MULTICRITERIA PERFORMANCE ANALYSIS OF THE EUROPEAN AIR NAVIGATION SERVICE PROVIDERS

Elton Fernandes
COPPE/UFRJ/Rio de Janeiro - Brazil
elton@pep.ufrj.br

Gustavo Calegaro de Andrade
PEP/COPPE/UFRJ/Rio de Janeiro - Brazil
gustavocalegaro@hotmail.com

ABSTRACT

Air Traffic Management (ATM) is a subject of great complexity, given the extent of the various factors that define the sector's performance mainly as it pertains to guaranteeing safe, regular and efficient flights. One fundamental element of ATM is the organization responsible for the traffic control which provides airspace control services. Different types of organizations work currently in this area, from wholly state-owned to private/public partnerships. In Europe, although each country is responsible for its own portion of airspace, there is a trend to jointly manage air traffic through a comprehensive information management system and collaborative decision-making procedures, both of which help to optimize resources toward a single sky. This also helps to improve efficiency in the use of airspace and airports. The objective of the present article is to increase awareness about the air traffic control performance of organizations in the European Union, using the support of Data Envelopment Analysis (DEA) and statistical inferences. DEA is a multi-criteria methodology used for comparing performance among organizations or other kind of observation units. The results reveal the position of these organizations with respect to the efficiency frontier according to some adopted criteria. The present analysis points out the efficient organizations and the paths that those outside the efficiency zone should take. Thus, this study is significantly pertinent, bearing in mind that there are estimations indicating that European airspace will need to accommodate the equivalent of twice the current number of flights in few years and will, therefore, need to optimally manage the available resources, to be able to meet the traffic demands without compromising safety, regularity and a good cost-benefit relation.

Keywords: Air traffic control, Air transport efficiency, Multi-criteria Analysis

1. INTRODUCTION

The growth of the international air transport industry has been a reality since the first companies began their operations in 1930. Even in the face of economic crises that have affected the sector, as in the 70's (oil crisis), or even after the terrorist attacks of September 11, 2001, the number of airplanes crossing airspace throughout the world has increased approximately 5% per annum (De Neufville, 2003). In 2008 we observed a strong economic crisis affecting, in the short-term, the rhythm of growth of international air traffic. However, Airport Council International (ACI) forecasts that air traffic movements in Europe will grow at an annual average of 3.3% until 2012 and somewhat between 2.4% and 2.0% from then until 2017 (ACI, 2008). In this context, it is of the utmost importance that all of the links of air transport be prepared to support the growth of the sector.

Air traffic control plays a very important role in the air transport industry. Besides being directly linked to the safety of passengers, the system seeks to improve efficiently and regularly of aircraft movements to avoid delays and reduce operational and airline corporate costs. Operational efficiency is fundamental to reduce harmful gas emissions into the environment and undesirable noise pollution. To more efficiently control airspace, with the ever-increasing number of flights, it is necessary to seek greater integration between Air Navigation Service Providers (ANSPs).

In Europe, the planning and management of airspace control presents a set of challenges being that the continent has independent national organizations that are responsible for controlling the airspace in a relatively small geographic area. Although the ANSPs, generally, are not subject to the process of direct competition, the perception of benchmarks can be the first indicator of their management quality. Thus, the aim of this article is to contribute to an increased awareness of the performance of air traffic control organizations in the European system, using the support of Data Envelopment Analysis (DEA) and statistical inferences.

2. STUDY CONTEXTUALIZATION

In 1944 there was a convention about International Civil Aviation, also known as the Chicago Convention, which established international airspace rules, safety patterns and detailed the rights of signatory countries relative to air transport as well as created the International Civil

Aviation Organization (ICAO). After this convention, the ANSPs, organizations responsible for the services of airspace control in the countries, were created. Initially, the ANSPs were instituted by the governments, responsible for the sovereignty of their own airspace. However, at the end of the 80's, privatizations and commercialization of the air transport sector had begun, changing a bit the scenario. According to Oster and Strong (2007), the motivation behind the changes varied from country to country, although with some similarities, such as: a necessity to complement the government's limited resources to finance capital and modernization investments; a desire to improve the performance of ANSPs in responding to the user's needs; and one less-common motivation, selling the control of air navigation as a means of injecting financial resources to the public coffers.

Impelled by a new scenario of air traffic control and by the concept of a Single European Sky, intended to combine technology, economy and the regulatory aspects for airspace use synchronized with plans and actions, behaving as a single continuous operation, the sector starts seeking management excellence, which necessarily passes through organizational performance evaluation. In this light, efforts have been made to track the sector's performance. Oster and Strong (2007) defined the principal dimensions to analyze an ANSP performance, which are: safety; separation of regulation and operation; efficiency of capital invested; financial structure and capacity; need for economic regulation; organizational independence; clear lines of responsibility; ease of interoperability; and definition of social and political objectives.

The European Organization for the Safety of Air Navigation (Eurocontrol) has presented systematic reports about their ATM organizations performance. In the more recent reports, "Complexity Metrics for ANSP benchmarking Analysis" Eurocontrol (2006), it was defined an important indicator for comparing ANSPs: the complexity of airspace. For benchmarking effects, the complexity indicators should capture the external factors impacting organizational management as well as the difficulty of operational tasks, such as: traffic density and flow structure. Therefore, in comparing the ANSPs, it is important to ensure that the performance study takes into consideration the fact that different organizations execute similar tasks with distinct levels of complexity, in other words, to consider the variation of operational complexity.

