Journal of Air Transport Management 91 (2021) 101977

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: http://www.elsevier.com/locate/jairtraman

Comparing proximity for couples of close airports. Case studies on city-airports in the pre COVID-19

Alessandro Massaro *, Silvia Rossetti

University of Parma, Italy

ARTICLE INFO

Keywords:
Airports
City-airport planning
Regional planning
Transport system analysis
Network analysis
Geographic information systems

ABSTRACT

Following the existing relationships between cities and airports, well depicted in the sectorial literature ((Thierstein and Conventz, 2018), (Tira et al., 2006), (Freestone, 2009), (Percoco, 2010), (Ventura et al., 2020))), this paper aims to investigate the linkages between the touristic traffic of some airports and the related development of the cities in which they are placed. The chosen case studies regard different remote regions (ONU, 2018) of three different countries (Italy, Norway, Cyprus), considering couples of near airports (Dziedzic and Warnock-Smith, 2015). The paper focuses the analysis on four couples of near airports, two from the South of Italy (Bari and Brindisi in the Apulia Region; Palermo and Trapani in Sicily), one in the North of Norway (Bødo and Narvik in Hålogaland) and the last one in the Republic of Cyprus (Larnaca and Paphos).

A GIS analytic methodology has been used to describe the differences between the different couples of airports. Managed by the GIS analytical evaluation, the purpose of this paper is to give support to the different theories about the development of couples of close airports, using geographic tools to support economic and financial planning ((Cook and Billig, 2017) (Graham, 2014), (AntonínKazdaa et al., 2017) (Young and Wells, 2011))]. There has been pointed out the results of the adopted methodology on the working Norwegian network system analysis.

1. Introduction

In the framework of the existing relationships that occur between cities and airports, well depicted in the sectorial literature (see, i.a., (Thierstein and Conventz, 2018), (Tira et al., 2006), (Freestone, 2009), (Percoco, 2010), (Ventura et al., 2020)), this paper aims at analysing proximity issues for couples of airports which are located close one to the other (Dziedzic and Warnock-Smith, 2015), highlighting the links between multiple-airport systems and the economic development of their territories (ONU, 2018). Particularly, the paper focuses on the case studies of the following couples of close airports: Bari and Brindisi (Italy); Palermo and Trapani (Italy); Bodø and Narvik (Norway); Larnaca and Paphos (Cyprus).

Different remote types of islands, contexts and regions have been included in the analysis: the four couples are located respectively in the Southern part of the Italian peninsula (in the Apulia Region and in Sicily, which is the main island of the Mediterranean sea), in the island of Cyprus, and in the extreme North of Europe. Those remote, but touristic, contexts allow to assess the different weight of the touristic traffic on the economic development of different couples of city-airports, and to address the evaluation on the diverse types of perspective growth.

Since in every couple there is one bigger airport, the paper considers different indicators to the different relation systems: competition and cooperation are always defined by the specific region in which every airport is placed.

The paper is structured as follows:

- Chapter 2 focuses on the materials and methods applied in the paper, briefly presenting the case studies that were chosen, both in terms of quantitive indicators and in terms of qualitative description.
- Chapter 3 presents the GIS analytic methodology that has been used to describe the differences between the different couples of airports. The GIS analytical evaluation provides a cartographic support to the different theories on the development of couples of close airports, and allow to use geographic tools to address economic and financial planning issues (see, i.a., (Cook and Billig, 2017) (Graham, 2014), (AntonínKazdaa et al., 2017) (Young and Wells, 2011)).

* Corresponding author.
E-mail addresses: a.massaro.a@gmail.com, alexmaxplan@gmail.com, alessandromassaro@studenti.unipr.it (A. Massaro).

https://doi.org/10.1016/j.jairtraman.2020.101977
Received 22 November 2019; Received in revised form 3 October 2020; Accepted 8 November 2020
Available online 19 November 2020

- Chapter 4 presents the results of the GIS analysis performed, drafting a qualitative SWOT analysis to understand the strengths and the weaknesses of the studied couples of airports, in terms of economic and territorial development.
- Finally, chapter 5 reports some conclusions for the paper, focusing on possible regional planning strategies to support the development of multiple airports-systems.

The overall adopted methodology is partially descriptive and partially GIS-based, since the goal of the paper is to describe the development of couples of close airports from a regional planning point of view.

The GIS database implemented refers to different population catchments areas and to a target of the different economic patterns derived. For each couple of airports, the GIS system analyses the distance between airports and facilities, improving travel times before and after the investments in the terrestrial and in the aerial route network system, discovering the future population catchment areas of each couple and highlighting the differences.

The influence of and on the different types of distances was analyzed both from the physical and from the regulatory point of views. Therefore, travel distances from, to and into the regions were compare to the distances among the different cities and airports development plans in the deregulation processes. From the consequent grid, the distances with a stronger impact on economic development were chosen to compare the different areas.

The adopted GIS system derives from the evaluation of the specific cultural territorial systems (Rotondo et al., 2016), (Ventura et al., cura di), (Paul and Densham, 1988-), (Di Pietro, 1978) and their proper relationships with the economic and financial systems (COST, 1408), (Van de Vijver et al., 2015), (Peiser et al., 2014), arguing to estimate the geographical patterns of the financial evaluation (VV, 2018), (Yu et al., 2013), (Iotti and Bonazzi, 2011) and to define specific direct linkages between aerial and terrestrial routes. The infrastructural network system was shaped to carry out accessibility analysis, estimating the overserved and underserved parts of each city and country. By this way, the system highlights the accessibility patterns changes related to the investments made and in perspective, spatializing the analogies and divergences among the different couples of airports.

Data about the average population density were mapped to understand the territorial average of population Gross Domestic Product (GDPp.i.). Thus, investments on the transport system were used to locate the new areas covered by the services and the likely attraction areas, and their weight in the evaluation of development. Improving the numbers of couples gives to the system the possibility to evaluate the needs of Public Service Obligations (PSO) to guarantee the equilibrated survival of each airport in the growth, or, in other terms, to assess if the cooperation and competition can be sufficient to design a common development (Healey, 2003), (Kwakkel et al., 2010), (Young and Wells, 2011). Travel times and speed path were used to describe every route, terrestrial, maritime (coast ship) and aerial. The frequency of population transported by the different transportation modes types became the tool to understand how much catchment areas change during the year and according to the weight of tourism in different airports. Once again, comparing the differences among the couples, it is also possible to derive new possibilities for the aerial route system management.

2. Materials and methods

2.1. Elements about the chosen case studies

The couples of airports (Table 1) involved in the analysis were chosen to give an exhaustive panorama of the European network system in its remote regions, developing a research activity that began in 2018 (Ventura et al., 2018), (Massaro, 2018), (Calderon et al., 2019). Specifically, the analyzed case studies belong to different countries, with varying systems of airports, and with various economic indicators regarding the touristic traffic and economic growth. The case studies in the remote region of South Italy belong to the same country, the differences between two airports on the land managed by only one company (Apulia Airport managing Bari and Brindisi Aiport) and two airports on an island (Palermo Airport and Trapani Airport, in Sicily, the principal island in the Mediterranean sea). On the other hand, the example of Northern Norway involves two airports on the coast and their links with a lot of other smaller airports on the close Lofoten Islands, in a country with a continuous growth of GDP p.i. In the last case study, the airports of Cyprus show a great example of touristic flow directly associated to an island (the third largest in the Mediterranean Sea).

Table 1
Main features of the analyzed airports and of the areas in which they are located.

SPECIFICATIONS	COUPLES OF AIRPORTS			
	BARI	PALERMO	BODØ	LARNACA
	BRINDISI	TRAPANI	EVENES	PAFLOS
Size of the Area (km²)	12.500 [a]	10.500 [b]	44.800 [c]	12.800 [d]
Density Population in/km² (2018 average)	263.12	189.42	10.42	133.87
GDPp.i. (euro, 2016 average)	17.565	7.679	41.614	32.002
Distance among the Airports (km)	112	70	170	105
Distance from city-center (km)	9.00 1.00	22.40 11.60	1.00 31.00	5.70 5.00
PAX (2018)	4.685.996 2.320.839	5.163.103 1.492.228	1.903.944 739.220	8.067.037 2.872.391

[a] The area correspond to the whole Apulia Region without the administrative territory of the Province of Foggia.
[b] The area correspond to the three administrative territories of the three Provinces of Trapani, Palermo and Agrigento
[c] The area, the largest, is between Trømso and Bodø, with Narvik in the middle, part of the study considers 1/3 of that.
[d] The entire island.

