manchester	England
	Lyon	France
	Frankfurt	Germany
	Amsterdam	Holland
	Athens	Greece
	Vilnius	Lithuania

[1] Data for Brasilian services was obtained from ANTP (2001). [2] For other services, data is available in Internet sites and additional data was provided by the Services upon request by the authors.

It is known that selecting key indicators to evaluate performance of transport systems and comparing systems with use of mathematical models is a goal pursued by all authors, as a great number of indicators may turn almost impossible a comparison and makes it difficult to generalize results (Benjamin and Obeng, 1990).

Transport service efficiency analysis are based in three basic inputs: labor, gas and capital. Labor may be represented by total number of employees (operational, maintenance and administrative) or by the total labor cost. Gas used is obtained directly in gallons or litters per year. Capital may be represented by the number of vehicles. But several alternatives can be chosen, as shown in section 4. Defining output is more complex, but generally is based in efficiency and effectiveness indicators. Several authors have suggested (see, Fielding, 1987) the use of vehicles/ distance traveled as a measure of efficiency and the number of passengers / distance traveled as a measure of effectiveness, and a combination of these two as a measure of overall performance.

Taking in consideration the data available for the selected systems, three inputs and one output were selected (Table 2). The three inputs were: total operational cost; total number of equivalent vehicles; and number of employees. These three inputs represent the basic inputs: labor, capital and operational costs, including gas and other expenses. The number of equivalent vehicles corrects for different transport modalities – metro and bus; equivalence considers the number of seats of each vehicle. The number of employees considers only those employed by the central administrative unit of the system. Thus, the emphasis is in the administration of the metropolitan system and not in the companies that actually deliver the transport service. Operational cost is expressed in 2001 dollars. As output the total numbers of passengers transported was selected, a variable that represents the efficiency of the service.

Table 2: Variables

Inputs	Outputs
X_1 – Operational Cost *X_2 – Number of Equivalent Vehicles* *X_3 – Number of Employees*	*Y_1 – Number of Passengers Transported*

The output oriented model was selected to maximize input use, that is, labor, vehicles and cost determine the maximum output, be it the numbers of trips, the number of kilometers traveled or the number of passengers transported, among other alternatives. Also, given the different sizes and heterogeneity of the systems, a DEA with variables returns to scale was adopted.

A comparative analysis based on efficiency scores considers those on the frontier, that is the ones efficient, and those under the frontier. Based on the results, the comparative analysis highlights characteristics of the efficient services that may help the re-organization of the Recife Metropolitan Area Agency. A brief review of the RMA Agency and Metropolitan Transport Consortium is presented in the next section.

RMA AGENCY AND METROPOLITAN TRANSPORT CONSORTIUM

The administrative agency for the Recife Metropolitan Area, known as EMTU/Recife, is composed of 29 members representing the state government, 14 municipalities that compose the metropolitan area, state congress, municipal council of all 14 municipalities, public and private operators representatives, and representatives of employees, of users, and of producers and service providers. But EMTU/Recife was not empowered to administer and control all municipal transport systems. Thus, superimposition persists and a rational route integration net is still to be implemented.

The Public Transport system is actually being re-organized. The objective is to approve an administrative agency in which state and municipalities establish a real partnership. The new Metropolitan Transport Consortium shall substitute EMTU/Recife. It is committed to plan, manage and control all transport services; manage all finance subjects; and adopt as a goal the expansion and improvement of the metropolitan transport service. It shall be composed of several different administrative and deliberative councils:

(a) a higher deliberative council in charge of approving all policies and directives relating to the transport system projects and models; (b) an administrative council to implement decisions taken by the deliberative council; (c) a fiscal council to monitor all financial aspects of the consortium; (d) a consultant council to discuss the proposed policies, plans and project; (e) an executive office to manage all transport services. The consortium shall be a state company; the state owns 51 % of shares, the municipality of Recife 30%, and the remaining municipalities own the other shares.

RESULTS

The efficiency scores obtained from the DEA model are presented in Table 3. The following systems were considered efficient: Seville, Madrid, Barcelona, Bilbao, Valencia, Manchester, Amsterdam, Athens, Vilnius and Sao Paulo. The others are inefficient in different degree: London, Lyon, Frankfurt, Recife, Belo Horizonte, Fortaleza, Joao Pessoa, Salvador and Teresina.

Table 3: Efficiency Scores of Public Transport Services

System	Score	System	Score
Seville	100,00%	Athens	100,00%
Madrid	100,00%	Vilnius	100,00%
Barcelona	100,00%	Recife	61,86%
Bilbao	100,00%	Belo Horizonte	69,88%
Valencia	100,00%	Fortaleza	75,90%
Londres	78,61%	João Pessoa	91,27%
Manchester	100,00%	Salvador	95,34%
Lyon	62,05%	São Paulo	100,00%
Frankfurt	71,65%	Teresina	82,50%
Amsterdam	100,00%		

Source: EMS software results.