3. METHODOLOGY

Although this article uses statistical inferences, as regression analysis and graphic analysis in its discussions, the conceptual basis that orientates the study is that of efficiency frontier through DEA.

The DEA methodology, initially presented by Charnes et al. (1978), proposes a multi-criteria approach adequate to evaluate performance, where various inputs and outputs can be considered. The DEA approach allows defining objectives aimed at input minimization, in other words, to use the lowest quantity of resources to obtain a determinate result, or the maximization of outputs, that is, obtaining the best result by applying a determinate level of resources. The model calls the evaluated unit, which in our study are the ANSPs, as Decision Making Unit (DMU).

The mathematical programming models provide an elegant manner of, simultaneously, constructing a frontier for a given technology from a set of observations and then calculate the distance from the frontier to each of the individual observations (Lins et al. 2000). From the original Constant Returns to Scale (CRS) model and, later, from the Variable Returns to Scale (VRS) model, the DEA methodology incorporates a multi-criteria method to support decision and, therefore, capable of modeling real-life complexity.

In the study developed for this article, the main question is about optimization of the selected input/output relations, considering the input orientation, bearing in mind that the output variable used in this study has an exogenous character, that is, does not exclusively depend on internal questions to the organization. Thus, we analyze, at a first moment, the approach orientated to input of the Variable Returns to Scale (VRS) model, once we are referring to organizations of distinct sizes and operational complexities. The proposed model, also known as BCC (acronym for Banker, Charnes and Cooper, 1984) considers variable returns to scale, in other words, substitutes the proportionality axiom between inputs and outputs by the convexity axiom, forcing the frontier to be convex and, therefore, allows the DMUs that work with low input values have increasing returns to scale and those that work with high values have decreasing returns to scale. The BCC model, according to the envelope point of view, can be represented by the following linear programming problem:

Input-Oriented BCC
$\mathrm{Min}\ \mathrm{h_o}$
Subject to
$\mathrm{h_0}.\mathrm{x_{i0}} - \sum \mathrm{x_{ik}}.\lambda_\mathrm{k} \geq 0, \forall \mathrm{i}$
$-\mathrm{y_{j0}} + \sum \mathrm{y_{jk}}.\lambda_\mathrm{k} \geq 0, \forall_\mathrm{j}$
$\sum \lambda_\mathrm{k} = 1$
$\lambda_\mathrm{k} \geq 0, \forall_\mathrm{k}$

Where: h_o is the analyzed DMU efficiency; x_{io} and y_{jo} are the input and output vectors, respectively, of the DMU analyzed; x_{ik} e y_{jk} are the input and output vectors, respectively, of the remaining DMUs of the model; λ_k is the vector whose optimum values form the convex linear combination that composes the performance of the analyzed DMU.

Although the DEA methodology is relatively recent, it has developed rapidly and, nowadays, it has an ample theoretical basis. Malmquist Productivity Index concept which measures Total Factor Productivity – TFP Growth allows that productivity evolution of the units evaluated can be tracked over years, was first introduced in 1953 by Malmquist and has been studied and perfected by many authors, as highlighted by Tone (2004). The Malmquist DEA method, as proposed by Fare et al. (1994), has recently been the most-studied to calculate TFP and is the one this study approached.

The Malmquist Index evaluates the evolution of DMU productivity between two periods of time. It is defined as the product of the terms *Catch-up* and *Frontier-Shift*. The term *Catch-up* (or recovery) refers to the degree that a DMU reaches to improve its efficiency, while the term *Frontier-Shift* reflects the innovation of efficient frontiers around the DMU between the two time periods (Tone, 2004).

The Malmquist-DEA method consists in applying the DEA linear programming algorithm to construct the production frontier of a determinate period and, later, to calculate, the ratio between the distances of two production points from distinct periods within the same unit to the constructed frontier. The following linear programming problems (1) and (2) should be solved to calculate the Malmquist Index:

(1) Within score in input-orientation:

$$\delta^s((x_0,y_0)^s) = \min_{\theta,s}\theta$$

Subject to

$$\theta.x_0^s \geq X^s.\lambda$$
$$y_0^s \leq Y^s.\lambda$$
$$\lambda \geq 0$$

(2) Inter-temporal score in input-orientation:

$$\delta^s((x_0,y_0)^t) = \min_{\theta,\lambda}\theta$$

Subject to

$$\theta.x_0^t \geq X^s.\lambda$$
$$y_0^t \leq Y^s.\lambda$$
$$\lambda \geq 0$$

Where: θ is the DMU efficiency in the period analyzed; X^s and Y^s are the input and output matrixes, respectively, of period s; x_o^s, y_o^s, x_o^t, y_o^t are the input and output vectors of the analyzed DMU during periods s and t; λ is the vector whose optimum values form a linear combination composing the performance of the analyzed DMU. In (1) the problem for s = 1 and 2 should be solved, and in (2) the problem for the pairs (s, t) = (1,2) and (2,1) is solved.

The Malmquist Index (MI), in accordance with the following formula, consists of four terms obtained in the linear programming problems: $\delta^1((x_0,y_0)^1)$, $\delta^2((x_0,y_0)^2)$, $\delta^1((x_0,y_0)^2)$, and $\delta^2((x_0,y_0)^1)$.