2.2. Italian airports: Bari and Brindisi (Apulia Region)

The first couple of airports is located in the south-eastern part of Italy, in the cities of Bari and Brindisi. Italian airport system is well described in the National Transport Plan (MIT (Ministry of Transport and Infrastructure), 2010), which takes into consideration the particular geographic shape of the country. In the Apulia Region, the four airports (Fig. 1) with passenger traffic are all managed by Aeroporti di Puglia (Apulian Airports) for the period 2012–2040. The most important feature of the system is its strategic location in the Mediterranean Sea and the most recent passenger traffic growth related to the two airports in this analysis, where Bari Airport has twice the traffic flow of Brindisi Airport. There is a plan associated with the specific functions of any airport in the Apulia Region (Table 2). The Company followed a positive financial development, related to the growth of travelled passengers in the last years, probably thanks to its regional but independent market dimension. Anyway, some different issues related to the cash flow and maintenance costs strength the same asset, increasing the curve of costs of the local facilities. Municipalities' involvement in the decision-making process could be enforced, solving mobility issues to enlarge the investment capability for the airport's growth, above all for the Brindisi airport equilibrate growth and for the related under-served Salento territory.

2.3. Italian airports: Palermo and Trapani (sicily region)

Managing of Palermo and Trapani's airports is of two different companies in which the Region has the predominance. In the biggest island of the Mediterranean Sea, there are two of the most important

Fig. 1. Catchment areas, Apulia airports.
Source: GIS based analysis by the authors

airports in Italy: Palermo and Catania (Fig. 2). Over the considerable difference with Palermo, Trapani Airport managed an impressive growth in recent years, related to the Low-Cost Carrier (LCC) Ryanair. The same LCC finds a good market in Palermo, as well. Since last year Ryanair abandoned Trapani Birgi Airport for some territorial organizational issues, also related to the geographical and administrative location of the Birgi Airport. However, the presence of Ryanair in the last decade underpins the capability of Trapani Touristic traffic (Table 2) and strengthen the linkage between the growth of airport traffic flow and the growth of the economy of the two provinces of Trapani and Marsala. Nowadays, the survival of the Trapani airport could link the unserved central-south areas of the whole region (Calderon et al., 2019). In this way, the last financial statement of the Largest ltd has a positive growth in recovering the quick investment.

2.4. Norwegian airports: Bodø and Narvik (hålogaland region)

In the Hålogaland, a part of Nordland and Trøms Regions, the thicken Northern Norwegian Airport system is increased by the traffic of two airports (Bødo and Trømso), even in an area of low population density, but with a substantial regional GDP p.i. Considering the other two smaller airports in the area with more significant touristic traffic flow in the last decade, dividing the system into two couples: Trømso and Bardufoss on one side; Bodø and Narvik, on the other hand, can be analyzed separately. Furthermore, there are connections with the other seven smaller airports in the surroundings (Fig. 3). The company that manages almost all the airports of Norway is Avinor ltd, which participates in the crucial investments on the Bodø airport and Bodø city redevelopment plan, following the core of the Norway Transport Plan decisions (Table 2). Avinor has an excellent financial statement, but a lot of airports and airliners failed in the whole country in the years. The recent investments in the route transport system end to advantage the shortest journey to the airport. In this direction, Narvik risks being one of the more requested places in the future, when the Lofoten road system modernization will complete. The issue becomes relevant if it is related to the risks for the Bodø investments because it could defeat the modernization of the roads.

2.5. Cyprus airports: Larnaca and Paphos (Greek Cyprus area)

In the area controlled by Cyprus Government (Greek Cyprus Area), the third largest and most populated island of the Mediterranean Sea, Larnaca, and Paphos, two airports with constant growth in the last years coexist (Fig. 4). The increase happens without a National Transport Plan. But due to geographical conformation of the Island, the roadway, shipway, and air transport systems' development improved separately, underlining the lack of transportation plan in front of a huge utilization (Table 2). An international consortium of 9 shareholders manages the airports, the Hermes Airport Ltd (concession agreement with the Republic of Cyprus), a company registered in Cyprus. France's Bouygues Batiment International is the owner of 21.99% of Hermes Airports. The passenger traffic flow of the two airports is more significant than all the other couples analyzed in this paper. In the last year, the two airports have carried almost 11 million of passengers (8,067,037 Larnaka and

Table 2
Table of investments, PSO, Expenditures related to transports, particularly to Air Transport System.

SPECIFICATIONS	TABLE OF INVESTMENTS			
	BRI	PMO	BOO	LCA
	BDS	TPS	EVE	PFO
Planned Investments (mln eu 2018)[a]	30.63 53.587	76.968 20.535	72.00 0.00	652 645
PSO for Specific Routes (mln eu 2018)[b]	–	PMO – Lampedusa PMO – Pantelleria TPS – Pantelleria	Andenes – BOO[c] Brønnøysund – BOO[c] Leknes – BOO[c] Mo i Rana – BOO[c] Mosjøen – BOO[c] Røst – BOO[c] Sandnessjøen – BOO[c] Svolvær – BOO[c]	LCA - Bruxelles
PSO Invitation to Tender (2018–20)[b]	BDS – TPS	TPS – BDS TPS – Ancona TPS – Parma TPS – Trieste TPS – Naples TPS – Perugia	–	–
State aid spending (mln eu 2009–2018) [b]	7072.6		–	11.9
Government expenditure by Transport (mln eu 2018) [b]	29,558.4		13,690.2	138.8
Government expenditure by Transport (% of GDP, 2018) [b]	1.7		3.7	0.7

[a] The dataset about Italy comes from the National Agency for Civil Aviation (ENAC), Source: (ENAC).
[b] The dataset around PSO comes from different sources, led by the European Commission and Eurpoean Commission Statistic: (Eurpean Commission), (I. T. F. ITF-OECD), (Widerøe).
[c] Source: (Eurocontrol), (I. T. F. ITF-OECD).

2,872,391 Paphos). The consistent growth (Republic of Cyprus), appears as a result of competition among the shareholders, as between the bigger ones, France, and British Companies (Cyprus Trading Corporration Plc). But competitiveness enlarges the weight of the market, and the relative foreign investments can be crucial for tourism development. However, a coordinated general plan for transports for the entire island is needed.

3. The GIS analytic methodology applied: theory and calculations

The analysis of the different couples of airports focused on some useful elements and tools for further evaluations. To assess the economic weight on airport dimensions, the percentage of the touristic traffic flow by transport and distances between airports, help to understand the touristic size in each country, underpinning the differences between every couple of airports analyzed.

One step below, travel-time measurements and catchment areas help to discover the shortest distances between airports, urban areas, and the surrounding opportunities like hospitals, ports, and main tourist facilities. The accessibility approach estimated travel times regards the different trajectories before and after the investments on airports and network infrastructures. Moreover, in this way, it was possible to understand the relationships between the various transport systems, giving an evaluation of the specific needs of the different areas analyzed.

Answering the weight of most affected areas, the percentage of investments has related to the dimension of the connected catchment areas. Thus, differences between the percentage growth of expenditures and investments in the transport system in the last years have addressed as a first step in depicting possibilities for the underserved areas.

Following dimensions of involved catchment area explicated by shape area, inhabitants' density, municipalities, GDP p.i., have been used to describe the settlements, highlighting similarities and differences.

The features regarding the different planning systems and indicators of evaluation, at last, have been used to understand the most similar features for each couple related to each investment's plan (as well as ongoing plans).

Using the Norwegian airport of Bødo and its corresponding airport of Narvik, it was possible to move an exhaustive description of the methodology, as well as their similar cities. In this way, we keep apart the whole system of possible transports (Roadway, Coastal Way, Railway, and Aerialway Systems are all working in the same area), adding the relevant number of little airports, the significant amount of islands. Even more, in that region are focused on the most critical investments in the only one airport's complete transformation among the different case studies.

The analysis places the Airport System of Norway Region and, consequently, the Airport of Bødo and Tromsø, as the critical nodes of the network, belonging to the couple Bødo -Narvik.

