Paolo Malighetti (Italia), Stefano Paleari (Italia), Renato Redondi (Italia)

Airport classification and functionality within the European network

Abstract

This paper aims to provide an insight into the roles and characteristics of the different typologies of airports by detailing a functional framework of the European network. The first part of the work focuses on the classification of airports employing clustering techniques. Then, the analysis employs an innovative methodology to verify the existence of subsystems (or modules) of high interconnectivity within the European aviation network. The classification provided defines the airports both as separate entities with specific characteristics and as parts of specific modules. Our motivation is to provide a new way to classify European network in order to have a better understanding of the role they played into the network. Our approachs aim to identify groups of airports as strategic groups that share common attributes/roles but also to identify intra-industry grouping based on network interactions. This paper hints at the existence of a solid multilayered network system within Europe, in which traditional hub & spoke networks and low-cost point to point networks are interviewed.

Keywords: airports, network modularity, cluster.
JEL Classification: L93.

Introduction

Airport network developments. The recent deregulation and liberalization of air transport markets have greatly affected and transformed the entire sector. In Europe this process has been accompanied by a series of concomitant purposeful events which have strengthened its impact, namely the privatization of airlines and airports, the creation of a single air transport market and the massive development of the low-cost phenomenon. As a consequence, the roles played by airports and the distinctive features of the airport network have changed over the last ten years. Current European and also extra-European connectivity models testify that the once typical reality of a domestic hub playing a vital role in international connections is now past its best days, as tellingly corroborated by the distribution of the international traffic: in 1995 Fiumicino airport would transport 40% of all international passengers (data include charter airline traffic, which is generally more well-distributed among the different airports than scheduled airline traffic), while the three largest airports would carry 71.2% of passengers overall. In 2006 Fiumicino airport's share fell to 26%, while the three largest airports as a whole carried 57.2% of the international passenger traffic. Most of the so-called secondary airports have lately undergone unprecedented growth and steadily gained primary importance, as may be said of London Stansted in Europe. Nonetheless, it is clear that the main features of said minor airports set them apart from those airports of similar size with a former history as hubs. The recent developments ask no doubt for further clarification on the typology of airports forming the network. The very concept of hub may assume different connotations in Europe: we may identify historic hub airports such as London Heathrow, Paris CDG/Rossy and Frankfurt, which are key airports for the diverse world alliances and their leading carriers; newly-conceived hub airports such as Munich, London Gatwick and Stansted, operated by specific airlines; and others such as Fiumicino and Malpensa airports which may hardly be said to belong to the hub category, though they are indeed achieving great results worldwide.

Need for airports classification. The target of this paper is to define with utmost accuracy the airport network and the airports' distinctive features, which may lead in turn to a better understanding of the undergoing development process of the airport network and to help identifying strategic groups.

Strategic analysis traditionally recognizes that firms are not homogeneous (Hatten, and Schendel, 1977) within the same industry, rather some firms are more alike than others, and can be grouped together. The seminal theoretical background on strategic groups has been provided by Hunt (1972), Porter (1976, 1979) and Caves and Porter (1977). Strategic groups in industries can be identified based on similarities in firm scale, similarity of products and services in terms of price, features and quality; similarity in technology, or the similarity in customers served, among other dimensions. For a taxonomy of the variables employed see McGee and Thomas (1986). Strategic groups have been employed in order to explain rivalry patterns and different profitability within the same industry. Hatten and Schendel (1977) also argued that the identification of strategic groups could help management to evaluate strategies.

In the air transport field, studies on airlines (Peteraf, 1993) supported the Porter suggestion (Porter, 1979) that rivalry is greater across groups than within groups.

Acknowledgements: We wish to thank participants at the AiIG 2007 conference in Milan and at the Airneth 2008 workshop in The Hague for their useful comments and ideas. The authors remain responsible for any remaining errors and inaccuracies.

In the field of airport business, few works have identified strategic groups and rivalry dynamics. The need for such as analysis emerged in Europe only in the last few years because of: i) the privatization process of several airport operators; ii) the further development of the deregulation process along the air transport supply chain; and iii) the competitive pressure made by secondary airports served by low cost carriers.

The airport industry is an interesting case. On the one side, all airports belong to the same network, most of them are operated by the same airlines and some of them serve the same group of passengers. In fact, a passenger trip usually involves at least two different airports. On the other side, airports are very heterogeneous in size, profitability and role played in the network.

The features described above explain the importance for airport operators and regulators to identify strategic groups for best-practice benchmarking and regulatory purposes. The role played by an airport within the network has been considered as one of the main variables indentified by literature. The Borenstein study (1989) firstly recognized its influence on pricing and profitability of the air transport as a whole.

The classification of airports into homogeneous groups represents a good starting point for the analysis of a variety of issues, such as the impact of air route deregulation, airport congestion, suitable development policies and regulatory norms, airport performance analysis and airport *benchmarking practices.*

Recent studies also suggest (Gulati et al., 2000) that a firm's network of relationships is a source of both opportunities and constraints and thus a network perspective offers the potential for mapping intra-industry structure in novel ways. In the case of airports, the first source of relationship between two airports is of course the presence of a route connecting each other. It is easy to understand why the presence of a route inexorably interconnects the behavior and the performance of the two airports (same airlines and passengers served). Thus our analysis does not simply rely on finding airports with similar characteristics, typically involving some cluster analysis, but also on finding airports with strong interconnections.

Previous empirical airport classifications. The paramount importance of the issue and the unavailability of an easy airport classification for operators and regulatory body is proved by the many consultations launched by the European Union as early as the Nineties (EC, 1999 and EC, 2003). The categorization of airports provided by the European Community, which is basically dimensional (number of passengers or volume of freight transported), is notably a reference point for the assignment of funds relating to the creation of new routes (EC, 2005).

In order to evaluate the impact of liberalization in Europe, Graham (1998) identifies 7 *clusters* according to the main characteristics of the areas served (*leisure destinations – important metropolitan areas*) and their main role (*intercontinental hub – major regional airports*), highlighting at the same time the risk for some European areas to be peripheralized.

The classification is based not only on the infrastructural services offered by each airport, but also on the identification of homogeneous clusters within which airports are found to share similar traits relating to performance, operational activities and roles within their geographical context. The service provided by air transportation is based on airport interconnectivity, access to local markets and nodes of connections within the airport network. The very characteristics of the network and its nodes are fundamental in outlining the overall structure of the market. Our paper is here meant to be a further development of Burghouwt and Hakfoort's study (2001), which examines the development of the European network between 1990 and 1998 by way of the hierarchic cluster methodology, thus defining 4 groups of airports according to the variables of typology and number of connections. Other studies (see Guimerà et al., 2005) concentrate more on the very characteristics of the network and the interconnectivity between subgroups to prove that the dimensions of airports and their functions may be totally unrelated. Studies on airport competition such as Cranfield University's (ATG, 2002) show that the most popular variables for airport classification centre on 5 different aspects: size (number of passengers, volume of freight, range of air services), geographical position (i.e. proximity to the capital), role (intercontinental rather than local hub), ownership (private or public) and association with a specific network. The studies so far conducted suggest somehow the equal importance of the variables defining airports as specific entities and of those intended to stress their role within a given network.