Of all Brazilian systems, only one was efficient. This represents 14 % of the analyzed systems. European systems scored much better: 75 % of the services were considered efficient.

Efficient systems combine several modalities, with the exception of Athens, Vilnius and São Paulo. Most offer metro service, exception being Seville and Vilnius. No system with only one modality was shown efficient. But several systems offering different modalities do not appear as efficient: London, Lyon and Frankfurt. Taking size as represented by inhabitants there is no clear pattern of efficiency in relation to size: 50 % of cities bigger than five million, 43% of cities from 2 to 5 million, 80% from 1 to 2 million and 33% of cities below one million.

Table 4 contains a statistical summary of minimum, average and maximum scores obtained in the DEA-V model.

Table 4: Statistical summary

Statistics	DEA-V
Minimum	61,86%
Average	88,89%
Maximum	100%

Source: EMS software results.

It is observed that 12 systems present scores above the average, 88,89 %. Only three Brazilian systems scored above the average.

The number that each system appears as a parameter for the inefficient systems are shown in Table 5.

Table 5: Number of times that efficient systems are indicated as reference for the inefficient ones

System	Number of references	System	Number of references
Amsterdam	7	Bilbao	1
Seville	6	Valencia	1
Vilnius	4	Manchester	1
Madrid	2	Barcelona	-
São Paulo	2	Athens	-

Source: EMS software results.

Amsterdam is a reference for seven inefficient systems, followed by Seville that is a reference for six. Vilnius is a reference for four, Madrid and Sao Paulo for two and Bilbao, Valencia and Manchester each for one and Barcelona and Athens are not a reference. The importance of being a reference is due to the contribution of their practices as a reference to increase the efficient of the inefficient systems.

ANALYSIS

The efficiency scores were analyzed according to the following criteria: power partition among the components of the administrative agency of the transport system and tariff structure.

Efficiency and Power Partition

Power partition among components of the administrative agency varies much for the analyzed systems. It varies in the number and representation of components and also in the percentage of votes that each component possess. According to Sampaio and Lima Neto (2005), the more power is distributed among components the easiest the decision process and the acceptance of decisions by the components of the agency. On the other hand, the predominance of one agent (more than 50% of the votes) weakens the partnership as it can decide practically alone. If the predominance makes it easy to take decisions (does not depend on other partners) and may lead to higher efficiency it weakens the partnership and as a consequence a division of responsibilities and costs. A partnership among governments and user associations is another important aspect to validate the system.

To comparatively analyze the systems in relation to power partition, a index is proposed:

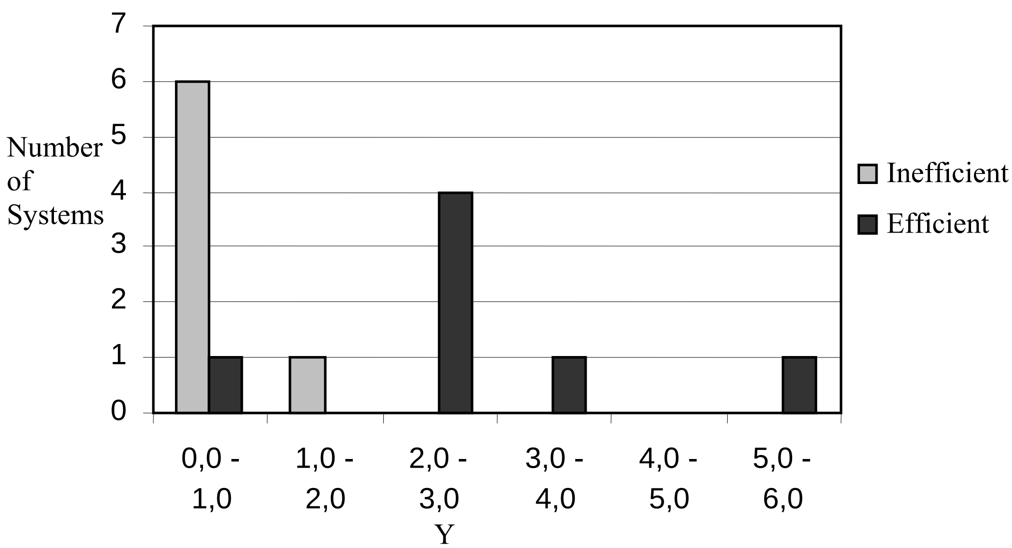
$$Y = N.[1 - (K_1 - K_2)/K_1]$$

$$K_1 = (100/N).\sum_{j=1}^{N} [N_j + \sum_{i=j}^{N} (N_{i+1})] \text{ e } K_2 = \sum_{j=1}^{N} P_j[N_j + \sum_{i=j}^{N} (N_{i+1})]$$

subject to $P_i < P_{i+1}$

Where N is the number of components of the administrative agency and P is the percentage of votes (places) corresponding to each component. Making $N_i = 1$ and defining $N_{N+1} = 0$, the value of the expression $[1 - (K_1 - K_2)/K_1]$ varies from 0, when power partition is unequal to the maximum, to 1, when it is equal to the maximum. This expression is similar to the Gini coeffient used to analyze the income inequality (Sen, 1973). The expression is multiplied by N to express that the higher is the number of participants (components) more efficient the system is expected to be. Taking the value for each system the Y index was calculated. Results are shown in Figure 1.[1]

Figure 1: Power Partition



Efficient systems, the only exception is Sao Paulo, present a higher Y than inefficient systems, showing that the higher the number of participants and more equal the power partition more efficient the system tends to be. That is, a more equal power partition is positively correlated to efficiency.