The network is built around the principal roads of Northern Norway, subdivided into different sections by typology, length, and maximum speed. The primary maritime routes which connect the various islands, the archipelago of Lofoten and the numerous fjords with the thin country peninsula, are included too, converting average speed from knots to kilometers per hour. On the other side, railway lines and railway stations, always subdivided into sections with maximum speed and typology, complete the network. In this last case, we have two different trunks, one from the south to Bødo and the other one to Narvik from Sweden.

Northern Norway is mapped by Counties and by Municipalities. They are all subdivided by population from 2011 to 2018 and by GDP from 2011 to 2016. Thus, it has been possible to describe the variations in percentage both in terms of population density per year and GDP per year.

About the Municipality of Bødo and Narvik, the tourism facilities have been georeferenced, classed by Municipality, Address, Typology, Bed Places, and Category (2016 values).

In the same way, Health facilities have been located and classed by Address, Name, Typology, Bed Places, Ward typology, Day Hospital, and Use (2016 values).

The connectivity measurement has been performed by Network Analysis tools, building the following matrixes:

- Origin-Destination Matrix between Hålogaland's Municipalities and Airports;
- Origin-Destination Matrix between Hålogaland's Tourist Facilities and Municipalities;
- Origin-Destination Matrix between Hålogaland's Health Facilities and Municipalities with small tourist villages;
- Origin-Destination Matrix between Bødo and Narvik Airport and Hålogaland's Touristic Facilities (Hålogaland);
- Location-Allocation Matrix between Hålogaland's Airports, Health facilities and Tourism Facilities.

Different territorial parts are managed to connect the relevant inhabitant's density with the shortest travel time, a tool to find the diverse territorial zones by the percentage of GDPpc variation. The structure of the work done is displayed in the scheme below (Fig. 5).

The OD Matrix comes from needs to weight the distances between airports, so the costs of the same bases its development on the Dijkstra's

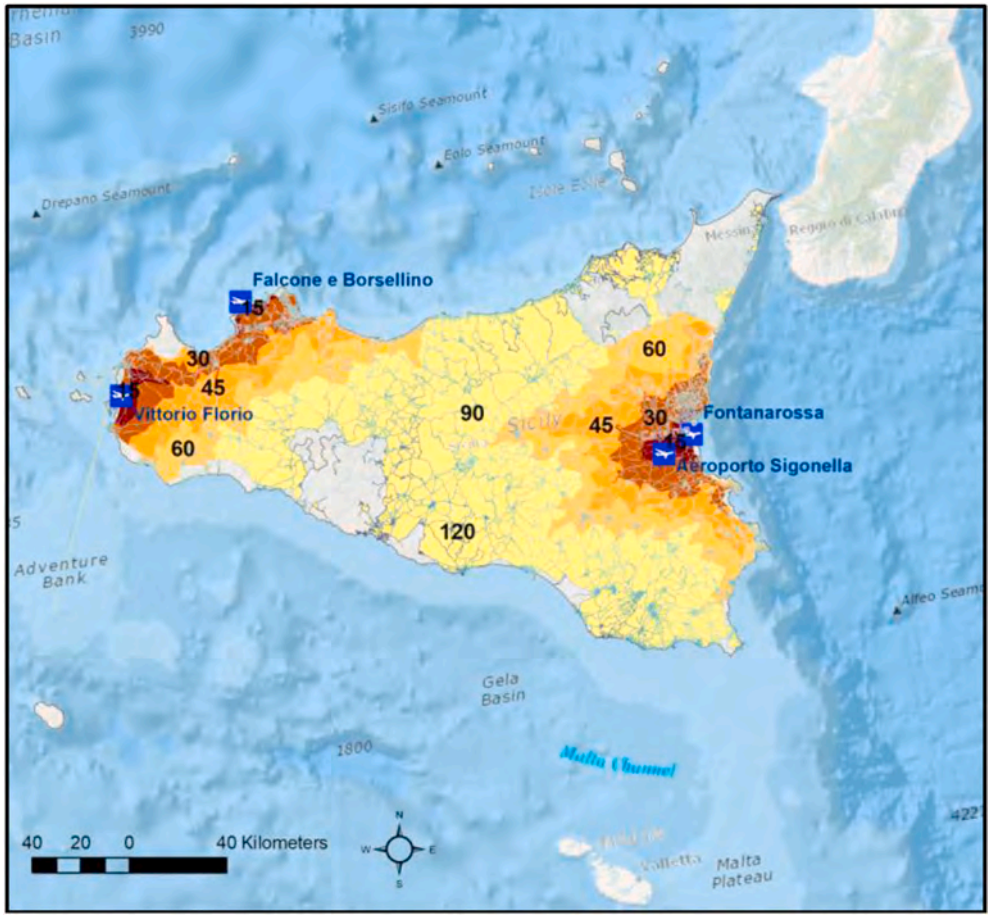

Fig. 2. Catchment areas, Sicily airports.
Source: GIS based analysis by the authors

algorithm on a graph with edges V and vertices A, expressed as a function of the number of edges, denoted |V|, and the number of vertices, indicated |A|, using big-O notation (a mathematical notation that describes the limiting behavior of a function when the argument tends towards a particular value or infinity):

$$O((|A| + |V|\log_2|A|)$$

It is useful to determine the distribution of journeys by minimum time and minimum cost, to build a classification of time-journey and time-cost between the different vertices and the demand points of the diverse using models.

The OD Matrix between the two airports connects the tourist facilities in the Hålogaland with the seven Airports of the network, computing various types of graph analysis measures on the networks; results highlight the possibility to arrive faster from Vaeroe to Narvik, than to Bødo, according to the investments (3 ML NOK) in the E10 roadway in Lofoten. On the other side, it influences the traffic from Bardofuss to Narvik-Evenes Airport, despite the transportation from the south to Bødo Airport, according to the road investments on the E6 and the consequent reduction time of journey.

Concerning health facilities, the network shows the most used hospitals in Hålogaland. Moreover, the network is affected by the lack of transport systems, which suggests the utilization of the Location-Allocation Model, implemented by GIS software (always based on the Dijkstra algorithm). Finally, to find a set of different solutions deriving from diverse systems of demand points (Hospitals, Tourist Facilities, Amenities), giving time by time, the most crucial airports in the area. Summarizing the solutions, the two Airports with the most relevance remain Bødo and Narvik, but this last gain the best location to the healthcare system.

This simple consideration highlights the possibility to consider the links between the Airport and the cities, managing the OD matrix between the two Airports and towns, including villages, of the Hålogaland (Fig. 6).

The analysis of the territorial sections (creating polygons around input features to a specific distance) shows the lack of linkages. The polygons are managed crossing data between the two roadways, built to connect the Hålogaland's Airports and the Hospitals. The result shows an important unserved area between Bødo and Narvik Airports and low service connections in the Lofoten islands. The gap follows the variation of the percentage of Unrestricted Revenue Pro Capita, underlining the active link between the transport network, tourism, and URpc.

Different territorial zones targeted by the time of journey toward the various Airports definitively used to capture the density of population involved in a specific time-journey, before and after the government's investments. The amount of the variations is consequently linked to the actual URpc of each municipality, discovering the possible change of the economic weight of the different territorial approaching zones to the airports.

An Aerial Route System is managed by the time of journey, building an OD Matrix by between the different Airports of the Hålogaland.

Every Airliner in the network is target by a specific code. Thus, it has been possible to depict the active route system in the whole route system network to the different Airports of Hålogaland.

The active route system is adding to every route the different features derived by the specific journey: the number of passengers, ticket price, type of vehicle, real speed – path, time of flight, arrival, and departure time.