The former two terms are related with measuring *within* equal periods, while the latter two terms refer to the *inter-temporal* comparison. If MI > 1 (3), it indicates progress in total productivity of the DMU factors analyzed between periods 1 and 2. In the case of MI = 1 and MI < 1, they respectively indicate performance *status quo* and a decreased total factor productivity.

(3) Malmquist Index

$$MI = \left[\frac{\delta^1((x_0,y_0)^2).\,\delta^2((x_0,y_0)^2)}{\delta^1((x_0,y_0)^1).\,\delta^2((x_0,y_0)^1)}\right]^{1/2}$$

4. CASE STUDY

The case study of this article involves 34 European ANSPs. The organizations analyzed are a part of the “Eurocontrol Performance Review Reports” (2005 and 2008). The selection was based on availability of the data to be used. The study analyzes ANSPs in two periods: 2004 and 2007. A sufficient time interval to compare the productivity increases of an ANSPs using traditional methods, such as: airspace redesign; labor recruitment and training; and investments. Initially, the classic VRS model was used and then the Malmquist Index.

The choice of variables (inputs and outputs) is one of the most delicate and important phases when using the DEA methodology, as the variables that are relevant and appropriate for establishing the chosen DMU relative efficiency are selected, maintaining the model as compact as possible in order to maximize the discriminating ability of DEA.

According to Smout (2007), Civil Air Navigation Services Organization (CANSO) and International Air Transport Association (IATA) defined five main performance indicators that can be used to measure ANSP performance: IFR movements per controller; Oceanic IFR movements per oceanic controller; ANSP cost per IFR movement; Total controller cost per controller hour and Total controller costs as a percentage of total ANSP cost. Converging with those performance indicators, we used as input: the number of flight controllers and the cost of the service providers. The amount of flight controllers refers to the number of workers who operate the system for air traffic control, including the Control Tower (TWR), the Approach Control Unit (APP) and the Area Control Centre (ACC). Already the cost of services are the total costs of controllable ANSP including services en route and terminal. So, these indicators translate the level of infra-structure and the cost operational management of each ANSP. In the definition of outputs, the controlled flight-hours and air traffic delays, the latter considered as undesired output. Nonetheless, both outputs extrapolate the management limits of an organization responsible for airspace control service provision, that is, these are exogenous variables. Therefore, the analysis orientation is defined aiming to minimize the resources (inputs). To maintain the discriminating ability in the DEA, this study used 2 inputs and 1 output, shown below:

Inputs:

- Number of controllers;
- Cost of Services, in million €;

Output:

- Controlled flight-hours, in thousand.

Despite not applying the flight delays to the proposed DEA model, it is pertinent to comment their relation in the air traffic system. The delays, in route as well as at the airport, also indicate the level of performance of the management of the organizations responsible for airspace control. However, the major part of the air traffic delays is not related to ATM. These delays are essentially related when the traffic demand exceeds route capacity and if there are no alternative measures available to solve them. Nonetheless, there are numerous other factors that influence delays. For example, the airports, the airline companies and the passengers all cause delays when it takes time to embark/disembark and at check-in, aircraft defects and technical failures, inadequate infra-structure capacity on the airport runways or aprons, etc. Furthermore, adverse climactic conditions also aggravate the problem. Due to the interlinking nature of the air transport system, delays in one bottleneck site propagate throughout the entire network. According to Eurocontrol in the Report on Punctuality Drivers at Major European Airports (2005), most of the delays result from a domino effect caused by primary delays, including those related to climactic conditions, technical errors, airport delays, etc. Also according to Eurocontrol, the level of ANSP delays can be used as an indicator to identify the areas where improvements to the system should be made, in view of its dynamic factor. Figure 1 highlights the level of delays of the ANSP analyzed in the study relative to the controlled flying-hours in 2004 and 2007. We note the trend for delays to increase with the increase of controlled flight-hours, even though not strongly correlated, as in Aena-Spain (AES), NATS-United Kingdom (NAU), DFS-Germany (DFG) and Skyguide-Switzerland (SKS). The latter together with Muac-Maastricht (MUA) present the worst relations. Exceptionally, ENAV-Italy (ENI) exhibit a significant decrease in delay levels with an increase of controlled flight-hours.