The system that presents higher Y is Madrid, with seven participants: the Community of Madrid with more power, 25 %, and the User Association with the least, 5 %, show a more equal power partition than all other systems. In addition to the two already mentioned, the municipality of Madrid and the other municipalities of the metropolitan

[1] No data was available for London, Manchester, Frankfurt, Amsterdam and Vilnius, on power partition.

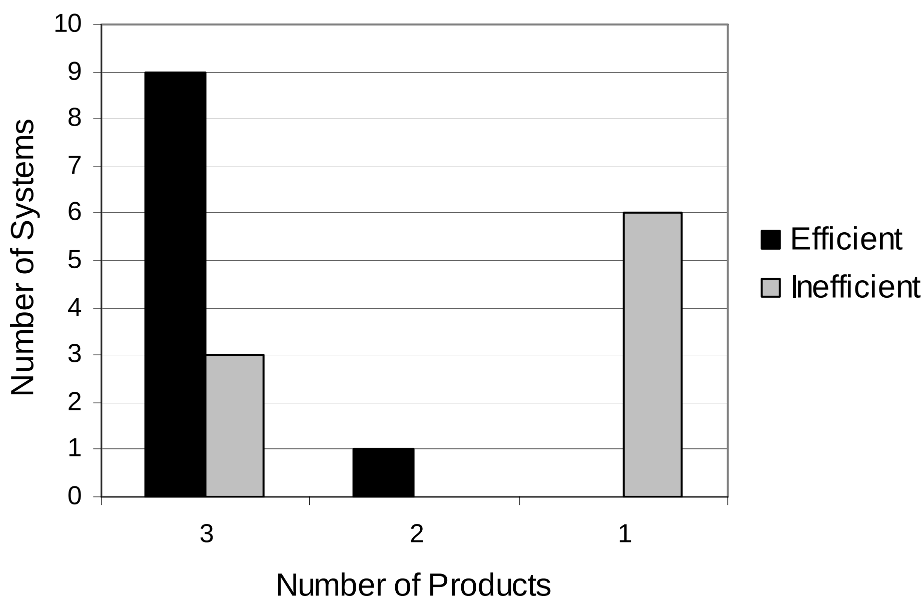
area, the central government, the association of companies in charge of the service and workers association are components of the Agency. As also shown in Sampaio and Lima Neto (2005) a partnership among government and beneficiaries is an important combination to improve service and efficiency.

The recently proposed (Recife) Metropolitan Transport Consortium achieves a Y equal to 2,58, an improvement in relation to actual Brazilian systems, in relation to power partition. But it does not include the participation of associations representing society.

Efficiency and Tariff Structure

All efficient systems, exception only of Sao Paulo, tariff structure is composed of three products: (a) unitary tickets; (b) multiple trip tickets; and (c) weekly, monthly or longer periods cards for multiple trips. Inefficient systems, with exception of London, Lyon and Frankfurt, offer only unitary tickets (Figure 2).

Figure 2: Number of Products



Tariff value varies according to concentric zones. But in efficient systems, again with exception to Sao Paulo, tariff decreases with the number of credits or the length of period of the card. Tariff final value is a function of product type and the number of zones crossed in a trip.

Thus, tariff structure in public transport systems shall be well defined offering users several ticket types that meet passengers interests and assure a better service and a expansion of demand. At the same time, multiple trip tickets and cards for longer periods are provided at lower costs in the benefit of both users and transport companies and agencies.

PROPOSALS FOR THE INSTITUTIONAL RE-ORGANIZATION OF RMA

Efficiency analysis comparing Brazilian and European transport systems may be very important to highlight aspects for service improvement. The DEA variable returns model used showed that only 14,3% of the analyzed Brazilian systems are efficient or 5,3% of the total analyzed systems. In contrast, only 25% of European systems were inefficient. A comparison of efficient and inefficient systems determines differential characteristics. Two characteristics are emphasized in this paper: the number of participants and power partition among components of administrative agencies and tariff structure.

In relation to power partition, an index was developed taking in consideration the number of participants and the power distribution among them. It is concluded that efficient systems present a higher number of participants, including central and local governments and associations representing communities, and that power is more equally distributed. As a consequence, a more democratic and broad partition system shall be pursued because it corresponds to a more developed society and may bring a higher efficient level.

Tariff structure analysis showed that efficient systems offer a great number of products, such as unitary and multiple trip tickets and cards for longer periods, improving the quality of the service provided at the same time that reduces costs and raises efficiency.

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