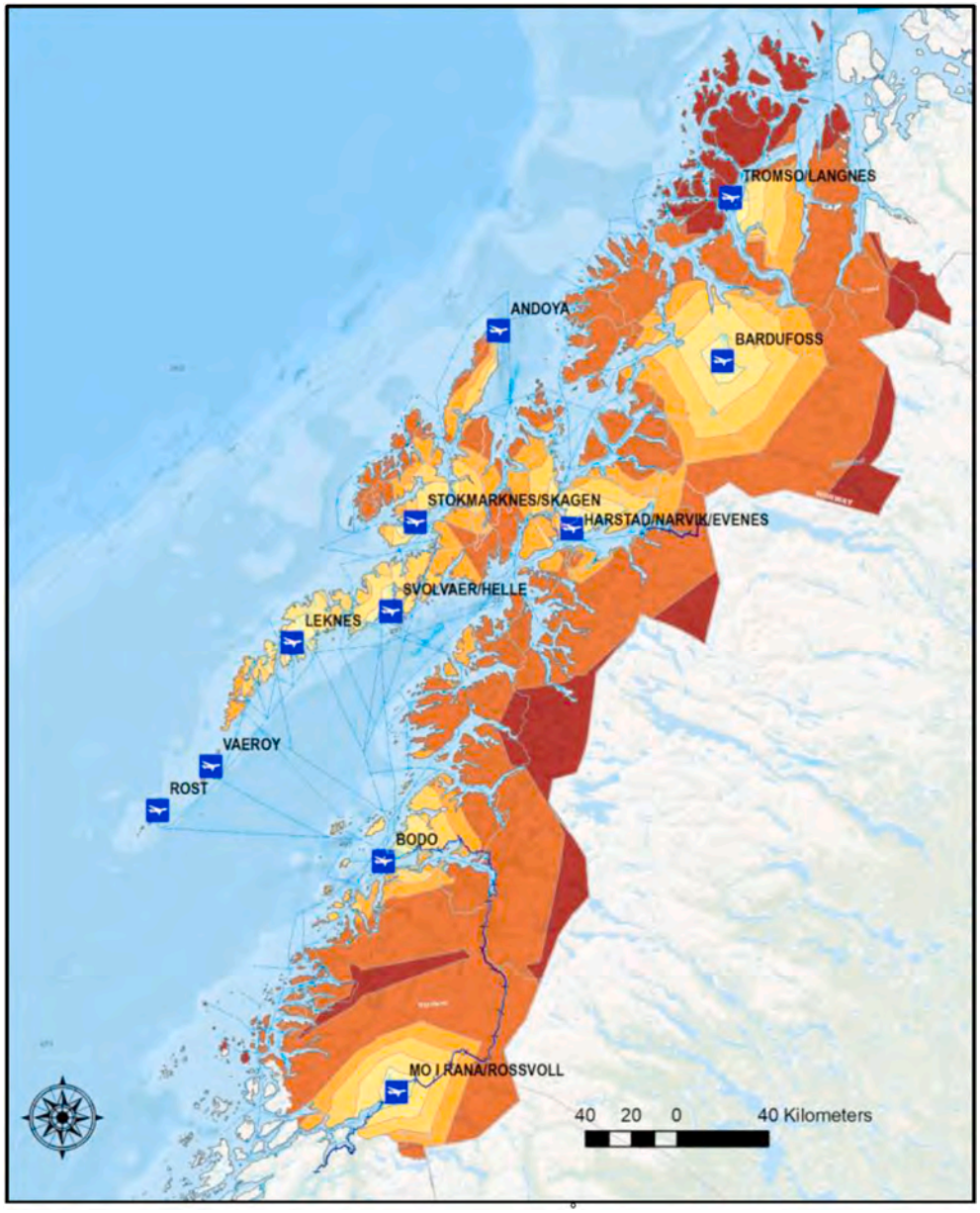

Fig. 3. Catchment areas, Hålogaland airports.
Source: GIS based analysis by the authors

The original OD Cost Matrix underlines the time of the journey by the terrestrial route network between the different airports.

It has been possible to extend the evaluation before and after the investments, so among two different times of journey, ante, and post expenditures.

The results have been compared to the active aerial route system, estimating the possible evolution of the route's needs in the network.

Adding data, derived from the precedent GIS analysis, is useful to estimate the weight of routes ongoing the evaluation better.

The system of air routes (Table 3) shows the number of seats per day (2018). So, it is possible to evaluate the movements from and to Lofoten islands in a different way, looking for a more equilibrated system, so for possible market development of the same. Following the goals of the national transport plan for the area, the reduction of time-journey on the road system, and the consequent shrinkage of the region, the reachable grow of the URpc (2018) for the airports will affect the areas around Lofoten, and between Narvik and Bødo.

Data acquired on the daily movements in the Hålogaland's Airports are in the following table (Table 3):Where every active route between the different airports is targeted by base:

- B^{a1} is the general base associated with the departure
- B^{a2} is the general base associated with the arrival
- A corresponds to the Airliner that has the flight
- T corresponds to the type of aircraft that made the flight
- S is the maximum speed available by the aircraft during the journey
- P is the ticket-price
- S are the seats available
- D is the daily frequency of the specific flight (ref.: June 2018, weekday)

Tot is the revenue from the tickets:

$$Tot = P \times S \times D$$

From a single calculation, the possible earning from the tickets derives, which has an amount of almost 700 M of euros per year (without

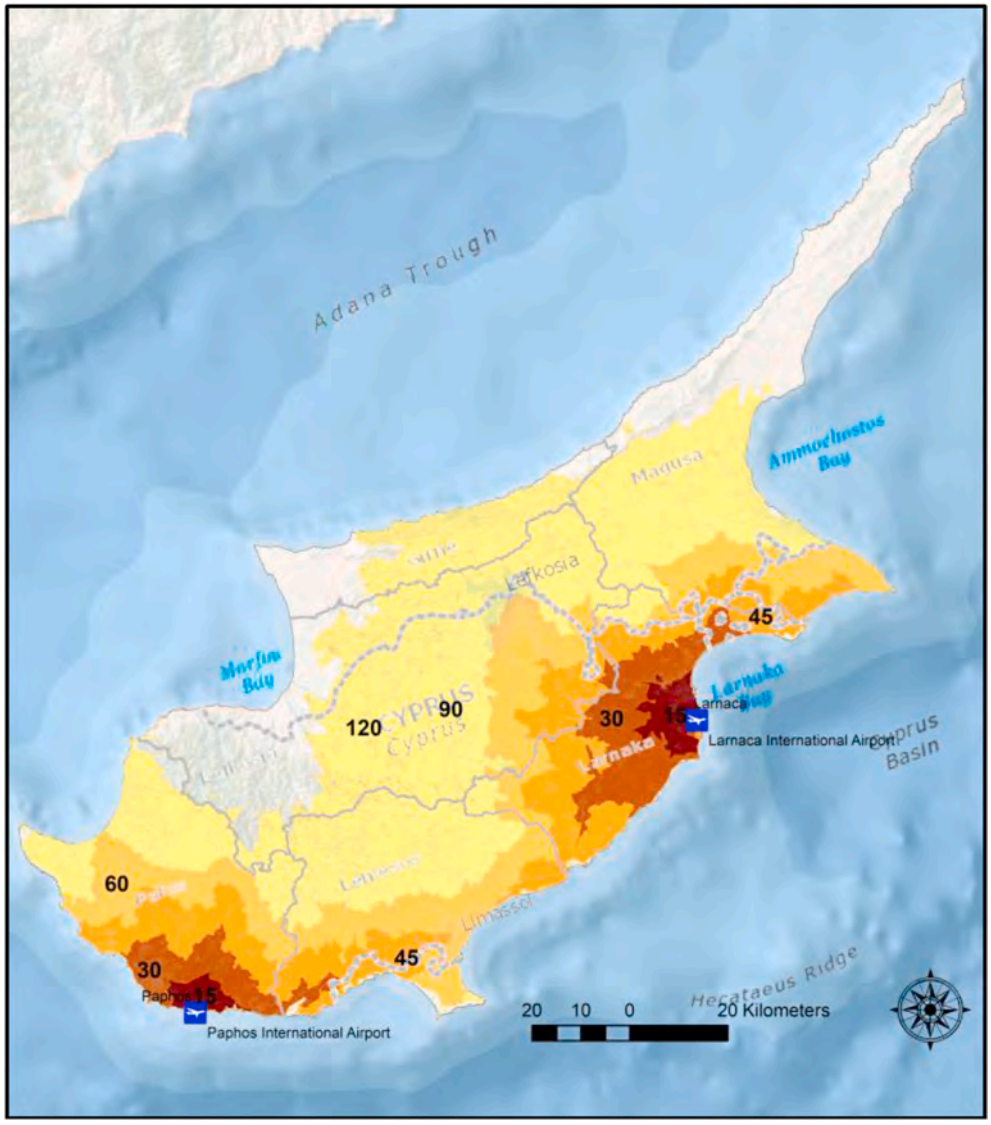

Fig. 4. Catchment areas, Cyprus airports.
Source: GIS based analysis by the authors

considering the movements over the festivities). The GIS evaluation helps to give a measurement of every edge, and it lets take a set of the shortest routes, using time as in the following formula:

$$SR = L(Ba1, Ba2)/S$$

which represents the indicator for the Shortest Route (SR) by time of journey.