Our paper belongs to this line of research and aims to assimilate the two types of variables mentioned above into the traditional methods of classification and cluster analysis.

1. Research methodology

The peculiarity of this paper lies in its classification of European airports by means of an innovative methodology. More specifically, airports will be grouped not only according to their own particular features, such as the number of passengers or freight volume, the overall movements effected, the number of routes or airlines, the number of residents of the catchment area and their relative GDP, but also according to the roles they play within the network.

An innovative technique will divide the overall European network into modules with the aim to identify the main features of the airport system within which the single airports are to be found. The single modules are intended to group together airports with very strong links between them in terms of number of connections, while being more weakly connected to the rest of the network. The methodology used here is known as *simulated annealing* and was first conceived to study the diffusion of heat in a solid body; it was later employed to simplify networks made of thousands of elements (neural networks, calculator networks, etc.) into relatively independent networks.

The function we will maximize in order to achieve the partition of the network is known as *modularity* M(P) of a partition P of the network (Guimerà et al., 2007) and is defined as follows:

$$M(P) = \sum_{S=1}^{N_m} \left[\frac{l_s}{L} - \left(\frac{d_s}{2L} \right)^2 \right],$$

where N_m is the number of modules (<= the number of elements within network N), L is the number of links within the network, l_s is the number of connections between the airports belonging to module s and d_s is the sum of the degrees (that is the number of departing flights) of the airports within module s. The objective of the maximization of function M leads to the identification of the optimal partition P into which the network is to be divided, that is the optimal number of modules N_m.

The objective function *M(P)* is at its highest when the network is partitioned into compact modules, that is when there are numerous connections between airports belonging to the same module. The same function would obviously be at its lowest with modules grouping together airports badly connected between them. The non-linearity of the objective function and the fact that the number of modules cannot be known beforehand do not allow the use of the traditional techniques of *clustering* (hierarchical *clustering* or *k-means clustering*) to solve the problem of the partition of the network into modules by way of maximization of the function *M(P)*. Guimerà and Aramal (2005) demonstrated that the most suitable technique that may be used here is the *simulated annealing*, an algorithm generating a stochastic optimization research where the probability to deviate from maximum increase of the objective function is strictly dependent not only on the improvement given by a new solution, but also on the search time. For further information on this methodology, please see Kirkpatrick et al. (1983).

The technique of *simulated annealing* has so far been applied to the airport system merely considering the existence of an interconnection between airports, thoroughly neglecting variables which may prove paramount in assessing the "strength" of the connections (i.e. the number of seats or the frequency of routes). Our paper aims to overcome this limit by considering the variable of the number of seats per route into the algorithm of modularization.

The methodology hereby applied may therefore be divided into the following parts, as shown in Figure 1:

- classification of the European airport network into clusters and identification of their characteristics;
- partitioning of the European airport network into modules by means of the *simulated annealing* methodology and identification of their role within the network;
- comparison of the results of clustering and simulated annealing.

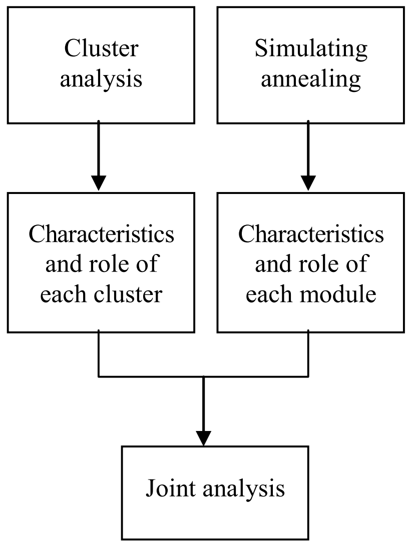

Fig. 1. Steps of the empirical analysis

2. Empirical analysis

2.1. Cluster analysis. In the empirical analysis we take into account the 467 airports with at least one passenger flight scheduled in Autumn 2007.

Clustering techniques aim to identify groups sharing similar features. The analysis carried out on European airports has primarily focused on the role they play within the airport system and the relative homogeneous elements. The variables that could be identified have been grouped into 4 categories:

- *Dimensional.* The role and importance of an airport are undoubtedly related to its traffic volume. The three main variables are: the number of seats available on scheduled flights (seats/day), the number of daily flights (flights/day) and the number of destinations served (dest.). Although there is a correlation structure between these variables, they subtly emphasize different aspects of the dimensional variable, namely intensity, density and scope of the service offered.

- *Destination of the connections.* This variable helps to classify the airport as an intercontinental gateway rather than a domestic connecting node. The analysis focuses in particular on the percentage of destinations offered within the EU (% EU dest) rather than domestic destinations (% dom dest). One more variable has been added to all the previous ones: it identifies the distribution of traffic among the routes made available and is meant to detect possible high points of concentration of the service. The variable employed here (route distribution) is the result of the HHI index, calculated as the sum of the squares of the number of seats offered on each route in relation to the total number of seats offered by the airport, divided by the same index as may be obtained hypothesizing an equal distribution of the number of seats offered among all the routes available within the same airport. The index thus shows a "relative" distribution of the routes, mitigated in that its dimensions are strictly dependent on the number of routes offered.
- *Variables of connectivity*: show the potentiality of an airport as intermediate connection. The variables used here are the so-called betweenness (*betw*) and limited percentage (*lim %*). The former is given by the number of times per day the airport works as intermediate connection between two airports linked through optimal connectivity, while the latter yields the percentage of times the airport cannot be bypassed through routes of similar duration (for further information see Malighetti et al., 2008). The two variables stress the potentiality for interconnectivity of the airport and the importance of the airport as intermediate connection.
- *Typology of service*: given the peculiarities of low-cost airlines, this variable has been conceived to centre on the volume of seats offered by said airlines (*% low cost*). The aim is to examine a *point-to-point* connecting structure, where the airports' role is quite unlike the *hub-and-spoke* structure's. The lack of a coherent definition of "low-cost" carrier has suggested the use of the list drawn by Eurocontrol (EU, 2007). It should be remembered here that the role of the airport is influenced by its importance within the network of the different airlines. To this end, the variable "base" is meant to show the number of airlines considering one airport as their main reference[1] (calculated as percentage of the overall number of seats available with one airline).

Table 1 shows the descriptive analysis for the different variables surveyed.