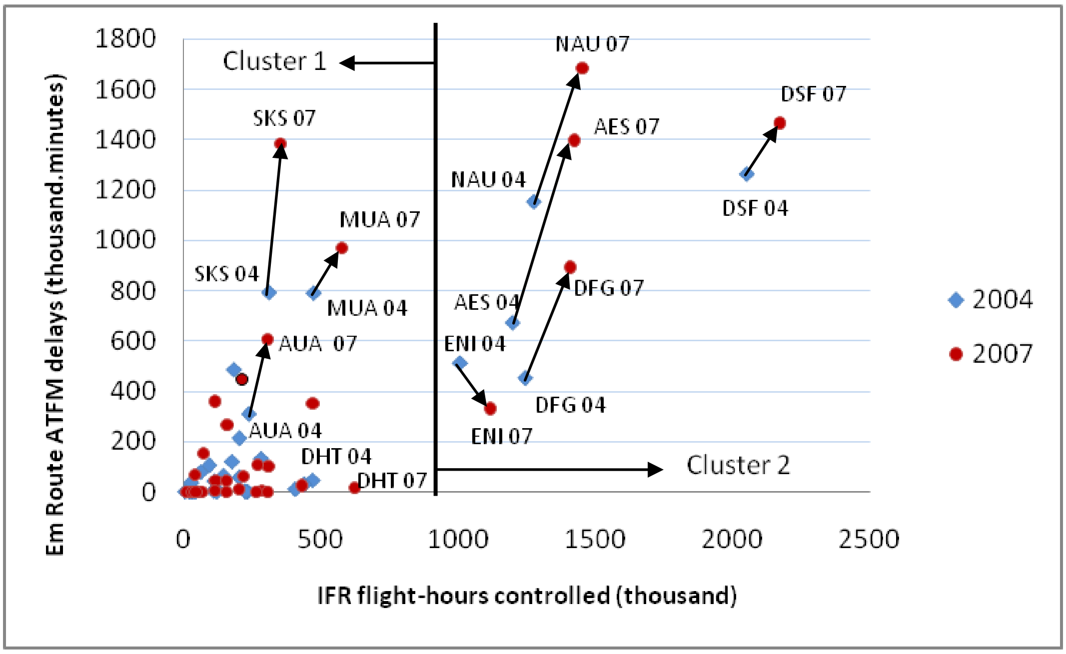

Figure 1 – Relation Delays in controlled route and flight-hours

In a general manner, Figure 1 shows an increase of European ANSP delays with an increase of controlled flight-hours, from 2004 to 2007. This indicates that it is difficult for the ANSPs to meet the growing demand without delays increasing.

4.1 VRS Model

In the DEA VRS model, the same ANSPs analyzed in 2004 and 2007 were considered a different DMU for each year. This approach was justified by the possibility to analyze the temporal evolution of each ANSP in relation to the others, considering that the technology used did not undergo substantial alterations during the years in question. Therefore, the

ANSPs were evaluated under a single envelopment formed by the combination of the DMUs of both years.

The results of the DEA VRS model with the efficiencies obtained are in the annex. The data used as inputs and output are available in the Eurocontrol reports (2005 and 2008).

Our sample can be divided into two clusters: the first with ANSPs having less than 1,000 (one-thousand) flight-hours controlled and cluster 2 those above this amount. In cluster 2 we find ENAV-Italy (ENI), NATS-United Kingdom (NAU), DSNA-France (DFS), Aena-Spain (AES) and DFS-Germany (DFG), and in cluster 1, the other ANSPs of Eurocontrol. All ANSPs of cluster 2 are in the area of decreasing return to scale. The results of the DEA-VRS model adopted (ANNEX) show that the ANSPs of cluster 2 improved their efficiency in relation to the frontier, with the least efficient being Italy and Spain with 62% and 63%, respectively, in 2004. In 2007 all of the ANSPs of cluster 2 demonstrated efficiency greater than 70%, which denotes a general increase in performance.

Cluster 1, where most of the European ANSPs are concentrated presents a very much diversified behavior in terms of efficiency. Belgium and Netherlands presented the lowest efficiency indexes in 2007, 24% and 36% respectively. However, these ANSPs have a high complexity score (Table 1), which can make more difficult to achieve a higher efficiency. A large part of the DMUs are located in the area of increasing return to scale, which indicates an excellent opportunity for improvement. Considering a single efficiency frontier for both years, 2004 and 2007, several ANSPs had a decreasing efficiency score. This could be due to some difficulties the smaller ANSPs had to adapt themselves to the new technologies been implemented for the “Single European Sky”. However, the Malmquist Index will give a better view of the ANSPs efficiency change.

4.2 Malmquist Index

For the Malmquist-DEA model the input orientation of the VRS model was maintained. The objective of using the Malmquist Index was to verify the technological changes and how each ANSP behaved itself. Table 1 summarizes the results obtained by the Malmquist-DEA model.

The change in the technical efficiency score is defined as the diffusion of best practices technology in management of the activities and is attributed to planning, technical experience and management. In this perspective, the European ANSPs experienced, at an average, a decline (Catch up effect = 0.986). The technological change is a consequence of innovation, in other words, adopting new technologies and, as a general rule, the ANSPs in the study experienced improvement (Frontier shift effect = 1.047). Therefore, we verified that, generally, there was a positive change in the efficiency of European ANSPs during the years analyzed (Malmquist índex = 1.027). Considering the complexity of the air traffic that each ANSP operates, it was concluded that, as an average, the more complex the airspace the greater was the positive change of the organizations, especially the technological change.

Table 1 demonstrates that with the exception of Spain, the ANSPs of cluster 2 are of great complexity (> 5.0). France was the only one to present a reduction in the Total Productivity Factor (Malmquist Index). However, it is very close to 1, indicating there was no significant change.