From total revenue per kilometer, so from frequency and seats available, the revenue by ticket per kilometer derives:

$$R_{AS} = Tot\ R/\ L(Ba1, Ba2)$$

Where R_{AS} is the daily revenue per route per kilometer.

Relating SR and RAS, it is possible to understand which parts of the active route system can be modified, adding new routes and what parts can loose those, comparing the difference between the two values for each journey.

An efficient tool for the decision-making process is to relate the average of URpc in the last years to the difference between SR and RAS. So it is possible to choose the superior values for the areas in which that average is more consistent. (Fig. 8).

A reduction of the impact of routes across the sea between Lofoten islands and Norway could mean to increase the weight of traffic in Narvik, adding the courses from and to Lofoten. It means to increase the movements of passengers in Narvik of more than 700 passengers by day: 40 by Wideroe from and to Leknes, Svolvaer, Stokmarkenes; 225 by Norwegian, from and to Andenes (Fig. 7). The growth can efforts the linkage between Lofoten islands and Sweden, being a direct railway trunk in Narvik. Bødo is subject to frequent international flies. Thus, a reduction of the local traffic has a positive adding value. Without decreasing the flows from and to Andenes, according to the political plans, the centrality of Narvik in the local traffic network helpful to facilitate the accessibility to the two leading hospitals near Narvik. This evaluation follows the reduction of cost by time journey for the airliners due to the central placement of Narvik in the Hålogaland network so that it can be as facilitation to the market entering of new carriers too.

4. Results

Deeply associated to the analysis above (Fig. 9), the urban development of the cities with the crucial airports have been studied under the GIS evaluation, try to operate between the different constraints of the planning system.

Patterns of GDP p.i., airport catchment area, and hospital catchment

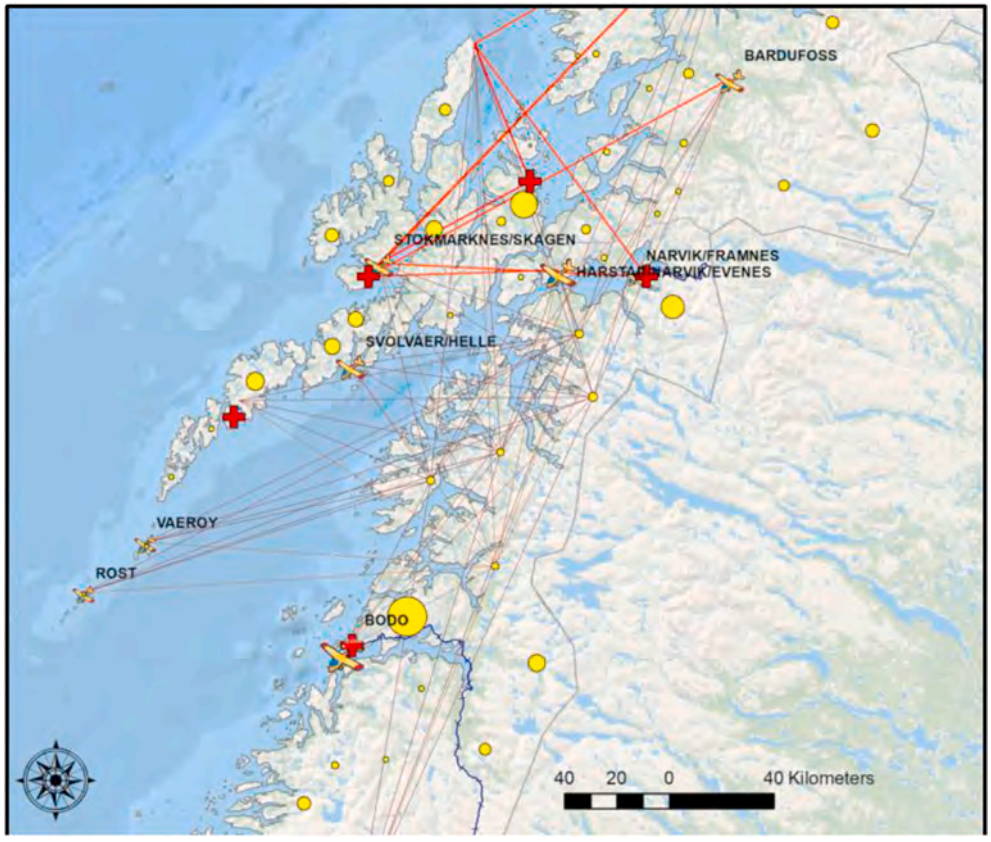

Fig. 5. Main features of the GIS network built for the analysis.
Source: Authors

area become tools for the evaluation of investments. Intersections between the diverse zones, subdivided by travel time, show the interactions among the different catchment areas, and the weight of population density indicates the relationships among the various needs (healthcare demand and travel speed demand).

Evaluation of peaks and overserved areas and relative measurements of underserved areas are useful to understand the needs of planning perspectives.

Planning systems and cooperation are the mainstream of the entire GIS evaluation conducted, which divides functions into different areas, determining the flow of investments, the needs of PSO, and the weight of cooperation, as well as the different shapes of route system utilization. Within this framework, the value of overlapped zones acquires extreme importance, subordinated to specific constraints and related particular laws. Even more, it is useful to detect the role of each smaller airport in every couple.

Comparing the PSO and airport competition (Table 2) becomes one of the elements to assess the functioning of the system and the weight of relationship among each airport couple in each specific economic order.

Route density, location-allocation demand for tourism, and health are measured. Route density helps in detecting the most utilized parts of each region, modelized on the specific transport use.

Location allocation for tourism facilities is related to the capability of the area to absorb the impact of tourism development and highlights the most relevant corridors for investments in real estate too. So, improving the number of needs, we used the health demand, to link the airport's cooperation to the underserved areas.

In this way, it has been possible to introduce a typical Strength, Weakness, Opportunity, and Threat (SWOT) Analysis (Table 4) summarizing the results derived from the experimented couples' analysis, evaluating internal and external factors, as well as current and future potential.

4.1. Strenghts

The increase in passenger traffic is an asset to the business of every couple. Thus, every couple has a central location in its particular country system, increasing the touristic traffic in the years, moreover with the incoming of Low-Cost Carriers (Fig. 10). The couples of airports are in remote regions. Still, their isolation stresses their leading role in the specific area, competing for the different distances from facilities, touristic destinations, and hospitals for the entire area analyzed.

A positive value of the export business gives to the different couples an essential role in their regions. Despite the diverse dimension of data about the traffic flows, underlining the leading role of Bødo, the Port of Narvik has the highest number of coastal ships calls in Hålogaland. However, the diverse use of the two ports underlines the importance of the exports of the whole area between the Lofoten Islands and the Norwegian coast. Still, Narvik maintains a leading role in the touristic flows, also regarding the dimension of data.

With their specific location, the smaller airports of every couple can grow the possibility of using undeveloped areas and improving the development of the runway. The planned investments in the roadways make an effort to the reduction of the distance between Lofoten islands and Narvik, to Bødo, the southern part of the Hålogaland. Still, the gap between Narvik and Bødo focuses on density population growth. Thus, it is possible to image the catchment area growing between the two airports. As a consequence, the traffic to Narvik Airport is destined to grow, despite the nearest airports of Bardofuss and the Lofoten airports. The dimension of the terminal and the apron should follow the prevision below. In the same way, are justified the investments in Bødo Airport. It could consider the health needs too, being the same path of evaluations of the journey time.

