Efficiency Measurement of Underground Railway Systems in Europe: Focus on the Portuguese Case.

P. Santos, Carina Joana

cjoanasantos@gmail.com

1. Abstract

This research is aimed at examining the performance of metros in Europe, using for the purpose two methods, the application of performance indicators and the non-parametric technique of data envelopment analysis (DEA).

The work was divided, essentially, into three parts. In the first part, an extensive literature and documentation research related to the subject was carried out, in order to understand what are the relevant issues and the stakeholders involved. Data were also collected and processed to be used in the performance analysis. In the second part, related to the organization of metros in Portugal, it has been considered, among other things, the national legislation on public transport, the sector institutional structure, the system financing, the various public services providing models, the state involvement and the transport services contracting schemes (e.g. public-private partnerships, PPP). The metro systems of Lisbon, Oporto and Sul do Tejo were analyzed in more detail, together with the future light rail system for Coimbra city. In the third part, a framework of performance indicators was proposed and 8 indicators of efficiency and effectiveness were analyzed in detail for the 39 European metros. Later, the DEA methodology has been applied to build three models for 37 metros, with different inputs (extension of the network, staff, vehicles and other operating cost) and different outputs (vehicle-kilometres, passenger and passenger-kilometres). The input-minimisation version of DEA was used for all the models, and each one tested with both constant and variable returns to scale.

Both methods have shown that London and Moscow metros are efficient. The metros of Lisbon and Oporto showed a poor performance, placed below the European average.

Keywords: Data Envelopment Analysis (DEA), Efficiency, Metro, Performance Measurement, Public Transport, Urban Railways.

2. Introduction

This study arises from the need to analyze the performance of metros in Portugal in comparison to the rest of Europe. Therefore, it has two main objectives: to analyze the Portuguese urban transport sector functioning and to study European metro operator's efficiency through benchmarking techniques.

To achieve the first objective it has been considered, among other things, national legislation on public transport, the sector institutional structure, the system financing, the various public services providing models, the state involvement and the transport services contracting schemes, with a special focus on metropolitan areas existing metro systems.

On the second objective achievement, first a framework of performance indicators has been proposed and 8 indicators of efficiency and effectiveness were analyzed (through ratios relating passenger, passenger-kilometres and vehicles-kilometres outputs with staff, vehicles, net length and stations inputs). Secondly, the DEA methodology was applied in three different models, with different inputs (net length, vehicles, stations, staff and "other operational expenses") and different outputs (vehicle-kilometres, passengers and passenger-kilometres).

The benchmarking application carried out in this document reflects the increasing importance of metro systems as an alternative to private transport in urban centres and their role as an element of social cohesion and sustainable urban mobility.

The investment dimension made annually in metro systems, along with the serious indebtedness of the sector, makes urgent to assess its performance level in order to outline measures that could make it more efficient with minimum charges.

3. State of the art

Leonard, (2001) proposes the following terminology, which seems quite enlightening. **Benchmarking** is a process. It is the means by which we try to achieve a superior level of performance, in a particular area, changing current practices in the company, leading to improvements in its performance. **Benchmark** is a standard of excellence, the basis of comparison to similar results. **Best practice** is the means by which the maximum level of performance (benchmark) is reached.

The benchmarking process can be developed inside or outside the company. It can be a systematic performance comparison between departments of the same company (internal benchmarking) or it can compare the performance of one company with other organizations or competitors in the sector (external benchmarking).

The cyclical process of Benchmarking can be described in 9 steps, as shown in Figure 1, adapted from Hanman (1997). The first 4 steps are the scope of this dissertation. Generally, 3 levels of benchmarking can be defined in 3 increasing degrees of commitment and cooperation, as described in Table 1 (EQUIP, 2000).