Table 1. Descriptive statistics of the variables used in cluster analysis

	№ dest	Seats/day	Flights/day	% EU dest	% Dom dest	Route distr.	Betweenness	% lim	% low cost	№ bases
Average	19.7	2,825.7	22.4	94.7%	59.1%	1.83	104	49%	26%	0.29
Deviation std.	34.3	7,262.2	47.4	11.4%	39.4%	1.00	329	41%	34%	0.73
25° percentile	21.0	2,065.1	19.9	100.0%	100.0%	2.22	38	84%	49%	-
75° percentile	2.0	90.3	1.9	96.0%	20.0%	1.08	-	0%	0%	-

For their suitability to the characteristics of the airport network, the techniques of hierarchical clustering have been employed here. For further information on these techniques please refer to Everitt (2001). The method of aggregation we have chosen is the so-called "Ward linkage", which employs as its aggregation criteria the minimization of the sum of the squares of the distances between airports belonging to the same cluster. Unlike the Average Linkage, the Ward Linkage method tends to originate slightly more spherical clusters and consequently can identify clusters for medium-size airports as well. The application of the Average Linkage method instead, although it may generally show a higher cophenetic correlation coefficient, generates a number of clusters formed by singletons or single observations. The optimal number of clusters is 8 as suggested by the structure of the Dendrogram and further confirmed by the Duda/Hart index.

Table 2 shows the average values of the different clusters for all the variables analyzed. A more detailed statistical analysis is provided in appendices A and B. The average silhouette width (Kaufman and Rousseeuw, 1990) of each and every cluster proves to be a good measure of the strength of clustering results. Silhouette values show to what extent airports within the same clus-

[1] The main airport of reference thus determined may not coincide with the main logistic base of the carrier.

ter are characterized by proximity, while stressing their distance from airports belonging to different clusters. They can therefore lead to an analysis of how compact and significant the single clusters are, and what kind of role and general characteristics they may have in relation with a specific airport. An analysis of the values shows that clusters 5 and 6 are less homogeneous than the others.

Table 2. Averages of the clusters identified

Clust.	№ dest	Seats/day	Flights/day	% EU dest	% dom dest	Route distr.	Betweenness	Lim %	% low cost	№ bases
1	177.9	44,701.6	281.3	54.4%	11.8%	2.64	1,696	58%	10%	2.25
2	116.4	19,041.7	143.3	71.1%	13.1%	2.51	1,087	67%	27%	2.38
3	72.3	7,812.7	67.6	73.2%	17.0%	2.85	356	81%	30%	1.55
4	46.5	5,523.3	41.8	91.4%	15.2%	2.15	90	63%	75%	0.33
5	27.9	3,884.8	35.0	97.0%	44.6%	3.83	129	67%	25%	0.35
6	13.0	1,000.4	10.7	82.6%	28.2%	1.70	18	46%	19%	0.25
7	9.9	976.7	7.8	99.1%	21.8%	1.50	7	48%	76%	-
8	3.2	233.6	3.7	100.0%	93.9%	1.38	9	40%	6%	0.09

A detailed review of the main characteristics of the clusters is provided here below.

<u>Cluster № 1</u> comprises 8 airports which may be defined as worldwide hubs for their specific characteristics. The main airports served by worldwide alliances belong to this group (London Heathrow, Paris Charles de Gaulle, Amsterdam, Frankfurt as well as Rome Fiumicino). The airports grouped here share all similar dimensional characteristics, especially in terms of density (number of flights) and intensity (number of seats). They have a high percentage of overseas destinations and can offer a wide range of opportunities for interconnectivity (high betweenness ratio). These airports also work as main base for a variety of carriers and are characterized by the low presence of low-cost carriers.

<u>Cluster № 2</u> (defined as "hub") groups 16 airports, namely former flag carriers' hubs (Athens, Vienna, Zurich, Brussels, Stockholm) and secondary medium or large-size hub airports (Gatwick, Orly). Malpensa and London Stansted also belong to this cluster. Unlike airports listed in cluster 1, those grouped here tend to favor European routes (on average 75% of the routes are within Europe) and are served by a variety of low-cost carriers.

<u>Cluster № 3</u> is called "secondary gate" and comprises 11 airports, among which Lisbon, Glasgow, Venice, Warsaw and Marseille airports. They are characterized by medium-size dimensions and offer a limited number of overseas destinations (less than 30% of the routes offered), with a visible concentration of traffic distribution over a limited number of destinations. Their role as intermediate connections (as assessed by a high limited % value) further confirms their main function as gates for local areas.

<u>Cluster № 4</u> groups together 33 airports with average traffic dimensions of 3-5 millions of passengers per year and are typically characterized by a high concentration of low-cost carriers (covering 75% of the seats offered on average). The main destinations are generally non-domestic and European: only 15% of the destinations are domestic, against an average of European destinations higher than 90%. This may be the result of the entry of low-cost carriers, which transformed secondary airports with limited local connections into structured realities belonging to a well-developed European network. Bergamo Orio al Serio, Ciampino and Pisa are the Italian airports belonging to this group.

<u>Cluster № 5</u> gathers 46 airports and is also called "*no low-cost gate*" (with the term "gate" referring to the European rather than overseas market). As formerly said, this cluster seems to be less homogeneous than all the previous clusters described so far. Destinations here are almost always European. Low-cost carriers play a minor role and routes are mainly domestic and intended to connect secondary airports within the country. Some airports may be connecting points between hub and secondary airports, as may be evidenced by the average of the limited % index (up to 63%) and by the existence of a number of heavily flown routes along with less demanded flights (the index of distribution of the routes is higher here than in any other cluster). Linate, Palermo and Valencia airports are to be counted in this group.

<u>Cluster № 6</u> is made of smaller, mainly regional airports. Like the previous cluster, it cannot be said to be remarkably compact.

<u>Cluster № 7</u> consists of airports dimensionally similar to cluster № 6, but mainly characterized by the large presence of low-cost carriers, determining a wide offer of European rather than domestic destinations.

<u>Cluster № 8</u> is the largest and is made of local airports (namely 238). Their offer is often limited to a restricted number of routes, only rarely more than 4 or 5, generally touching domestic destina-

tions; low-cost carriers are seldom found to operate here and are absent in more than 75% of the airports listed in this category (as shown in Appendix A). This is the case of the Norwegian airports network and surprisingly of French secondary airports (25). Italian examples are Aosta, Crotone and Lampedusa airports.

To sum up all the above, cluster analysis may be said to lead to the following conclusions:

- low-cost airports have been classified into two different clusters according to their dimensions;
- major airports may be said to fall into three main categories: i) the big intercontinental hubs at the top; ii) airports offering sometimes even intercontinental services for a limited area, in an intermediary position; iii) hubs with a good intra-European network, but less apt than airports of cluster 1 to offer intercontinental services.

2.2. Simulated annealing. Table 3 shows the modules derived by considering the number of offered seats per route into the algorithm of modularization.

More specifically, 13 modules were generated, stretching from a maximum number of 128 airports (first module) to a minimum of 7 (13^{th} module). Major airports are those with the higher number of offered seats (be it towards airports of the same module or outside), while the most important airports are the strongest within the module. The most important airports of each module may be regarded as "the new European capitals of air transportation".

The HHI (concentration index) per airport and country[1] shows whether the connections operated in a module are strongly concentrated around the airports and countries of reference.