In every couple of airports, there is a strong linkage between the city and its airport's history. But in Narvik, it is possible to find commercial

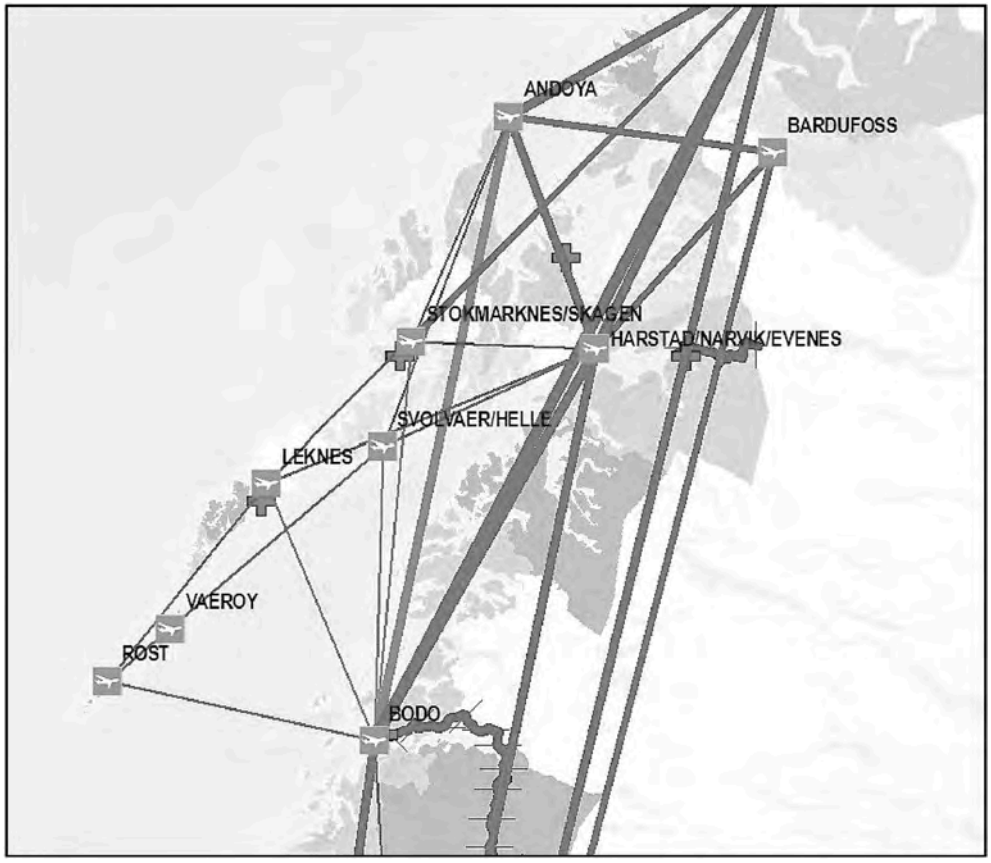

Fig. 6. – OD Cost Matrix reducted to the most expensive journey (Time), [Hospitals-Airports + Municipalities-Airports], Hålogaland.
Source: Authors

and business relationships, not always with positive effects, as well as the recent closure of the historic Airport. On the other side, the prominent role of Military Aviation dismission gives to the Bødo Airport the possibility to reduce the noise pollution, as well as new chances to develop the city, reducing the sprawl of the past years along the coasts.

The same five internal features of the Strengths calculate for the other couples, following the same results for the smaller airports of each pair. Improving the touristic traffic flow, also with mixed-use of the Airports, thus following the increasing of the values deriving from LWC traffic, each couple of the airports analyzed can contribute to the continued success of the network. The quality of the products exported, the strong financial position of the country in the European contest, add to the specific region of the Hålogaland a prominent place in the transport traffic and to one particular couple of airports a robust financial place, to gain and maintain active leadership in the future.

4.2. Weaknesses

The evaluation of the internal features of the couple's workflow, have to be focused on negative points too, to prevent and to achieve full potential. Deeply conducted on calculations, the measurement of the accessibility keeps up its efforts from proximity evaluation tools. In this case, the aerial routes play the leading role, because they indicate whose catchment areas of the searching population could deserve numbers in the future. Proximity gives a result cumulative for each couple, about the limited accessibility for all the airfields in the analyzed couples of airports. Examining the Hålogaland, political goals push on A Airport, despite the investments in road accessibility to the Narvik Airport.

On the other hand, Bødo Airport pays the extreme proximity to the city downtown, and it is an issue regarding noise pollution on the future perspectives of urban development. In this specific case, the two railway trunks underline the difficulty of linkage between Bødo and Narvik. Due to the hard territorial shape, the connections between North and South of Norway find a topic source in this place. Otherwise, the railway underlines the endpoint role played by each city of this couple, deserving the gap to each other. Other typical issues regarding proximity, so accessibility, affect the other analyzed couples. Therefore, it is possible to conclude that in the investigated areas, the transportation infrastructure is not sufficient for accessibility development.

The disproportional surge in tourist traffic, as well as a shortage of transport infrastructure, creates a barrier to keeping part of the transit tourist flows. So, the investments for the terminal and the apron of the smaller airports are justified for every couple analyzed. But, they should follow the needs, not only a mere reshaping.

Many airports need PSO to survive in Hålogaland, as well as in the other networks analyzed, underpinning the inability to meet demand, due to the high costs and the distance among the investment goals through the different locations.

4.3. Opportunities

Systems of different airports show the possibility to cooperate in growing impact assessment, subdividing functions and roles, and understanding the needs of their specific locations. These efforts can be viewed in the Apulia region in Italy, as can work in the other systems, despite the political situation of Cyprus and the centralized ownership of Norway. Furthermore, it needs to be addressed focus on the entire system of airports in a region, to assure the role to each one, strengthening, for example, its historical utilization.

The projections on the last adjustments of smaller airports' Terminals show an undervaluation of the needs, who must need the management addressed to the growth and their role. The growth evident for

Table 3
Air-route system analysis.

A	T	S	B[a1]	B[a2]	P	S	D	Tot
Norwegian	Boeing	800	Andenes	Bardufoss	219,3	185	1	40.570,5
Norwegian	Boeing	800	Andenes	Bodø	234,6	185	3	130.203
Norwegian	Boeing	800	Andenes	Narvik	226,9	185	1	41.976,5
Norwegian	Boeing	800	Andenes	Tromsø	218,3	185	2	80.771
Norwegian	Boeing	800	Andenes	Oslo	79,6	185	1	14.726
Widerøe	Dash-8	500	Andenes	Bodø	250	40	1	10.000
Widerøe	Dash-8	500	Andenes	Narvik	250	40	1	10.000
Widerøe	Dash-8	500	Andenes	Tromsø	250	40	1	10.000
Widerøe	Dash-8	500	Andenes	Storkmaknes	250	40	1	10.000
Norwegian	Boeing	800	Bardufoss	Andenes	420,9	185	1	77.866,5
Norwegian	Boeing	800	Bardufoss	Narvik	285,5	185	1	52.817,5
Norwegian	Boeing	800	Bardufoss	Bodø	261,5	185	1	48.377,5
Norwegian	Boeing	800	Bardufoss	Oslo	84,5	185	1	15.632,5
Norwegian	Boeing	800	Bodø	Bardufoss	225,1	185	1	41.643,5
Norwegian	Boeing	800	Bodø	Andenes	362,3	185	1	67.025,5
Norwegian	Boeing	800	Bodø	Narvik	263,5	185	1	48.747,5
Norwegian	Boeing	800	Bodø	Oslo	89,2	185	4	66.008
Norwegian	Boeing	800	Bodø	Tromso	215,4	185	1	39.849
SAS	Boeing	850	Bodø	Oslo	250	40	7	70.000
SAS	Boeing	850	Bodø	Tromsø	250	40	4	40.000
Widerøe	Dash-8	500	Bodø	Leknes	250	40	6	60.000
Widerøe	Dash-8	500	Bodø	Andenes	250	40	1	10.000
Widerøe	Dash-8	500	Bodø	MoiRana	250	40	4	40.000
Widerøe	Dash-8	500	Bodø	Storkmaknes	250	40	7	70.000
Widerøe	Dash-8	500	Bodø	Tromsø	250	40	7	70.000
Widerøe	Dash-8	500	Bodø	Svolvaer	250	40	3	30.000
Widerøe	Dash-8	500	Bodø	Rost	250	40	2	20.000
Widerøe	Dash-8	500	Bodø	Narvik	250	40	3	30.000
Widerøe	Dash-8	500	Leknes	Bodø	250	40	7	70.000
Widerøe	Dash-8	500	Leknes	Rost	250	40	1	10.000
Widerøe	Dash-8	500	Leknes	Tromsø	250	40	1	10.000
Widerøe	Dash-8	500	Leknes	Oslo	250	40	1	10.000
Widerøe	Dash-8	500	Mo i Rana	Bodø	250	40	5	50.000
Widerøe	Dash-8	500	Mo i Rana	Oslo	250	40	1	10.000
Norwegian	Boeing	800	Narvik	Bardufoss	265,4	185	1	49.099
Norwegian	Boeing	800	Narvik	Bodø	271,1	185	3	150.460,5
Norwegian	Boeing	800	Narvik	Andenes	362,3	185	1	67.025,5
Norwegian	Boeing	800	Narvik	Tromsø	248,1	185	4	183.594
Norwegian	Boeing	800	Narvik	Oslo	119	185	7	154.105
SAS	Boeing	850	Narvik	Oslo	250	40	4	40.000
Widerøe	Dash-8	500	Narvik	Tromsø	250	40	3	30.000
Widerøe	Dash-8	500	Narvik	Bodø	250	40	1	10.000
Widerøe	Dash-8	500	Narvik	Andenes	250	40	1	10.000
Widerøe	Dash-8	500	Rost	Leknes	250	40	1	10.000
Widerøe	Dash-8	500	Rost	Bodø	250	40	2	20.000
Widerøe	Dash-8	500	Rost	Svolvaer	250	40	1	10.000
Widerøe	Dash-8	500	Stokmarknes	Oslo	250	40	1	10.000
Widerøe	Dash-8	500	Stokmarknes	Bodø	250	40	4	40000
Widerøe	Dash-8	500	Stokmarknes	Tromsø	250	40	2	20000
Widerøe	Dash-8	500	Svolvaer	Rost	250	40	1	10000
Widerøe	Dash-8	500	Svolvaer	Andenes	250	40	1	10000
Widerøe	Dash-8	500	Svolvaer	Bodø	250	40	4	40000
Widerøe	Dash-8	500	Svolvaer	Oslo	250	40	1	10000
Norwegian	Boeing	800	Tromsø	Andenes	468,9	185	1	86746.5
Norwegian	Boeing	800	Tromsø	Narvik	275,9	185	2	102083
Norwegian	Boeing	800	Tromsø	Bodø	271,1	185	1	50153.5
Norwegian	Boeing	800	Tromsø	Oslo	128,6	185	5	118955
SAS	Boeing	850	Tromsø	Bodø	250	40	5	50000
SAS	Boeing	850	Tromsø	Oslo	250	40	9	90000
Widerøe	Dash-8	500	Tromsø	Bodø	250	40	8	80000
Widerøe	Dash-8	500	Tromsø	Narvik	250	40	1	10000
Widerøe	Dash-8	500	Tromsø	Andenes	250	40	2	20000
Widerøe	Dash-8	500	Tromsø	Storkmaknes	250	40	2	20000
Widerøe	Dash-8	500	Tromsø	Leknes	250	40	2	20000