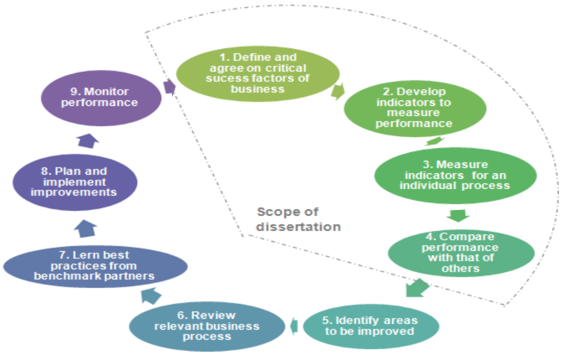

Fig. 1: The continuous improvement process of *benchmarking* – a nine stage model

Table 1: *Benchmarking levels*

Level	Category	Elements
I	Self-Assessment	Measure your own company's performance (over time)
II	Comparison	• Compare your performance with database of anonymous indicator value. • Identify improvement areas and best "standards"
III	Partnering	• Work with relevant partners, perhaps with some outside the direct business sector. • Exchange confidential information. • Learn best practices and the means of implementing the necessary changes. • Ideally, this should be a two-way process.

The process of external benchmarking between operators, corresponding to the level III, is not common. The main reasons for this are confidentiality, lack of efficient tools to identify comparable practices and a remarkable resistance to information dissemination. In spite of this, there are several organizations, groups such as Comet, NOVA, ALAMYS, UITP, EMTA, ERRAC, among others, who have been doing, among other things, benchmarking projects on public transport (PT), especially on metro. In this context, the European Union has supported various projects, such as BEST, BOB and the MODUrban.

Despite the various benchmarking studies published about PT, the majority does not focus on one specific means of transport, providing only a comparison between PT and private transport. The benchmarking studies focused on metro publicly available are rare and therefore more valuable. Nevertheless, its use was very helpful to this research and for that reason, the article from Costa, (1998) and Frasquilho, (2005), must be pointed out.

4. Organization of Metro systems in Portugal

4.1. National legislation applicable to the transport sector

The Portuguese public transport system structure is based on the Law on Inland Transport system (the so called Lei de Bases dos Transportes Terrestres, LBTT), Law No. 10/90 of 17 March. Chapter IV of this law presents the foundations for the planning and operation of transport in the Portuguese metropolitan regions, foreseeing the institution of Metropolitan Transport Authorities (MTAs). Although they have been planned in the 90s, the AMTs were only created more than 13 years later, by Decree-Law (DL) No. 268/2003 of 28 October. This decree, now under revision, establishes the MTAs in Lisbon and in Oporto.

4.2. The transport sector institutional structure in Portugal

The institutional organization is composed by various entities (Cruz, 2006):

1) The Government and directly dependent entities:

- The Government, responsible for decision and financial levels (financing the railway infrastructure for surface light rail, subway and train and road infrastructure together with the municipalities covered);
- Directly dependent on the Government, as the old General Directorate for Land and Inland Waterway Transport (DGTTF), which assumes the competences of regulating the land and inland waterway transport sector, and regarding railways, the National Institute of Railway Transport (INTF);

2) Municipalities, responsible for urban and local transport concessions for urban and municipal road operators, school lines and road design on municipal network (Law 10/90, LBTT)

3) Metropolitan Areas and Regions, which competencies are dependent on the creation of the future MTAs, created by Decree-Law 268/2003 of 28 October. These authorities will have powers of regulation and coordination on various modes of transport within the limits of the corresponding metropolitan area.

4.3. Financing metro systems

A metro system, given its size and infrastructure, requires heavy investment. Its financing may refer to 3 categories, namely infrastructure, rolling stock and operation of the system (financing the public service).

The Durable Infrastructure Investment (DIFs), apart from the use of EU funds (European Regional Development Fund), is usually supported by the state, given the weight and importance of this financial effort, but in some cases may be partly or entirely covered by local government and regional authorities (cities and metropolitan authorities).

Regarding investment in rolling stock, this is normally supported by the operator through its own equity and debt. This practice is common, especially when the market is opened to the private sector.

Financing a metro system operation involves a public service component. The metro system subsidization policy differs from country to country. In Barcelona, the *Autoritat del Transport Metropolita* (ATM) fully subsidizes the operation of the system, covering the operating deficit each year. Although having the advantage of transport operators indebtedness avoidance, this policy does not bring incentives for efficiency by itself.