Table 1 – Efficiencies of the DMUs analyzed in the Malmquist-DEA model

ANSPs			Catch-up effect	Frontier-shift effect	Malmquist index	Complexity Score (2007)
Cluster 2	ENAV, Italy	ENI	1,212	1,067	1,294	6,1
	NATS, United Kingdom	NAU	1,019	1,087	1,108	11,8
	DFS, Germany	DFG	1,065	1,026	1,092	11,4
	Aena, Spain	AES	1,040	1,029	1,070	4,1
	DSNA, France	DSF	1,000	0,985	0,985	6,4
Cluster 1	MUAC, Maastricht	MUA	1,077	1,242	1,338	9,7
	DHMI, Turkey	DHT	1,084	1,228	1,331	2,7
	ATSA, Bulgaria	ATB	1,133	1,119	1,268	2,1
	IAA, Ireland	IAI	1,103	1,116	1,231	1,9
	NAV (FIR Lisboa), Portugal	NAP	1,063	1,111	1,181	2,3
	Austro Control, Austria	AUA	1,036	1,114	1,154	7,7
	MK CAA, Fyrom	MKF	1,389	0,803	1,115	3,0
	Croatia Control, Croatia	CRC	0,995	1,120	1,115	3,7
	LPS, Slovak Republic	LPS	1,002	1,112	1,114	4,2
	LGS, Latvia	LGL	1,087	1,009	1,096	2,0
	Skyguide, Switzerland	SKS	0,946	1,114	1,054	11,9
	Finavia, Finland	FIF	0,932	1,118	1,042	1,6
	Belgocontrol, Belgium	BEB	0,931	1,099	1,023	12,5
	ROMATSA, Romania	ROR	0,892	1,122	1,001	2,5
	DCAC, Cyprus	DCC	0,902	1,098	0,990	2,2
	MATS, Malta	MAM	1,223	0,799	0,977	0,6
	EANS, Estonia	EAE	1,050	0,920	0,966	1,8
	HungaroControl, Hungary	HUH	0,858	1,118	0,959	4,4
	NAVIAR, Denmark	NAD	0,857	1,115	0,956	3,7
	LFV/ANS, Sweden	LFS	0,846	1,122	0,949	3,1
	LVNL, Netherlands	LVN	0,855	1,098	0,938	8,9
	Oro Navigacija, Lithuania	ORL	1,065	0,841	0,896	1,9
	UkSATSE, Ukraine	UKU	0,781	1,131	0,883	1,7
	Avinor, Norway	AVN	0,759	1,119	0,849	2,3
	ANS CR, Czech Republic	ANC	0,764	1,112	0,849	6,4
	HCAA, Greece	HCG	0,737	1,122	0,827	2,2
	MoldATSA, Moldova	MOM	0,975	0,807	0,786	0,6
	NATA, Albania	NAA	0,944	0,784	0,740	1,8
	Slovenia Control, Slovenia	SLS	0,916	0,799	0,732	4,7
Average			0,986	1,047	1,027	3,934
Max			1,389	1,242	1,338	12,500
Min			0,737	0,784	0,732	0,600
Std. Dev			0,142	0,127	0,160	3,216

5. DISCUSSION OF THE RESULTS

It is interesting to note the tendencies existing in the relations among the variables studied in the DEA model. Initially, analyzing the controlled flight-hours in relation to the cost of the service provided, a clear disposition of the sample was verified. As the controlled flight-hours become more voluminous, a greater dispersion is observed, which is derived from geographic positioning (Figure 2). In this dispersion, as seen in Figure 2, the definition of two distinct clusters is observed, having to do with the number of resources used and the services provided: a first cluster formed by the smaller-scale ANSPs and a second cluster formed by the larger-scale ANSPs, showing the same structure of the clusters identified in Figure 1. In the first cluster, the EANS-Estonia (EAE) and Muac-Maastricht (MUA) organizations have a better cost relation and the second cluster the Aena-Spain (AES) organization stands out as presenting the worst relation. Although there are cost variations for controlled flight-hours, adjusting the trend of these variables indicate a correlation coefficient very near to 1 (0.9313, Figure 2). This indicates a reasonably proportional behavior between costs and controlled flight-hours. Another analysis can now be done, in comparing the evolution of the organizations in the period studied. A natural movement is perceived as that with the growth of controlled flight-hours the cost for services provided increase. Nonetheless, there are few exceptions to this trend, such as ENAV-Italy (ENI) where a reduction of costs with an increase of controlled flight-hours is observed.