Source: Authors

every couple and acquires a specific value in Hålogaland, where the number of airports increases.

Joint management for both airports may satisfy more effectively the urge of the area for the airline business, thus triggering a crucial, pivotal role for smaller airports of the couples.

To link between the port and railway station to the Airports could change the attitude, but it should accompany better public transport service, which could be quickly assured by the bus. So we could differentiate the couples, understanding the landscape attitudes. Still, the investments should be addressed to strengthen the role of every airport in each pair, targeting different catchment areas using specific needs.

The impact of the NATO activities on the landscape can be considered directly proportional to the age of the Base, increasing the relationships on earth in the years. So, it can bring additional traffic

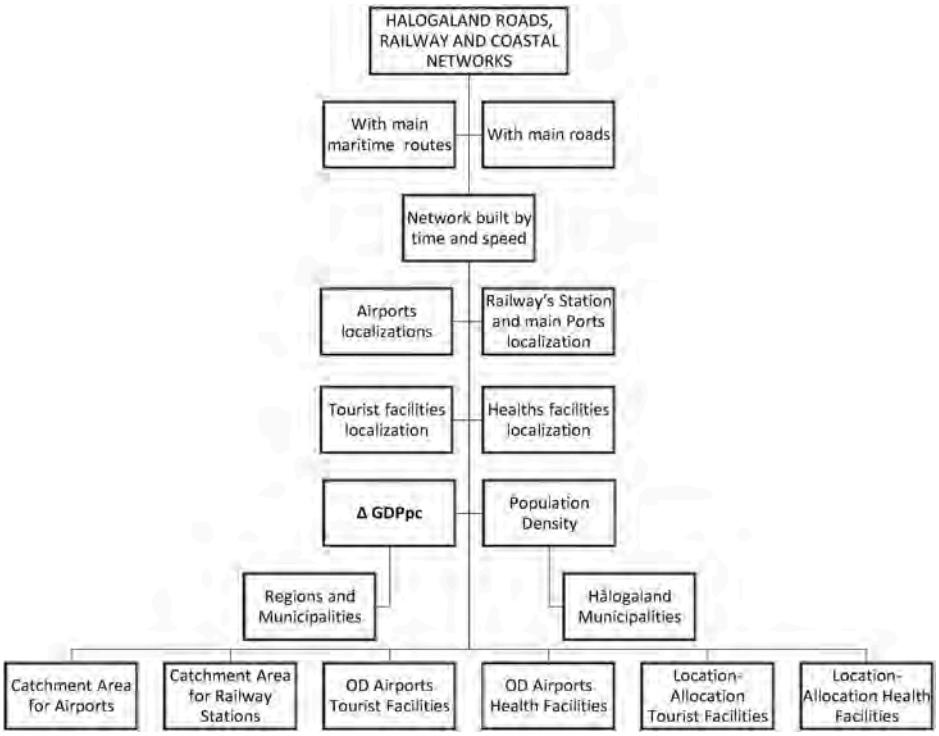

Fig. 7. Air Routes by seats and cost of journey (Time), [Municipality subdivided by Unrestriced Revenue Pro Capita], Hålogaland.
Source: Authors

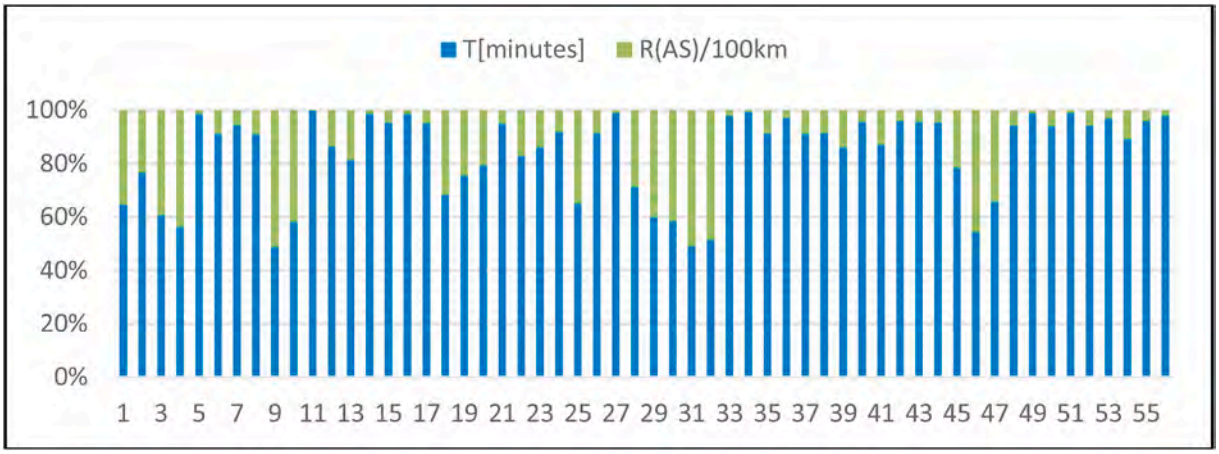

Fig. 8. Comparing routes by time of journey and ticket revenue per kilometer (Hålogaland).
Source: Authors

demands to the Airport. And, this is the case of smaller airports again, despite the dismission of the Military Base in Bødo Airport.

The Airports are situated close to the Sea, on different distances from the urban centres of the cities. Despite the various scale of kilometres, further resources could be addressed, integrating economic development with the valuable landscape under a comprehensive policy of tourist resource development.

The entire sheet of opportunities tries to gain benefit from the growth of the existing market, pointing on the unicity of the landscape too. The environment within which the airports operate offers opportunities to develop that can also be viewed in airliners marketing, trying to create the network within the unserved areas. More difficult could be the entering of a new low-cost carrier in Hålogaland with these considerations, as the costs and recent history of that market in the area demonstrate. But, moving from evaluation about accessibility, it could be turned in a resource, therefore in the other couples.