One way to encourage efficiency is to estimate the deficit incurred by the operator, covering this amount and only this amount that should be stated in contract. Thus, if the operator presents excessive costs causing higher deficits, they must be borne solely and exclusively by the operator. This situation is common in public-private partnership contracts (e.g., metro concession of Lille, by Keolis).

In Portugal, several PT operators receive annual compensation from the State, in the name of public service obligations (PSO), but in a lower proportion than the estimated cost of these obligations. The underlying model of public transport services financing is determined by the respective ministry, without revelling the underneath criteria to transport companies. In future, PSO should be, according to the EU transport sector strategic guidelines, subject of contracts between the state and the transport operators.

4.4. Public transport services providing models

In general, the Portuguese scenario can be segregated into three distinct parts (Cruz, 2006):

- Public transport services provided by **public transport operators**, owned by the state and under its control, direct or indirect;
- **Municipal operators** responsible for:
  - **Municipal services**, managed by the City Council;
  - **Local authority services**, managed by an autonomous unit of the City Council with administrative and financial autonomy, but without legal personality, and
  - **Municipal and intermunicipal enterprises**, where management services are delegated to enterprises established in Municipal Assembly, with administrative and financial autonomy and legal personality. There may be the involvement of a private entity, leading to the creation of joint ventures (Institutional Public Private Partnership). The private capital choice, under the new legal regime for the local business sector (SEL), must be subject to tender.
- **Private operators**, who pursue their activities through some kind of concession, lease or management contract. This entails, among other things, municipal and intermunicipal concessions, where the public partner is the city council or the municipalities association. The process must be subject to public tender.

4.5. Transport services contracting schemes in Portugal

The transportation systems in Portugal are mostly run by companies comprised in the State business sector, varying the type of contract (or the lack of it). The direct management by the State or through companies created specifically for this purpose proved to be inefficient. The trend is the state interference reduction and the degovernmentalization of the regulatory activity. For that purpose are suggested public-private partnerships (PPP) as a form of contracting public services.

Conceptually, the PPP usage is based on:

• The historical evidence that public sector has difficulty in controlling inherent risks of large scale infrastructure projects;
• The transfer of these risks to the private sector (to a greater or lesser extent);
• Higher funding costs if the responsibility for the initial investment is transferred to the private sector.

Figure 2 shows the benefits from the use of PPP model.

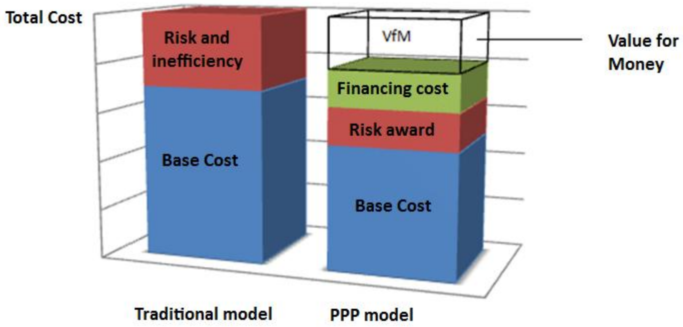

Fig. 2: Public-Private Partnership benefit

Among the different types of contractual PPP, one can distinguish:

• **Concession contracts** - where the investment is borne by the private and this is directly paid by users of the service (direct award of tariffs). The commercial risk is mostly private and the concession contract term is usually set between 20 and 35 years;
• Lease contracts - in which the investment is public, but the operator is paid by users through the direct award of tariffs. The commercial risk is shared between private and public parties and the delegation contract varies between 8 and 15 years;
• **Management contracts** - where the financing is provided by the State who imposes the tariffs to be charged to users by the private management. The operator is paid by the state. In this type of contract, the risk is mostly public and the period of delegation varies between 2 to 5 years, in general;
• **Contracts for outsourcing** - which relates to a management contract of a very short period.

The institutional PPP refers to the creation of joint ventures (entry of private capital in the company). The former regime of SEL (Law No. 58/98 of August 18) did not required, in companies of mostly public capital, that the entry of private capital should be subjected to tender procedures. This situation was altered by the creation of a new legal regime of the SEL (Law No. 53-F/2006, from Dec. 29), which requires the existence of competition for the choice of private capital for the municipal enterprises (E.M.) and their submission to regulation of the sector.