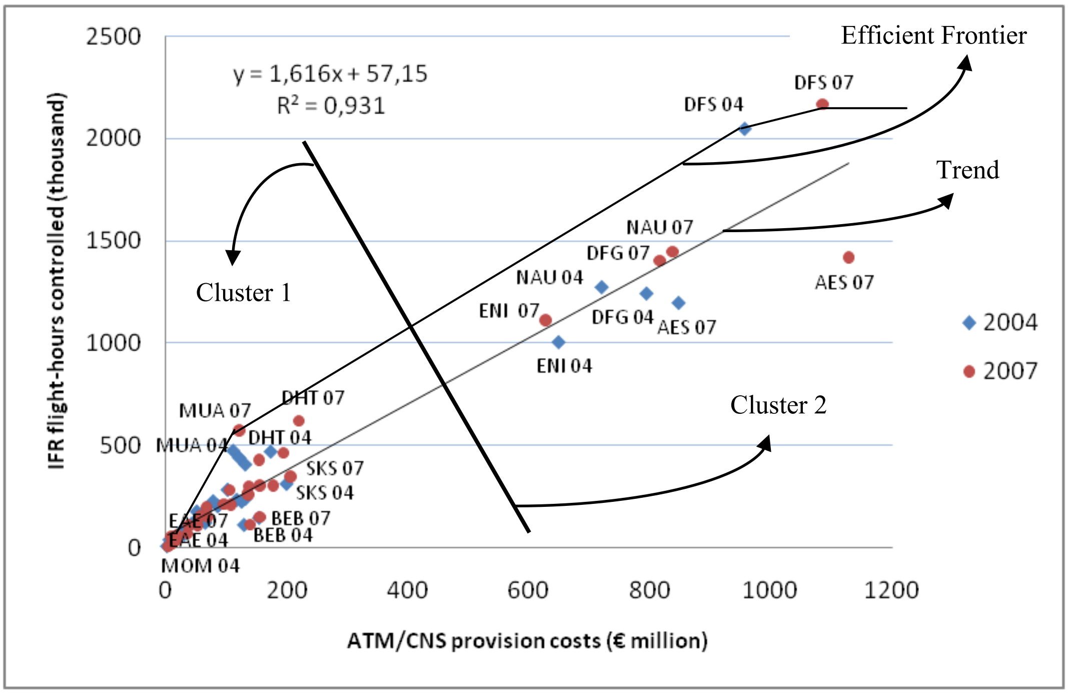

Figure 2 – Relation Controlled flight-hours and Cost of services provided

In figure 3, the same division of clusters 1 and 2 observed in figures 1 and 2, can be observed, confirming these clusters. Figure 2 as well as figure 3 indicate a strong adjustment between the input and the output variables used in the DEA-VRS model. When observing the efficiency frontier in these figures we can note the results of the efficient ANSPs displayed in the annex: EANS-Estonia (EAE) 2004; EANS-Estonia (EAE) 2007; Muac-Maastricht (MUA) 2007; MoldATSA-Moldova (MOM) 2004; NATS-United Kingdom (NAU) 2007; DSNA-France (DFS) 2004; and DSNA-France (DFS) 2007. Generally, the trend curve of figure 3 indicates that an increase of controlled flight-hours implies an increase in the number of controllers as well. However, the proportion of this increase is differentiated among the ANSPs, with even some cases of reduction, such as: ENAV-Italy (ENI) and UkSATSE-Ukraine (UKU).

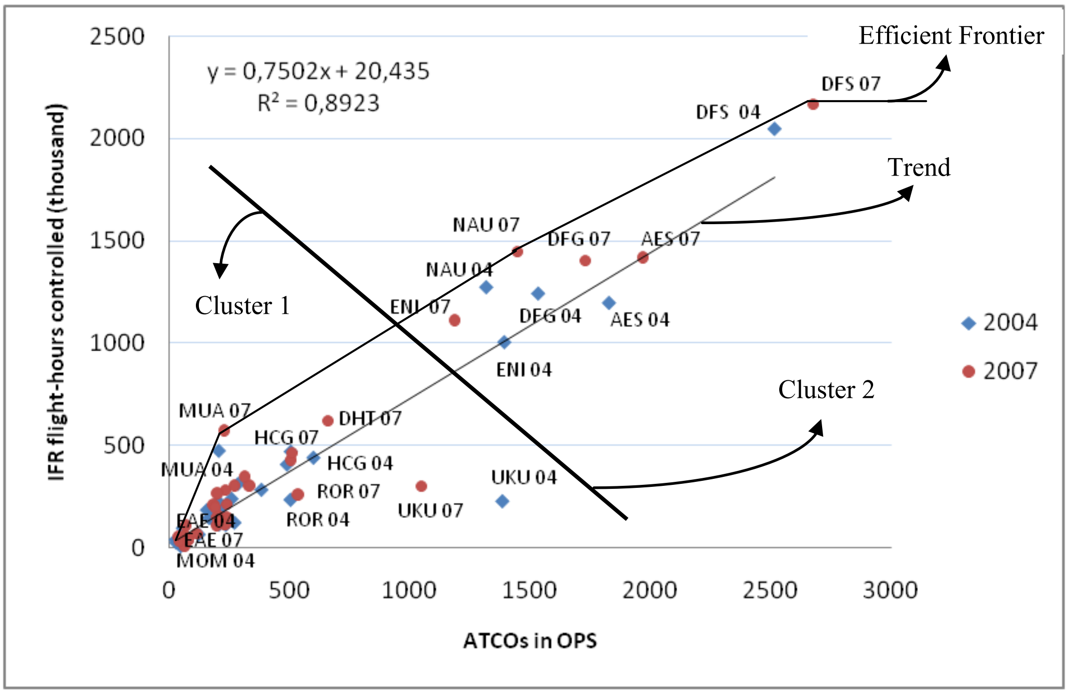

Figure 3 – Relation Controlled flight-hours and Number of controllers

Given the presence of two distinct ANSP clusters, with respect to the number of resources used and the services provided, the formation of two efficient frontiers related to these two groups is suggested. In figure 4, we observe the formation of these efficient frontiers which improve orientation for the ANSPs of each group.