Referring to the country HHI, it is possible to classify the modules into two categories. The first relates to modules with higher country concentration indexes. One would expect to find these modules in an un-liberalized environment since they are composed of mainly domestic airports headed by the most important airport in the country. The French, the Norwegian, the Swedish, the Greek, the Italian, the Spanish, the Finnish, the Portuguese, the Danish and Icelandic modules belong to this category.

The second kind of module comprises airports of different countries and thus lower country concentration index. Modules 1, 4 and 10, headed by Heathrow-Dublin, Frankfurt-Palma De Mallorca and Brussels-Prague respectively, belong to this category.

In particular, the first module includes the major European low-cost airports, among which Stansted, Luton and Dublin, along with the major Italian low-cost airports, such as Ciampino, Orio al Serio and Pisa, but it now comprises more traditional airports located in Great Britain and Ireland as well. The European low-cost and the English and Irish traditional networks have merged. In other words, it may be said that the *point-to-point* network originated by the presence of low-cost operators has joined with the *hub-and-spoke* network of Great Britain and Ireland, which is mainly run by traditional airlines. This is hardly surprising, given that in these countries low-cost airlines operate along with traditional operators at the same airports.

Interestingly, the "Italian" module headed by Fiumicino has Paris Charles De Gaulle as the major airport. The latter cannot be included into module 2 with the other French airports because they are better integrated with the second-largest Paris-based airport of Orly. This is partially explained by the recent development of a high-speed train service as an alternative to the airline network to connect Paris Charles De Gaulle and some of the main French cities. Charles de Gaulle has been classified within the "Italian" module thanks to its numerous connections with the major Italian airports, especially Fiumicino, Linate and Malpensa. This may be explained by the secondary role played by Alitalia within Skyteam, its worldwide alliance. Many intercontinental connections run by the alliance are as a matter of fact offered by Air France, with the airport of Charles de Gaulles as its hub. This is the reason why the Italian network appears to be well connected with the Paris-based airport, at least in terms of seats offered.

An analysis of the group headed by Reykjavik Domestic airport shows that the percentage of internal connections equals 100%. This means that all the 7 Icelandic airports of the module are solely connected between them and have no kind of connection with the rest of Europe, be it direct or not. As a matter of fact, international connections towards and from Iceland are run at Reykjavik International airport, which is not linked to the other 7 domestic airports and indeed is part of the Danish module headed by Copenhagen.

[1] Defined as $\sum_{i=1}^{n} s_i^2$, where s_i is the share of connections offered respectively by the single airports forming the module and the relative countries of reference.

Table 3. Modules derived through the use of the simulated annealing method considering the seats available on the direct connections between the 467 airports examined

No.	No.of airports	Major airport	Key airport	% internal connections	HHI airport	HHI countries	Main country
1	128	London Heathrow	Dublin	64.1%	289	3,119	United Kingdom
2	48	Paris Orly	Paris Orly	56.8%	1,491	9,968	France
3	48	Oslo	Oslo	74.1%	1,710	9,972	Norway
4	46	Frankfurt	Palma De Mallorca	55.8%	716	5,284	Germany
5	33	Stockholm-Arlanda	Stockholm-Arlanda	57.8%	1,822	9,730	Sweden
6	31	Athens Eleftherios	Athens Eleftherios	49.0%	2,350	8,354	Greece
7	31	Paris Charles De Gaulle	Rome Fiumicino	45.8%	1,127	8,505	Italy
8	30	Madrid Barajas	Madrid Barajas	47.7%	1,137	10,000	Spain
9	20	Helsinki-Vantaa	Helsinki-Vantaa	44.5%	2,761	10,000	Finland
10	17	Brussels National	Prague-Ruzyne	15.2%	1,627	1,948	Czech Republic
11	16	Lisbon	Lisbon	34.5%	1,678	9,366	Portugal
12	12	Copenhagen	Copenhagen	20.8%	3,002	7,939	Denmark
13	7	Reykjavik Domestic	Reykjavik Domestic	100.0%	3,201	10,000	Iceland

Table 4 shows the exchanges of offered seats among the modules. It is possible to see that the highest exchanges are within each module. The only exception is module 10 headed by Brussels which exchanges more seats with module 1. Even if the percentage of seats exchanged among airports in the same module is a good proxy for the compactness of the module, the modularity function, described in the methodology section, weights compactness against the dimension of the module, in terms of offered seats. In particular, the maximization of this objective function tends to form small and compact modules. This is to avoid the paradoxical solution in which all the airports are classified in the same module, which a % of internal connection which equals 100%. For the same reason the strong module headed by Heathrow and the weak module headed by Brussels are considered separately even if there the latter exchange heavily with the former.

Table 4. Seat exchanges between any couple of modules

No.	Major airport	1	2	3	4	5	6	7	8	9	10	11	12	13
1	London Heathrow	64%	3%	1%	11%	1%	1%	6%	6%	1%	4%	1%	1%	
2	Paris Orly	16%	57%	1%	6%			8%	5%		4%	2%		
3	Oslo	9%	1%	74%	3%	4%		1%	1%	1%	2%		5%	
4	Frankfurt	15%	2%		56%	1%	3%	7%	9%	1%	3%	1%	2%	
5	Stockholm-Arlanda	10%	1%	5%	7%	58%		2%	1%	5%	4%		7%	
6	Athens Eleftherios	12%			26%		49%	7%	1%		4%			
7	Paris Charles De Gaulle	17%	4%		16%	1%	2%	46%	6%		5%	2%	1%	
8	Madrid Barajas	20%	2%		18%			6%	48%		3%	2%	1%	
9	Helsinki-Vantaa	12%	1%	2%	11%	10%		3%	3%	44%	6%		6%	
10	Brussels National	29%	5%	2%	17%	3%	3%	11%	7%	2%	15%	3%	3%	
11	Lisbon	16%	4%	1%	16%			8%	12%		6%	35%	1%	
12	Copenhagen	21%		10%	17%	11%		5%	2%	4%	7%	1%	21%	
13	Reykjavik Domestic Airport													100%

The % of internal connections measures the "compactness" of the modules and is calculated as the number of seats available on routes within the module divided by the total number of European seats offered by the airports of the module. Apart from the isolated Icelandic module, which has a 100% percentage of internal connections, the most compact modules are the Norwegian module and, surprisingly, the international module headed by Heathrow-Dublin.

Figure 3 maps the airports of the different modules. Interestingly, Module 1 also includes low-cost airports in Spain, France and Italy and the main airports in Romania.