The contract of public service through the approval of "Public services contracts" after contest was identified as the main solution to cover the budget deficits coming from historical operating deficits of public transport operators, to regular with transparency the payment of the public service obligation to operators, either public or private, and allow a more efficient transport system (where each player fulfills its goals).

The Portuguese Code of Public Contacts (*Código dos Contratos Públicos*) have entered into force on July 31, but can be simultaneously used with the previous legislation till the end of the year, by the time it will hold exclusivity. The goal set by the new code is to achieve greater transparency in the relations between authorities and operators through the debureaucratisation of contract processes (greater speed and accuracy of procedures, equality, competition and the provision of efficient services).

5. Efficiency of Metro systems in Europe

5.1. Domain Analysis

In this thesis two different techniques were used to evaluate metro operators' performance, namely the calculus of performance indicators and the non-parametric methodology of Data Envelopment Analysis (DEA). In 2006, there were some 206 metro systems in operation in Europe. Out of the 206 metros systems (including heavy conventional metro and light rail solutions), 54 systems (36 heavy conventional metro plus 18 hybrid solutions) were chosen, scattered in 25 countries.

5.2. Performance indicators

One of the first advantages of performance indicators usages relates to the need for collection and compilation of information from the organization. This measure requires first and foremost a self-knowledge on the company's activity, which justifies, by itself, its implementation. Furthermore, the determination of these indicators allows a more aware and proactive management. If one compares the figures recorded in different organization it can even serve as a stimulant to improve the company's performance.

The determination of the various performance indicators begins with the indicator's definition and calculus formula or measurement criteria. After being calculated, it follows the interpretation of the results. The explanation of the results is made through the analysis of explanatory factors. These factors attempt to justify or reflect on results validity, based on data directly or indirectly related with the sector. They can be classified into controllable or not controllable. In the first group, the controllable factors, are all factors that are in some way under the operator action, and in the second one, those which the operator does not have intervention (eg, population density or GDP per capita).

After the interpretation of results, the next step is the comparison with the benchmarks. These values, considered as appropriate, are associated with current practices in the sector, i.e. the average values. In the analysis, it was applied a margin of 5% to the average values, resulting in a band of values where the located operators have acceptable performance. Operators with superior performance are, in the cases where the objective is to maximize the ratio, above the reference band (eg, passengers carried per employee), or vice versa, below the reference band when the goal is to minimize the indicator (eg, operating costs per employee).

This thesis has proposed a framework of indicators that are judged to be appropriate to review a metro performance, and has been organized into 6 groups, namely supply and demand, human resources, quality of service, economic and financial indicators, efficiency and effectiveness. The list of indicators was drawn up having as a starting point, tables proposed by other studies and organisations.
Each of the 6 groups of indicators have particular goals. The first attempt to assess the levels of supply and demand experienced in each metro system. The performance of a transport system is intimately connected to these two factors, more specifically, to the ability of adjust supply to demand.

The second group attempt to evaluate the performance of the actual body of the organization, discussing, among other factors, the rate of absenteeism. Staff training is also addressed, with consequences on the quality of service and implications for the ability to work.

The third group concerns to the quality of service. This includes several factors, ranging from issues of accessibility for people with reduced mobility, issues of environmental protection or issues of reliability (of rolling stock and punctuality). The satisfaction of the customer is also important.

The fourth group relates on economic and financial indicators, indicators related to cost control, with revenue analysis and other results, such as operating costs coverage by revenues.

The efficiency indicators are divided into 3 categories, allowing to examine the production levels (through perfomaces rates of vehicle-kilometres and trips), the levels of labor productivity (through ratios that relate the vehicle-kilometres and seat-kilometres produced with the staff) and the levels of capital (ratios which relate vehicle-kilometres and seat-kilometres produced with vehicles, stations or the network lenght).

The last group concerns the effectiveness indicators, subdivided into three groups: levels of occupation, labor effectiveness and capital effectiveness. Among the indicators related to levels of occupancy, one can distinguished 2 measures of occupation (one absolute and other relative). The efficiency ratios are usually expressed by linking the volume of passengers or the passenger-kilometres with vehicles, network lenght, stations or with staff.