4.4. Threats

The business catchment area strategy finds its basis in new tourist routes. A problem-solving approach depends on economic reasons only.

The four couples are affected by unbalanced managerial systems, where private interests are predominant, also because sometimes there is the predominance of an only owner, as in Norway's case, with Avinor management of 45 airports.

Over the economic issues linked to the new tourist routes, the role of each airport can affect a small network, as in the Hålogaland. The linkages between the several airports acquire a predominant role in the area, especially considering the different needs under imposed on the hard connections, like arrive in the Hospital from a village on a little

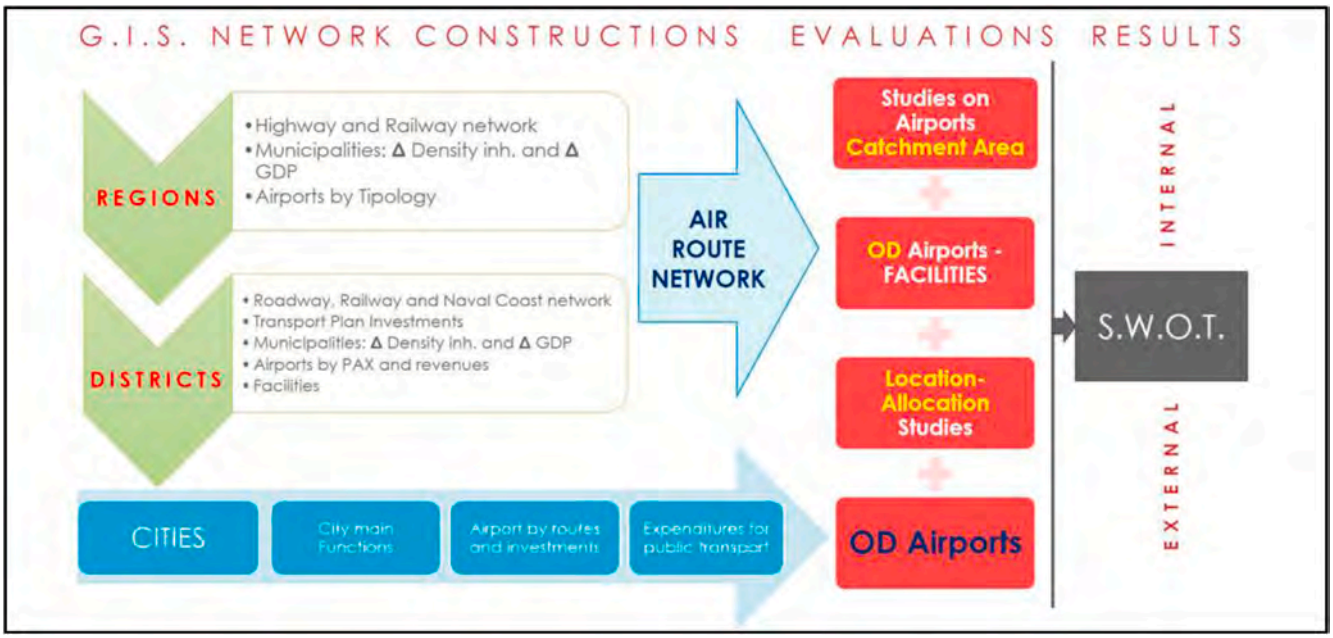

Fig. 9. Construction process of the GIS analysis.
Source: Authors

Table 4
S.W.O.T. Analysis.

Strenghts	Weaknesses	Opportunities	Threats
Traffic PAX growth	Accessibility	Comprehensive Networks building	Empiric attitude and short period interventions
Geographic Situation	Setting up network connections	Terminal Building	Unbalanced Managerial Systems
Export Statement	Smaller Building capability	Network attractiveness	Underestimate of environmental risks
Smallers' Capacity Building	PSO	Transport Linkage	Further urban development in dangerous areas closed to the runways
History		NATO Base Environmental development	Military Aviation
Internal		*External*	

Source: Authors

fjord, or to arrive in an oil-base from the same place. Therefore, an over imposed strategy plan can increase the overlapping effects.

In each couple of airports, there are risks without a direct linkage to plans, or not entirely addressed by investment solutions. The risk increase of the time to gain an organic planning system can be fatal in the remote urbanized areas of Cyprus. In the same way, little islands and fjords of Hålogaland need a comprehensive plan to follow their needs to the government's transport planning investments.

At least one airport for each couple presents close urbanized residential areas, and this stresses the dangerous impact, an obstacle for those areas to become integrated into the city. In this case, Hålogaland presents a significant risk in Bødo airport's new plan.

All couples are affected by military problems. Thus, it is necessary to manage the interaction with the territorial areas to make an effort in the connectivity directions, reducing the risks of pollution.

5. Conclusions

This paper has underlined the relationships between different couples of close airports and evaluated the associations between distances and urban development. Various planning systems have been studied in different areas, aa well as the constraints that increase the specific characters of every region. Investment perspectives focus on overcoming limitations, but the absence of a comprehensive design plan stresses the overlapping effects, above all, on the airports' fringe areas. The case of Cyprus, without a National Transport Plan, is typical at this stage, where nowadays still resist areas without rights and where tourism impact risks to be fatal on the environmental future. With other shades, the other couples of airports are affected by unbalanced planning systems. Even if the Apulia Airport System seems to be different, with the strategic ownership of the whole number of the civil airports in only one stock company, the effects of the private property affected the relationships between the airport and the city (Brindisi). The needs of a balanced planning system are also evident in the opposite model in Norway, where a centralized superordinate ownership participates in the investments on the road system, and it seems that could be an advantage. But the expenditures on roads have caused airports and airliners closure in the recent past, so more attention has to paid in the territorial dimension of a more balanced system. Solving problems for an airport and a city must press the collaboration among the two airports, giving positive effects to the airline competition. The analysis on the Sicily Airport System underpins, more than the others, the importance of the underserved areas and the economic evaluation about the most distant clusters of the catchment area. Therefore, it seems that the strengthening of the relationships between the different airports of each couple can give more possibilities to an equilibrate growth, to contain diverse functions for the two airports, to provide more options to airliners in market diversification, and using the local most reliable transport system as a tool to enforce the cooperation linkage and enlarge the capability growth of GDPp.i.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

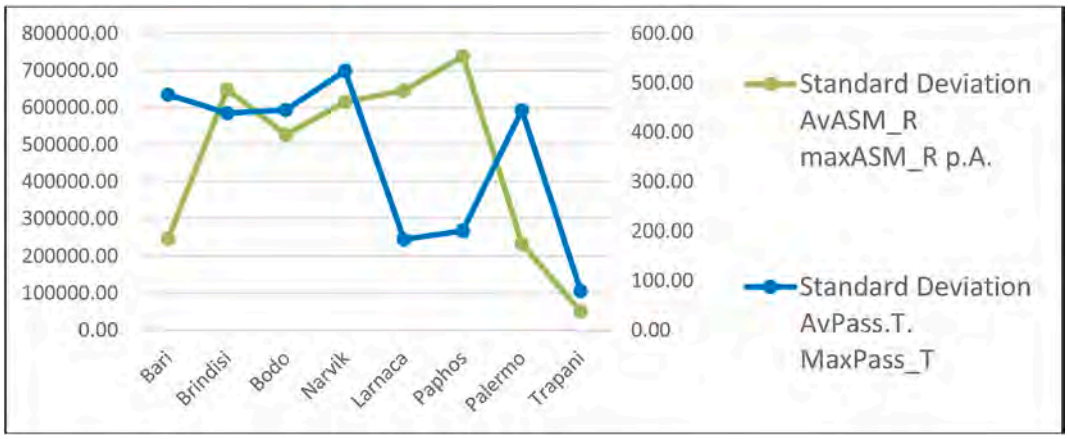

Fig. 10. – Comparing Couples Working. Comparison between the standard deviation graph between the average of transported passengers by each airport of every couple and the maximum of transportable passengers, and the standard deviation graph between the average ASM (Available Seats per Mile) Revenue per Airport and the maximum ASM revenue.
Source: Authors

CRediT authorship contribution statement

Alessandro Massaro: Writing - review & editing, Writing - original draft, Data curation, Methodology, Formal analysis, Investigation, Visualization. **Silvia Rossetti:** Writing - review & editing, Supervision, Validation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jairtraman.2020.101977.

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