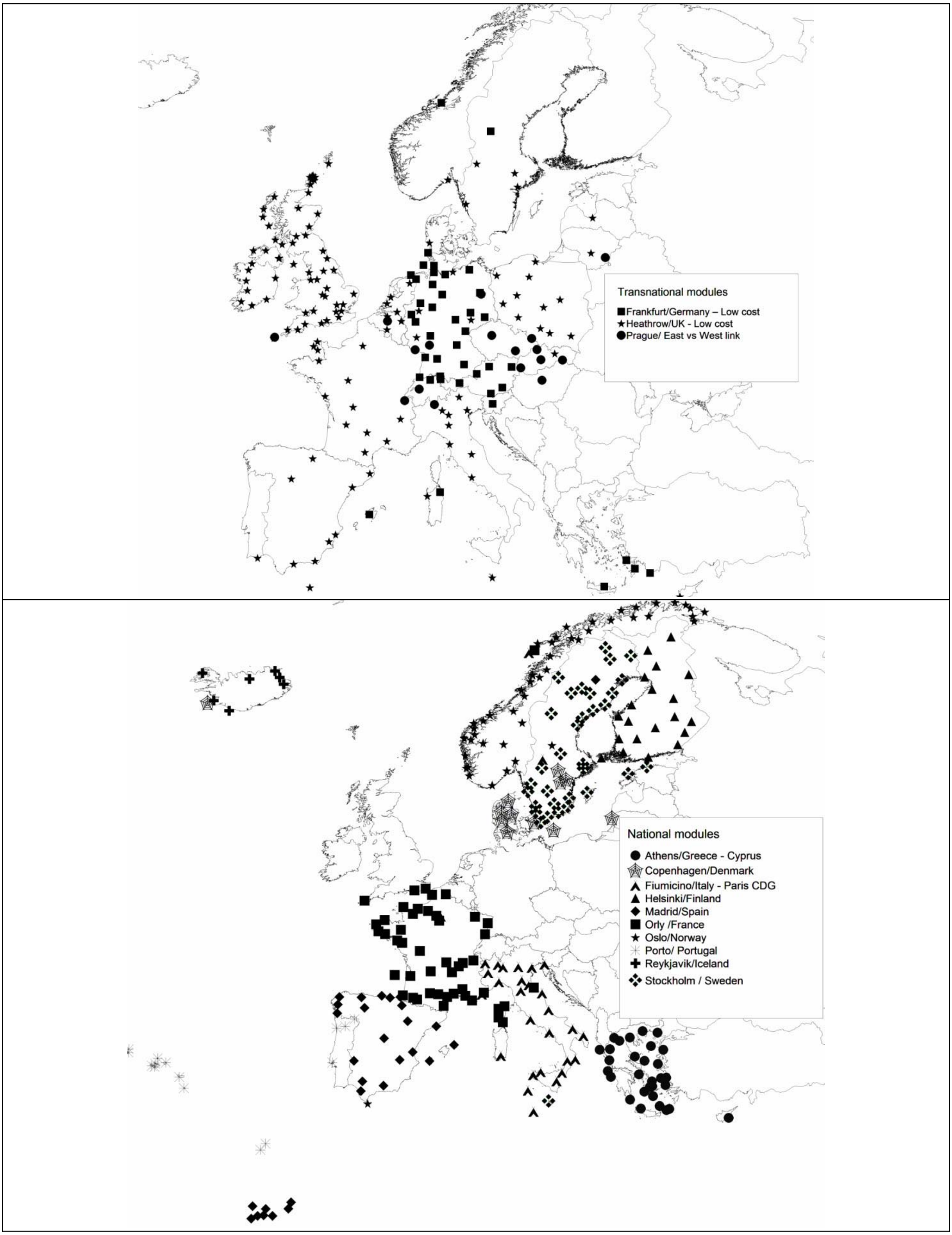

Fig. 2. Maps of the modules derived from the simulated annealing. The top figure represents the airports belonging to the three transnational modules (module 1, 4 and 10) with a Country concentration index lower than 6,000. The bottom figure shows the "national" modules with a higher concentration index

Table 5 shows the percentage of European seats offered by the 20 major carriers in Europe within each module. The main carrier, Lufthansa, offers 44% of its European seats on routes between airports belonging to module 4. It does not surprise since module 4 is headed by Frankfurt which is the main base of Lufthansa. It offers also seats for routes between airports of module 1,5%, and module 7,5%. The remaining seats are offered on routes connecting different modules. The main low-cost carriers, Ryanair and easyJet, offer respectively 74% and 48% of their seats within module 1. Ryanair does not offer seats within other modules.

Table 5. Share of seats offered by the main European carriers within each module

Rank	Carrier	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Lufthansa	5%			44%			5%						
2	Ryanair	74%												
3	Air Berlin	2%			59%									
4	SAS			37%		16%							3%	
5	easyJet	48%	2%					2%	1%					
6	Air France	1%	47%					7%						
7	British Airways	38%												
8	Hapag Lloyd Express				51%									
9	Iberia	1%							47%					
10	Alitalia							65%						
11	Monarch Airlines	63%												
12	Spanair								66%					
13	Olympic Airlines				1%		52%							
14	SWISS				23%						1%			
15	KLM	32%												
16	FlyBE	81%												
17	Aer Lingus	56%												
18	Condor Flugdienst				56%									
19	Air Europa Lineas Aereas								50%					
20	bmi	84%												

Table 6 shows for each module, the HHI concentration index per operating carrier and the major three carriers. Module 1 has the lowest concentration index. As expected the major carrier in this module is Ryanair offering almost 30% of seats exchanged within the module. EasyJet is in second position, with 13.81% followed by British Airways with 8.48%.

The module with the highest concentration index is the French module, headed by Paris Orly. In this case the major carrier, Air France, offers more than 86% of seats within the module. SAS is the major carrier in the Scandinavian modules 3 and 5, and is in second position in the Danish module.

In module 4, headed by Frankfurt, the major carrier is surprisingly the low-cost Air Berlin, with 36.58% followed by Lufthansa with 29.05%. In module 7, the Italian module headed by Paris Charles De Gaulle-Rome Fiumicino, Air France comes in third position after the two Italian carriers, Alitalia and Airone. It confirms the important role played by Air France in the Italian module with its connections to Paris Charles De Gaulle.

Table 6. The HHI concentration index by carriers and first three carriers by offered seats in each module

No.	HHI	First carrier		Second carrier		Third carrier	
1	1,327	Ryanair	29.78%	easyJet	13.81%	British Airways	8.48%
2	7,479	Air France	86.22%	CCM	5.09%	easyJet	3.75%
3	5,461	SAS	71.47%	Norwegian Air Shuttle	15.73%	Wideroe	10.14%
4	2,517	Air Berlin	36.58%	Lufthansa	29.06%	Hapag Lloyd Express	16.65%
5	3,407	SAS	54.50%	Malmo Aviation	12.40%	flynordic	12.32%
6	4,888	Olympic Airlines	63.66%	Aegean Airlines	27.67%	Cyprus Airways	8.40%
7	1,729	Alitalia	34.24%	Air One	16.43%	Air France	8.95%
8	2,488	Iberia	34.61%	Spanair	30.30%	Binter Canarias	13.51%
9	4,162	Finnair	56.59%	Falcon Express	26.66%	Blue1	15.72%
10	2,080	CSA	37.39%	SN Brussels Airlines	20.35%	Easyjet Switzerland	9.80%
11	2,565	TAP-Portugal	38.09%	SATA International	21.71%	SATA - Air Acores	21.17%
12	3,362	Cimber Air	42.30%	SAS	38.29%	Icelandair	6.91%
13	10,000	Air Iceland	100.00%				

2.3. Sensitivity analysis. The simulating annealing methodology classifies each airport in one and only one module, following the maximization of the modularity function. However, it is possible that some airports may be included in other modules with only a limited loss of the objective function. In order to assess the robustness of the classification into modules, in this section we carry out a sensibility analysis.