As an example of this performance indicator methodology application, 13 performance indicators were used (1 indicator of supply and demand, 1 indicator of quality of service, 3 economic and financial indicators, 4 indicators of efficiency and 4 indicators of effectiveness) for a sample of 35 metro operators, a set of 18 European countries.

For each indicator was made a "fact sheet" that identifies and characterizes it with a graph of benchmarking which sets the values observed for the various operators. The range where it is considered that the operator has a acceptable performance (range of reference) is colored with dark pink. It is shown here, as an example, the analysis of the indicator 5, and the summary table of results for the indicators of efficiency and effectiveness (see table 2)

Indicator 5: Operating revenues / Operating costs

Name: Racio between Operating revenues and operating costs.
Definition: Coverage of operating costs by operating revenues
Unity: €/pass
Importance: High.
Meaning: This indicator tries to assess the economic performance of the operation of the transport service.
Reference value (benchmark): 78,5%.
Comparative analyse of the operators:

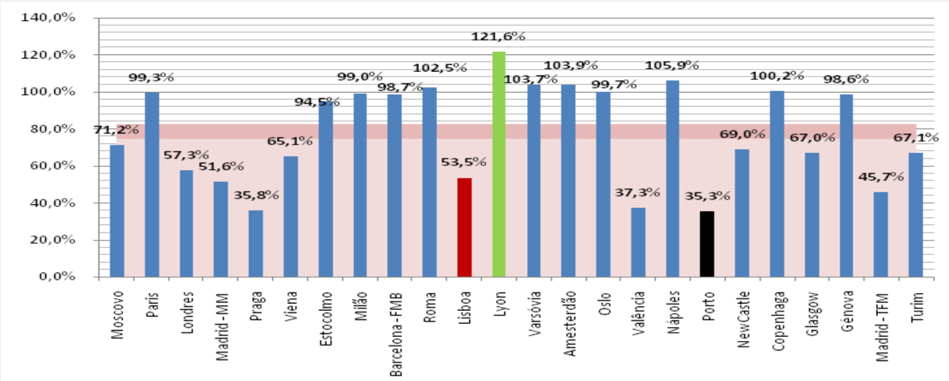

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Table 2: Summary of results for indicators of efficiency and effectiveness (the 3 best and worst performances)

	Ranking	I6	I7	I8	I9	I10	I11	I12	I13
Best	1st	Helsinki	Frankfurt	Moscow	Moscow	Helsinki	Saint	Moscow	Moscow
	2nd	Berlin	Moscow	Saint Pet.	Saint Pet.	Milan	Moscow	Saint Pet.	Saint Pet.
	3rd	London	London	London	London	Moscow	Helsinki	Paris	Paris
Worst	1st	Genova	Genova	Valencia	Valencia	Dnepro.	Glasgow	Valencia	Valencia
	2nd	Samara	Stockholm	Oporto	Oporto	Samara	Samara	Samara	Glasgow
	3rd	Brussels	Glasgow	Stockholm	Genova	Yeka.	Yeka.	Oporto	Oporto

Although the performance indicators allow a quick and accessible reading of an organization activity, there are some limitations associated to their analysis of results. The major flaw is that they are partial measures of productivity that relate only one of the production factors (input) and one of the results (outputs) that the organization "produces".

Furthermore, the application of performance indicators in the analysis does not include the operational and institutional environment (Marques and Brochado, 2007). The possible explanatory factors (population, GDP per capita, average distance to the stations, absenteeism rate of the employees, climate, rate of motorization, among others), despite influencing and explaining in some way, the results for the various indicators, are difficult to be directly correlated to each indicator individually.

Another aspect to keep in mind is the treatment of outliers. The outliers relate to observations that have a large distance of the remaining sample or are inconsistent with this. In the analysis of performance indicators, the outliers concern operators whose performance is, in the various indicators, distant or out from the average of the sample. In such cases, we must examine what causes this disparity and whether it is justifiable or not. The direct analysis of the benchmarking graphics suggests two possible outliers, namely Moscow and Turin metros. To ascertain the reliability of these observations it is necessary to analyze further these two operators using other statistical methods.