Figure 4 contemplates the two inputs and the output used in the DEA-VRS model, aiding in visualizing the ANSP positions in relation to the efficient frontier. The frontier for cluster 1, formed by EANS-Estonia (EAE) 2004, Muac-Maastricht (MUA) 2007, should serve as a reference for the other smaller-scale ANSPs. The ANSPs composing this cluster presented a low relation of cost for services provided and number of controllers in relation to the controlled flight-hours. In this group, the closer the ANSPs are to the graph origin, the more efficient they will be. Likewise, the ANSPs that are distanced from the efficient frontier present worse performances. We can note in figure 4 that a large part of the smaller-scale ANSPs are located in an intermediary region and those that negatively stand out are: Belgocontrol-Belgium (BEB), LVNL-Netherlands (LVN), MoldATSA-Moldova (MOM) and UkSATSE-Ukraine (UKU). The first two can be influenced by the level of complexity of the controlled airspace (table 1), since the traffic density and the flow structure could require greater effort and resources for service providing and, thus, increase the input/output relation. The latter two can be considered sample *outliers*, bearing in mind that they are new small nations that appeared with the fall of the Soviet Union. This indicates that these ANSPs, during the periods analyzed, were in the phase of developing their infra-structure and management and, therefore, displayed performances very distinct from the rest. Above the frontier for cluster 1, we find the frontier for cluster 2, formed by the larger-scale ANSPs. Two ANSPs define the efficient frontier for each of the two groups (Figure 4). Cluster 2 is defined by NATS-United Kingdom (NAU) 2007 and DSNA-France (DFS) 2004, and cluster 1 by EANS-Estonia (EAE) 2004 and Muac-Maastricht (MUA) 2007. In terms of cost per controlled flight-hour (Cost/HC) the efficiency interval of cluster 2 is € 580 to € 470, while in terms of controllers per 1,000 (thousand) controlled flight-hours (OPS/HC), it is 1.23 to 1.00. These parameters for cluster 1 are: € 210 to € 170 (Cost/HC); and 0.63 to 0.39 (OPS/HC). Being that these ANSPs, in the DEA-VRS model, are confirmed as belonging to the efficient frontier, the graphic analysis gives us more objective benchmarking parameters.

Another aspect that can be observed in figure 4 is the evolution of the ANSPs from 2004 to 2007. The ideal ANSP movement is the displacement to the efficient frontier, moving in the direction of the (0.0) point in figure 4, because in this direction there will be a decrease in the relation of cost of services provided per controlled flight-hour as well as in the relation of number of controllers per controlled flight-hour. It can be said that the ANSPs outside of the frontier can, through imitation, reach the frontier. Going beyond this would mean innovation. ENAV-Italy (ENI), ATSA-Bulgaria (ATB), IAA-Ireland (IAI) and NAV (FIR Lisboa)-Portugal (NAP) stand-out as the ANSPs that obtained the best efficiency evolutions, a fact that is confirmed by the Malmquist Index (table 1).

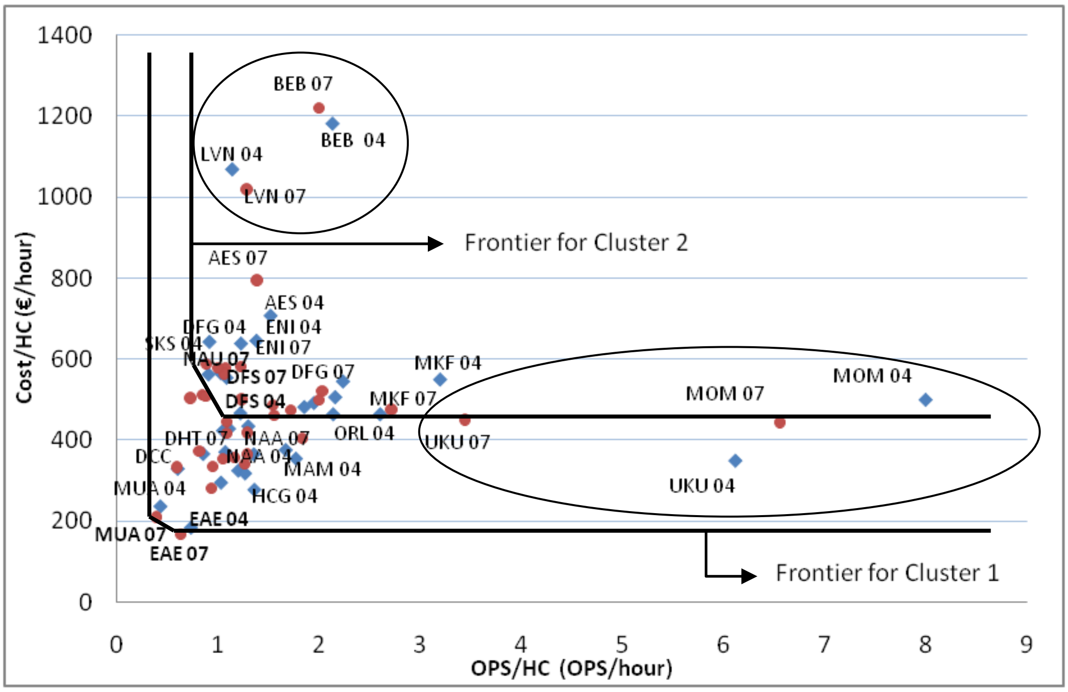

Figure 4 – Efficient Frontier of the relation number of controllers (OPS) and cost of services provided (Cost) with flight-hours controlled (HC)

6. CONCLUSION

The proposal of this article was to present a performance analysis of the European organizations responsible for the services of controlling their airspace, using Data Envelopment Analysis (DEA), as well as statistical inference and graphic analysis, as forms to assist in interpreting the results. Aiming to evaluate the sector's temporal evolution, two years were studied, 2004 and 2007, using the classic VRS model and the Malmquist-DEA-VRS model, orientated for the Input.

In data collection for this study, the authors found no articles that use the Data Envelopment Analysis (DEA) to analyze the performance of ANSPs. This research was based on reports from the Eurocontrol Performance Review Reports (2005 and 2008). The selection of variables (inputs and output) was limited by the availability of the data found in reports by the Eurocontrol. Thus, the coverage of performance evaluation was restricted to two variables of inputs and one output. The complexity of operating environment is an important variable to be included in future studies. Why not be available for both dates of analysis it was only talked about and becomes a limitation of the study.