For any airport we calculate the objective function loss derived from classifying it into any other module. The 2nd best module for each airport is the module in which the loss of the objective function is at its minimum. In other words, for any airport, the 2nd best module is the best alternative of the optimal module. We also calculate the percentage loss in the objective function by classifying the airport in the second-best module. The higher the objective function loss passing from the first-best module to second-best module, the higher the robustness of the optimal classification. If the objective function loss is zero, the airport may be classified indifferently into the two modules. Table 7 shows the 2nd best module and the related objective function loss for the major airports and for the most important airports of each module.

Table 7. Objective function loss and sensibility index for the major airports and the most important airports in each module

No.	Major airport	2nd best module	Objective function loss	Sens. index	Key airport	2nd best module	Objective function loss	Sens. index
1	London Heathrow	10	2.0%	15.5%	Dublin	13	4.4%	60.7%
2	Paris Orly	11	5.5%	63.0%	Paris Orly	11	5.5%	63.0%
3	Oslo	12	5.4%	50.7%	Oslo	12	5.4%	50.7%
4	Frankfurt	10	3.4%	23.5%	Palma De Mallorca	8	3.5%	25.5%
5	Stockholm-Arlanda	12	3.0%	34.5%	Stockholm-Arlanda	12	3.0%	34.5%
6	Athens Eleftherios	4	3.1%	31.1%	Athens Eleftherios	4	3.1%	31.1%
7	Paris Charles De Gaulle	2	0.3%	2.7%	Roma Fiumicino	10	5.3%	47.8%
8	Madrid Barajas	11	5.4%	34.1%	Madrid Barajas	11	5.4%	34.1%
9	Helsinki-Vantaa	5	1.1%	20.5%	Helsinki-Vantaa	5	1.1%	20.5%
10	Brussels National	12	0.4%	5.8%	Prague-Ruzyne	7	0.5%	7.2%
11	Lisbon	8	0.6%	12.5%	Lisbon	8	0.6%	12.5%
12	Copenhagen	5	0.3%	3.6%	Copenhagen	5	0.3%	3.6%
13	Reykjavik Domestic Airport	9	0.3%	100.0%	Reykjavik Domestic Airport	9	0.3%	100.0%

The airport with the highest objective function loss is Paris Orly belonging to the French module with 5.5%. It means that Paris Orly is robustly assigned to module 2. However, employing the objective function loss passing from the first-best to the second-best module as a proxy of robustness has some shortcomings. The most evident disadvantage is that the objective function loss relates to the variation of the modularity of the entire European network. Even an airport as big as Paris Orly, optimally classified in one of the most compact module, brings a loss of only 5.5% when forced into the 2nd best module. If we consider the case of a small airport with only a couple of routes, all offered in its first-best module, passing to any other module brings an objective function loss of about 10-6%. It does not mean that that airport may be indifferently classified in any module.

For this reason, we calculate a relative proxy for robustness, called sensibility index, also shown in Table 8, defined for each airport as the objective function loss passing from the first-best to the second-best module divided by the possible maximum loss. The latter is computed under the assumption that the airport offers seats only to other airport belonging to the first-best module. In the case of the small airport with a few routes only towards other airports of the same module, the sensibility index equals 100%, since the airport has no exchange with the other modules. The lower the sensibility index, the lower the robustness of classifying an airport into its first-best module. Unsurprisingly, the sensibility index of the Reykjavik Domestic Airport is 100% since it does not exchange out of its module. In other words, even if the objective function loss is only 0.3%, it cannot be classified into any other module. The same can be said of the other airports belonging to the Icelandic module. The major airport with the smallest sensibility index is Paris Charles De Gaulle, with only 2.7%. It means that this airport, classified into the Italian module, could be classified almost equally well in its second-best module, the French module.

Table 8. Distribution of sensibility indexes for airports in each module

Module No.	Major airport	Number of airports	Range				
			0.8-1	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2
1	London Heathrow	128	50%	16%	10%	9%	14%
2	Paris Orly	48	48%	15%	19%	8%	10%
3	Oslo	48	88%	6%	2%	0%	4%
4	Frankfurt	46	33%	17%	11%	15%	24%
5	Stockholm-Arlanda	33	67%	9%	6%	9%	9%
6	Athens Eleftherios	31	74%	0%	6%	16%	3%
7	Paris Charles De Gaulle	31	29%	16%	10%	16%	29%
8	Madrid Barajas	30	33%	17%	3%	27%	20%
9	Helsinki-Vantaa	20	75%	0%	0%	15%	10%
10	Brussels National	17	18%	6%	6%	12%	59%
11	Lisbon	16	75%	0%	0%	6%	19%
12	Copenhagen	12	42%	0%	17%	17%	25%
13	Reykjavik Domestic Airport	7	100%	0%	0%	0%	0%

Table 9 shows the distribution of the sensibility index among airports in each module. For example, 50% of airports belonging to module 1 have a higher than 0.8 sensibility index. In the Norwegian module, 88% of airports have a higher than 0.8 sensibility index. The higher the number of airports with low sensibility index values, the looser the module. The module 10, headed by the Brussels airport has 59% of airports with a sensibility index lower than 0.2. It is the loosest module in the European network, as indicated also by its lowest compactness (see Table 1).

For any module, Table 9 shows the percentage of airports with a given second-best alternative, weighed by the number of exchanged seats. This table gives an idea of how much two different modules are interrelated. For example, module 10 is the best alternative for airports belonging to the first module, in 39% of the offered seats. It confirms the interrelation between the low-cost based module, number 1, and the module headed by the Brussels airport, number 10.

Module 12, headed by Copenhagen is always the second-best alternative for airports belonging to the Norwegian module, headed by Oslo. It is also the second-best alternative for airports belonging to the Swedish module headed by Stockholm, in 80% of the offered seats.

Table 9. Percentage of airports with a given second-best alternative, weighed by the number of exchanged seats

Module No.	Major airport	1	2	3	4	5	6	7	8	9	10	11	12	13
1	London Heathrow		5%	3%	3%	1%	1%	8%	33%	1%	39%	2%	5%	
2	Paris Orly	13%				1%		53%			21%	12%		
3	Oslo												100%	
4	Frankfurt	5%					18%	17%	39%	1%	19%			
5	Stockholm-Arlanda									7%	13%		80%	
6	Athens Eleftherios	18%			82%									
7	Paris Charles De Gaulle	10%	30%		36%						25%			
8	Madrid Barajas	14%	2%		62%						12%	11%		
9	Helsinki-Vantaa	19%				81%								
10	Brussels National	51%	12%	2%	1%			23%					11%	
11	Lisbon				24%			7%	69%					
12	Copenhagen	25%		5%		70%								
13	Reykjavik Domestic Airport													

3. Joint analysis

The purpose of the analyses presented in the previous sections was to provide a classification of airports that could lead to the identification of their respective roles and characteristics of homogeneity. Put together, the results yield interesting views and provide at the same time indirect confirmation of the exactness of the analyses. For each cluster, Table 10 presents the percentage of distribution of airports among the different modules. For example, 25% of the airports classified in the "global hub" cluster, belongs to module 1.