To circumvent all the problems, other approaches of performance evaluation were developed, based on frontiers of production or cost. These frontiers can be assessed by parametric or non-parametric methods. This dissertation applies the non-parametric approach Data Envelopment Analysis (DEA). The great advantage of this methodology in relation to performance indicators is to enable aggregate, in one measure of valuation, multiple inputs and multiple outputs. The DEA technique was applied in assessing the performance of the various European metro operators, for the year 2006.

5.3. Data Envelopment Analysis

The methodology of Data Envelopment Analysis (DEA) is a non-parametric technique of mathematical programming, aimed at assessing the relative performance of organizational units, in the presence of a uniform set of multiple inputs and multiple outputs. As a non-parametric approach, instead of assuming a function to the production frontier (as in parametric methods), it constructs the frontier by the best practices observed in the available sample. It does not need, therefore, a prior specification to the weights of each input/output, neither requires judgments on the production function form. In the presence of an industry with multiple inputs and outputs, the efficiency of each operator is assessed by the distance that separates him from the frontier.

This methodology was developed by Charnes, Cooper and Rhodes in 1978 (Charnes *et al.,* 1978) based on studies conducted by Farrell in the 50's (Farrell, 1957). In those initial studies, Farrell uses as a reference, an industry which employs two inputs (x_1 and x_2) to produce a single output, for the most simple case of constant returns to scale (CRS). In the 80s, (Banker et al., 1984) introduces the possibility of variable returns to scale (VRS). These may be increasing returns to the scale or decreasing returns to the scale.

In the simplest case of a production process with a single input and single output, efficiency (measured in relation to the optimal value) can be described as (1) or as (2) in the case, more usual, of an industry that employs multiple inputs in the production of multiple outputs.

$$Efficiency = \frac{Output}{Input} \quad (1) \qquad\qquad Efficiency = \frac{weighted..sum.of.outputs}{weighted..sum.of.inputs} \quad (2)$$

This approach requires the prior definition of weights to be applied to the inputs and outputs under study for the several operators, which carries beyond the difficulty in measuring the actual inputs and outputs, the determination of weights to be applied (Benito *et al*., 2005). The method of DEA has overcome this difficulty by allowing each operator to establish its own weights, with the aim of achieving the most favorable combination when compared with other operators of the sample (Charnes *et al.,* 1978). Thus, one operator's efficiency (h_k) can be maximized affecting the efficiency of all operators to below or equal to one. Mathematically the problem can be stated as follows:

$$Max: h_k = \frac{\sum_{i=1}^{I} a_i y_{ik}}{\sum_{j=1}^{J} b_j x_{jk}} \quad (3)$$

subject to

$$\frac{\sum_{i=1}^{I} a_i y_{im}}{\sum_{j=1}^{J} b_j x_{jm}} \leq 1 \ , \ m = 1, \dots, k, \dots, M$$

$$a_i, b_j > 0 \qquad i = 1, \dots, I; \ \ j = 1, \dots, J$$

where,
y_{ik} - output i of unit k
x_{jk} - input j of unit k
a_i - output i weight
b_j - input j weight
M - number of units
I - number of outputs
J - number of inputs.

The resolution of the simplified model (imposing a constant value to the denominator) results in values for each h_k between zero and one, which match the efficiency of each operator. If h_k is equal to 1, the unit k is efficient in relation to others. If it's less than 1, the unit k is within the boundary of production, and is therefore considered relatively inefficient.

The dual formulation application (minimizing) in linear programming allowed to build a distinct approach to the efficient frontier, formed by the union of linear segments (facets) parallel to the axes that minimize the amount of inputs while maintaining the level of output production. In such formulation, the selection of weights falls on the operators and not on the inputs and outputs as in the previous. According to this formalization, the operator k is considered effective if the slacks are null and if h_k is equal to the unit, namely when there is no composition of weights such that the efficiency of k is exceeded by that of another unit. Conversely, if h_k is less than the unit and/or if the slacks are positive, the values of λ_m will lead to a composite unit whose efficiency surpasses that of k, that is considered inefficient in relation to units in the PF. The extent of that inefficiency is given by h_k, which represents the highest proportion of current levels of input k that the company should use to ensure at least the current levels of output.