Despite that the service demands of the ANSPs are defined by the external environment, regulation, density and flow demand etc, it is of significant importance to study the sector, seeing the need for optimization of resources for the creation of the single European sky. The study divided the ANSPs into two clusters, according to the number of flight-hours controlled. In this way, each ANSP outside the efficient frontier should observe the benchmarks of his group, as they fundamentally influence in the investment decisions and, thereby, in choosing the strategies for optimizing their resources.

The study defined four ANSPs that can be considered as benchmarks for the others, so that the European ANSPs have objective references to orient their development.

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ANNEX

Efficiency for Group 2

ANSPs		Efficiency	Return to Scale
DSNA, France 2007	DSF07	100%	Decreasing
DSNA, France 2004	DSF04	100%	Decreasing
NATS, United Kingdom 2007	NAU07	100%	Decreasing
NATS, United Kingdom 2004	NAU04	92%	Decreasing
ENAV, Italy 2007	ENI07	84%	Decreasing
ENAV, Italy 2004	ENI04	62%	Decreasing
DFS, Germany 2007	DFG07	84%	Decreasing
DFS, Germany 2004	DFG04	78%	Decreasing
Aena, Spain 2007	AES07	72%	Decreasing
Aena, Spain 2004	AES04	63%	Decreasing

Efficiency for Group 1

ANSPs		Efficiency	Return to Scale
EANS, Estonia 2007	EAE07	100%	Increasing

EANS, Estonia 2004	EAE04	100%	Increasing
MUAC, Maastricht 2007	MUA07	100%	Decreasing
MUAC, Maastricht 2004	MUA04	90%	Increasing
MoldATSA, Moldova 2007	MOM07	84%	Increasing
MoldATSA, Moldova 2004	MOM04	100%	Increasing
DCAC, Cyprus 2007	DCC07	83%	Increasing
DCAC, Cyprus 2004	DCC04	85%	Increasing
NATA, Albania 2007	NAA07	70%	Increasing
NATA, Albania 2004	NAA04	93%	Increasing
DHMI, Turkey 2007	DHT07	67%	Decreasing
DHMI, Turkey 2004	DHT04	56%	Decreasing
LGS, Latvia 2007	LGL07	63%	Increasing
LGS, Latvia 2004	LGL04	55%	Increasing
HungaroControl, Hungary 2007	HUH07	60%	Decreasing
HungaroControl, Hungary 2004	HUH04	68%	Decreasing
MK CAA, Fyrom 2007	MKF07	59%	Increasing
MK CAA, Fyrom 2004	MKF04	53%	Increasing
MATS, Malta 2007	MAM07	58%	Increasing
MATS, Malta 2004	MAM04	57%	Increasing
LFV/ANS, Sweden 2007	LFS07	58%	Decreasing
LFV/ANS, Sweden 2004	LFS04	64%	Decreasing
NAV (FIR Lisboa), Portugal 2007	NAP07	57%	Increasing
NAV (FIR Lisboa), Portugal 2004	NAP04	47%	Increasing
IAA, Ireland 2007	IAI07	55%	Decreasing
IAA, Ireland 2004	IAI04	47%	Decreasing
Croatia Control, Croatia 2007	CRC07	54%	Decreasing
Croatia Control, Croatia 2004	CRC04	51%	Decreasing
ANS CR, Czech Republic 2007	ANC07	51%	Increasing
ANS CR, Czech Republic 2004	ANC04	55%	Decreasing
HCAA, Greece 2007	HCG07	50%	Decreasing
HCAA, Greece 2004	HCG04	75%	Decreasing
Austro Control, Austria 2007	AUA07	47%	Increasing
Austro Control, Austria 2004	AUA04	39%	Increasing
UkSATSE, Ukraine 2007	UKU07	46%	Decreasing
UkSATSE, Ukraine 2004	UKU04	58%	Decreasing
Skyguide, Switzerland 2007	SKS07	45%	Increasing
Skyguide, Switzerland 2004	SKS04	44%	Increasing
NAVIAR, Denmark 2007	NAD07	45%	Decreasing
NAVIAR, Denmark 2004	NAD04	48%	Decreasing
Oro Navigacija, Lithuania 2007	ORL07	44%	Increasing
Oro Navigacija, Lithuania 2004	ORL04	46%	Increasing
ATSA, Bulgaria 2007	ATB07	43%	Decreasing
ATSA, Bulgaria 2004	ATB04	35%	Decreasing
Finavia, Finland 2007	FIF07	41%	Decreasing

Finavia, Finland 2004	FIF04	40%	Decreasing
ROMATSA, Romania 2007	ROR07	39%	Decreasing
ROMATSA, Romania 2004	ROR04	40%	Decreasing
Avinor, Norway 2007	AVN07	38%	Increasing
Avinor, Norway 2004	AVN04	56%	Decreasing
Slovenia Control, Slovenia 2007	SLS07	37%	Increasing
Slovenia Control, Slovenia 2004	SLS04	50%	Increasing
LPS, Slovak Republic 2007	LPS07	37%	Decreasing
LPS, Slovak Republic 2004	LPS04	35%	Decreasing
LVNL, Netherlands 2007	LVN07	36%	Increasing
LVNL, Netherlands 2004	LVN04	40%	Increasing
Belgocontrol, Belgium 2007	BEB07	24%	Increasing
Belgocontrol, Belgium 2004	BEB04	23%	Increasing