Table 10. Comparison of the groups identified through cluster analysis (columns) with the modules derived through simulated annealing (rows). The percentage shows the number of existing airports normalized to the total of the cluster they belong to

Module/cluster	1) global hub	2) hub	3) secondary gate	4) connect. EU low-cost	5) no low-cost gate	6) regional airports	7) minor low-costs	8) local airports
Heathrow/UK – low cost	25%	25%	18%	70%	11%	18%	70%	14%
Orly/France	0%	6%	18%	0%	9%	23%	4%	12%
Oslo/Norway	0%	6%	0%	0%	11%	0%	0%	18%
Frankfurt/Germany – low cost	25%	19%	18%	24%	11%	9%	13%	5%
Stockholm/Sweden	0%	6%	0%	0%	7%	2%	0%	12%
Athens/Greece – Cyprus	0%	6%	9%	0%	7%	2%	0%	11%
Fiumicino/Italy – Paris CDG	25%	6%	9%	0%	15%	18%	0%	5%
Madrid/Spain	25%	0%	0%	0%	28%	0%	4%	5%
Helsinki/Finland	0%	6%	0%	0%	0%	0%	4%	7%
Prague/East vs. West link	0%	13%	18%	3%	0%	9%	3%	3%
Porto/Portugal	0%	0%	9%	3%	2%	5%	0%	5%
Copenhagen/Denmark	0%	6%	0%	0%	0%	9%	1%	3%
Reykjavik/Iceland	0%	0%	0%	0%	0%	5%	0%	2%
No. statistics/cluster	8	16	11	33	46	44	71	238

From the joint analysis of the modules and clusters we identified, the following observations may be drawn:

- The majority of the modules include at least one airport (six in the case of module 1) which for its characteristics may be identifiable as global or regional hub (cluster 1 or 2). An exception is represented by the Icelandic module, which is strictly local, and the Portuguese headed by Lisbon airport, classified as secondary gate.
- The first module includes, in addition to the vast majority of the English, Dutch and Irish airport network and the London-based airports of Heathrow, Gatwick and Stansted, 70% of the European airports which were classified as low-cost connectors and minor low-cost airports.
- The typical pre-deregulation European airport network, with all domestic networks centred around the main airport and the traditional main carrier, has to date been maintained in limited areas such as northern Europe, especially in the Scandinavian peninsula, and southern Europe, namely in Greece, Spain, France, Portugal and Italy. In these modules low-cost airports may be said to be hardly present (cluster 4 and cluster 6).
- The largest European traditional carriers, such as Air France or Lufthansa, have strategically sought integration with the network of vulnerable rivals, namely Alitalia, Austrian Airlines or Swiss Airlines, with the aim to increase their feedering area and the number of connections towards their main hubs. Examples of this are the presence of Charles de Gaulle within the module headed by Fiumicino and the integration of the major Austrian and Swiss airports into the module headed by Frankfurt airport.
- Some minor airports do not belong to their domestic module and appear instead within an international network (module 1). This has been favored by the development of the low-cost phenomenon, with its point-to-point connection structure bypassing the domestic hub-and-spoke networks, thus leading to integration at a European level.
- In those European countries where the development process of the low-cost model has seen great improvements, as is the case in Great Britain, Ireland and The Netherlands, the network created following the liberalization of the market has been integrated with the key domestic systems. This kind of module is the first in Europe showing a spatial integration of the hub-and-spoke and point-to-point models within a European network reaching beyond domestic boundaries, so much so that it may be said to be hardly possible to distinguish the one from the other. A similar process of integration is also visible, although in minor degrees, in the predominantly German network headed by Frankfurt airport (module 4), which includes some German low-cost airports such as Tegel and Hannover.
- Among the "domestic" modules, the Spanish headed by Madrid is notably characterized by the presence of two of the major worldwide hubs, namely Madrid and Barcelona airports, the absence of important secondary gates and the strong share (28%) of airports classified in cluster 5 (no low-cost gates). The strategy of growth and development of the Spanish network has therefore given priority to the two main hubs, which are directly connected with a number of regional and local airports through a wide and multi-layered hub-and-spoke network.

- One more point of interest is given by the presence of an "atypical" module, namely № 10, headed by the airport of Prague and including Brussels among its major airports. Its main characteristics are a low domestic concentration (a number of airports based in the Czech Republic, Slovakia, Hungary, Switzerland, Lithuania and Germany can all be found in this module) and the scarcity of low-cost airports. The role of this module is to connect airports of Central and Eastern Europe to the very heart of Europe, represented by the airports of Brussels and Geneva.

Conclusion

The main objective of this paper is to provide a useful tool to classify airports and identify strategic groups by considering both their characteristics and their positions into the network.

We considered 467 European airports with at least one scheduled flight in autumn 2007. We classify each airport into clusters, by employing traditional clustering tools, and into modules, by employing the innovative simulated annealing methodology.

We find two different kinds of modules. The first relates to modules composed of mainly domestic airports headed by main national hub with a low presence of low-cost carriers. The second kind of module comprises airports of different countries with a predominant presence of low-cost carriers.

The results are of interest from the operators point of view. The classification of the European airports into modules, by simplifying the network, allows a better understanding of the competitive context in which each airport operates. The groups and characteristics identified provide a base for testing whether competition is more severe among similar airports belonging to the same group than among similar airports belonging to different groups.

From the policy-maker point of view, this study permits to analyze the European network as a multilayered network in which hub & spoke-based networks and point-to-point-based networks are melted together. The best strategy to enhance the connectivity of a Country or a specific region should consider the characteristics of the related airports and of the modules they belong to.