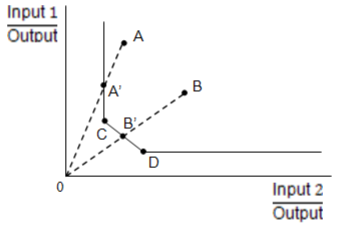

Fig. 3: Efficiency evaluation and input slacks

For the operator A, the technical efficiency (TE) is given by OA '/ OA and for B by OB' / OB. From the figure analysis you can gauge that, despite being situated on the production frontier, the point A' is not globally effective, as it is possible to reduce the production of inputs while maintaining the same level of output (it is technically efficient but not allocatively efficient). This approach has the underlying principle of CRS, which does not always correspond to the reality of the industries studied. Banker et al. (1984) introduced in a model adaptation that would allow them to accommodate the possibility of VRS. In the model BCC (Banker et. Al., 1984), the aggregate or overall efficiency of a particular unit in the assumption of VRS can be decomposed into two parts, pure technical efficiency (PTE) and scale efficiency (SE). The scale efficiency counts the degree of savings that would occur if the operator is in great scale, and ranges from 0 to 1. For values equal to unity, there is scale efficiency. If there is a difference between the TE returned by the models of DEA assuming CRS and VRS, one can conclude that the operator has scale inefficiency.

In this dissertation the European metro performance was analyzed based on the non-parametric approach of DEA, using the software Excel Solver DEA proposed by Zhu (2002), assuming CRS and VRS. Three models were developed with different combinations of consumed inputs and produced outputs by the operators. The inputs and outputs needed to be quantifiable and the more homogeneous possible between operators. From the inputs and outputs available, it were selected those that best characterize the dynamics of the industry.

The model 1 includes three inputs and two outputs obtained for 37 metros in Europe.

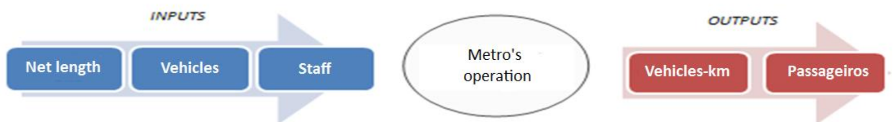

Fig. 4: Model 1

In the second model, a fourth input related to operating costs was added. The operating costs (operational expenses, OPEX) from the profit and loss accounts of the several metro reports included the consumption of stocks, supplies and services and external costs with staff. As the model also full, the staff of the corporation, the cost inputted to the model cannot be directly the operating costs, to avoid inflate the total labor force in the model. This makes it necessary to first exclude the costs of personnel. These new costs deducted will be "other operational costs" (other operational expenses, OOPEX).

The third model replaces passenger for passenger-km, which is more accurate in assessing the actual use of the service. It was evaluated in 26 metros.

The various models were geared towards the minimization of inputs. The following graph illustrates the TE (blue), and gains from scale economies (in red) to 37 metros of operators in Europe, which form the model 1. The same type of analysis was done for the other two models.

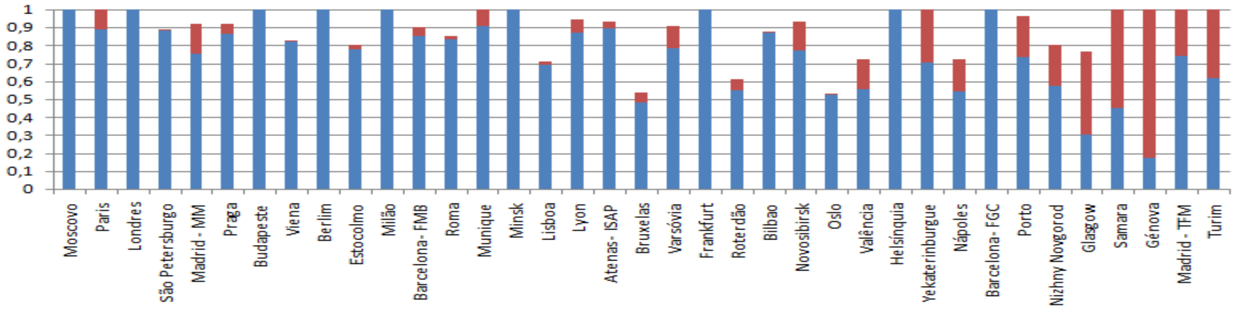

Fig. 5: Technical efficiency (blue) and scale economy gains (red) in model 1

The graphs presented for each model shows there are scale economies, giving greater gains in efficiency of operators with lower volume of passengers carried. Yields are therefore increasing the scale.

Table 3 summarizes the main results obtained by the models. Table 4 shows for example, the targets of Lisbon and Oporto metro operators, in model 1, assuming CRS.

Table 3: Summary results of the different models for metro operators

	Model 1	Model 2	Model 3
TE average (CRS)	0,76882	0,84939	0,68297
PTE average (VRS)	0,89353	0,96191	0,82737
SE average	0,86190	0,87917	0,82547
Minimum TE	0,53074	0,77578	0,40890
Minimum SE	0,17218	0,21181	0,27412
TE Lisbon (RCE)	0,69292	0,83284	0,49101
PTE Lisbon (RVE)	0,70684	0,89335	0,59839
TE Oporto (RCE)	0,73608	0,84614	0,61736
PTE Oporto (RVE)	0,96155	1	0,77123

Table 4: Targets of metro operators of Lisbon and Oporto for model 1, considering CRS

	Lisbon		Oporto	
	Actual Value	***Target***	**Actual Value**	***Target***
Net extension (km)	35,60	35,60	58,88	58,88
Vehicles (unit)	338	338	72	72
Staff (unit)	1702	1179	426	314
Peers	Berlin, Helsinki, Budapest, Moscow		Helsinki, Budapest, Moscow	

6. Conclusions

From the analysis of performance indicators one could see that the various metro operators, like the other companies of TP, have high operating costs compared to the revenue generated. For most metro operators tested, operating revenues do not cover the operating costs of the system. The average rate of coverage of operating costs by operating income is around 78.5%. The situation is even worse for the Portuguese metros, not even reaching the 50%.

The Russians metros, Moscow and St. Petersburg, present, in most indicators of efficiency and effectiveness, better performance. London is an efficient metro, showing good results in the ratios of productivity. Focusing on effectiveness indicators, Paris is effective in the usage of the stations and network. Helsinki presents the best results in terms of productivity and effectiveness of labor. As for the worst performances, Valencia appears to be the winner. Genoa and Glasgow are not in a favorable position neither. The Oporto metro presents a poor overall performance, in both efficiency and effectiveness indicators; although we must bear in mind its recent entry into operation (2003).

The DEA technique results corroborate the conclusions drawn from the performance indicators analysis. The Portuguese landscape is not favorable, showing low levels of efficiency and effectiveness in comparison with the average rate of the economy (Lisbon and Oporto metros have always appeared inefficient). Moscow and London metros are generally effective for the 3 models. In terms of reference for the Portuguese metros, the listed peers are Moscow, Helsinki, Barcelona-FMB and Berlin metros.

In general, operators show a large dependence on operating subsidies. The fact that they are not valued monetarily neither contracted leads to the allocation of subsidies in random value, granted according to the financial availability of the State, which usually leads to insufficient value in relation to investments, forcing the bank debt. To control the indebtedness of the industry and ensure an improved quality of service, it is necessary to promote measures to improve the effectiveness and efficiency. These consist firstly in match supply to demand, by increasing the supply in times of increased demand by users and cut off those periods.

Regardless of whether or not entrance into force of MTAs, the large volumes involved in the financing of the system require the definition of new strategies and funding schemes. Operators must be able to attract higher levels of revenue through alternative means of revenue from traffic, should be eligible for more funds, coming, for instance, from taxes on companies that benefit directly from the metro network, as in France through the *Versement du Transport*. So that the need for funding is the lowest possible, it is necessary to reduce the operational costs of the system. This can be achieved in various ways, including reducing the operator's staff and bet on increased productivity through training and qualification of its employees. Monitoring the average age of the fleet also helps to reduce the costs of maintenance and increase the levels of reliability (lower number of failures, greater punctuality).

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