References

1. ATG, Air transport group (2002), *Study on Competition between Airports and the Application of State Aid Rules*, commissioned by European Commission Directorate-General Energy and Transport.
2. Borenstein, S. (1989). Hubs and High Fares: Dominance and Market Power in the U.S. Airline Industry, *The RAND Journal of Economics*, 20 (3), pp. 344-365.
3. Burghouwt, G. & J. Hakfoort (2001). The Evolution of the European Aviation Network 1990-1998, *Journal of Air Transport Management*, Vol. 7, pp. 311-318.
4. Caves, R., Porter M.E. (1977). From entry barriers to mobility barriers: Conjectural decisions and contrived deterrence to new competition, *Quarterly Journal of Economics*, May, pp. 241-261.
5. Duda, R.O., and Hart, P.E. (1973). Pattern Classification and Scene Analysis. New York, NY, USA: John Wiley and Sons.
6. EC, European commission, (1999). Study of alternative airport capacities.
7. EC, European commission. (2003). Outlook opinion of the Committee of the Regions on 'The capacity of regional airports", *Official Journal of the European Union*, 2003/C 256/09.
8. EC, European commission, (2005). "Community guidelines on financing of airports and start-up aid to airlines departing from regional airports, *Official Journal of the European Union*, 2005/C 312/1.
9. Everitt, B. et al. (2001). Cluster analysis, 4th edition, Arnold, London.
10. Graham, B. (1998). Liberalization, regional economic development and the geography of demand for air transport in the European Union, *Journal of Transport Geography*, pp. 6, 2: 87-104.
11. Guimerà, R., Amaral L.A.N. (2005). Functional cartography of complex metabolic networks, *Nature*, pp. 433, 895-900.
12. Guimerà, R., Mossa S.,Turtschi A., Amaral L. (2005). The worldwide air transportation network: Anomalous centrality, community structure, and cities' global roles, PNAS Proceedings of the National Academy of Sciences of the United States of America, Vol. 102 (22), pp. 7794-7799.
13. Guimerà, R., Sales-Pardo M., Amaral L.A.N., (2007). Classes of complex networks defined by role-to-role connectivity profiles, Nature Physics, 3, January 2007, pp. 63-39.
14. Gulati, R., Nohria, N., Zaheer, A. (2000). Strategic Networks, Strategic Management Journal 21, pp. 203-215.
15. Hatten, K.J. and D.E. Schendel (1977). Heterogeneity within an industry, *Journal of Industrial Economnics*, XXVI(2), pp. 97-113.
16. Hunt, M.S. (1972). Competition in the major home appliance industry 1960-1970, Unpublished doctoral dissertation, Harvard University.
17. Kaufman L., Rousseeuw, and P.J. Rousseeuw (1990). Finding Groups in Data: An Introduction to Cluster Analysis, Wiley, 1990.
18. Kirkpatrick, S., Gelatt C.D., Vecchi M.P. (1983). Optimization by simulated annealing, Science, pp. 220, 671-680.
19. Malighetti Paolo, Paleari, Stefano, Redondi, Renato (2008). Connectivity of the European airport network: "Self-help hubbing" and business implications, *Journal of Air Transport Management*, 14, 2, pp. 53-65.

20. McGee, J., Thomas, H. (1986). Strategic Groups: Theory, Research and Taxonomy, *Strategic Management Journal*, 7 (2), pp. 141-160.
21. Peteraf, M.A. (1993). Intra-Industry Structure and the Response Toward Rivals, Managerial and Decision Economics, 14 (6), pp. 519-528.
22. Porter, M.E. (1976). Interbrand Choice Strategic and Bilateral Market Power, Cambridge MA: Harvard University Press.
23. Porter, M.E. (1979). The structure within industries and companies performance. Rev. Economic and Statist. 61, pp. 214-28.

Appendix A. Statistics/cluster

	N° dest	Seats/day	Flights/day	% EU dest	% dom dest	Route distr.	Betweenness	Lim %	% low cost	N° bases
Cluster 1	N° airports: 8									
Average	177.9	44,701.6	281.3	54.4%	11.8%	2.64	1,696	58%	10%	2.25
Deviation std.	35.8	13,227.6	46.5	13.0%	8.4%	0.51	487	10%	4%	1.98
25° percentile	208.5	52,028.8	311.1	60.5%	20.0%	2.79	2,039	68%	14%	4.00
75° percentile	151.0	34,882.6	246.3	43.5%	6.0%	2.31	1,420	51%	7%	0.50
Cluster 2	N° airports: 16									
Average	116.4	19,041.7	143.3	71.1%	13.1%	2.51	1,087	67%	27%	2.38
Deviation std.	23.0	7,685.3	36.8	13.4%	11.2%	0.53	595	20%	24%	1.09
25° percentile	135.5	25,887.6	166.5	82.0%	24.5%	3.01	1,219	86%	37%	2.50
75° percentile	98.5	13,203.9	121.3	61.5%	4.5%	2.10	693	50%	11%	2.00
Cluster 3	N° airports: 11									
Average	72.3	7,812.7	67.6	73.2%	17.0%	2.85	356	81%	30%	1.55
Deviation std.	14.0	1,792.3	19.0	7.4%	14.9%	0.77	244	76%	21%	0.82
25° percentile	86.0	8,925.6	84.0	81.0%	26.0%	3.14	518	78%	38%	2.00
75° percentile	65.0	6,931.9	60.2	68.0%	3.0%	2.13	203	39%	15%	1.00
Cluster 4	N° airports: 33									
Average	46.5	5,523.3	41.8	91.4%	15.2%	2.15	90	63%	75%	0.33
Deviation std.	16.8	2,899.9	21.7	7.1%	12.3%	0.57	86	16%	18%	0.54
25° percentile	58.0	7,667.3	50.9	97.0%	23.0%	2.43	107	76%	90%	1.00
75° percentile	38.0	3,504.7	26.8	87.0%	4.0%	1.77	35	50%	65%	-
Cluster 5	N° airports: 46									
Average	27.9	3,884.8	35.0	97.0%	44.6%	3.83	129	67%	25%	0.35
Deviation std.	16.9	3,286.8	27.3	4.4%	23.6%	1.30	165	23%	17%	0.64
25° percentile	33.0	5,156.4	47.8	100.0%	58.0%	4.53	213	87%	37%	1.00
75° percentile	15.0	1,587.6	15.0	93.0%	28.0%	2.83	12	53%	10%	-
Cluster 6	N° airports: 44									
Average	13.0	1,000.4	10.7	82.6%	28.2%	1.70	18	46%	19%	0.25
Deviation std.	12.5	1,185.8	10.8	15.2%	31.2%	0.56	30	39%	27%	0.44
25° percentile	20.5	1,437.0	17.9	97.5%	50.0%	2.00	24	84%	27%	0.50
75° percentile	3.0	161.2	2.6	74.0%	0.0%	1.25	0	0%	0%	-
Cluster 7	N° airports: 71									
Average	9.9	976.7	7.8	99.1%	21.8%	1.50	7	48%	76%	-
Deviation std.	7.6	941.0	6.1	2.2%	18.9%	0.34	10	34%	24%	-
25° percentile	15.0	1,206.0	11.3	100.0%	36.0%	1.68	12	76%	100%	-
75° percentile	3.0	286.4	2.8	100.0%	0.0%	1.22	-	0%	59%	-
Cluster 8	N° airports: 238									
Average	3.2	233.6	3.7	100.0%	93.9%	1.38	9	40%	6%	0.09
Deviation std.	3.0	365.7	5.1	0.0%	13.8%	0.54	19	46%	16%	0.31
25° percentile	4.0	249.7	4.6	100.0%	100.0%	1.54	9	96%	0%	-
75° percentile	1.0	48.0	1.3	100.0%	100.0%	1.00	-	0%	0%	-