Optimum Allocation of Time Resources For Transport Operation Enterprises

Maria Sartzetaki *msartze@econ.duth.gr*
Senior Researcher (PhD)
Department of Economics
Democritus University of Thrace
University Campus, Panepistimioupoli Komotini, Greece

Dimitrios Dimitriou *ddimitri@econ.duth.gr*
Associate Professor
Department of Economics
Democritus University of Thrace
University Campus, Panepistimioupoli Komotini, Greece

Aristi Karagkouni *arkaragkouni@gmail.com*
Research Fellow
Department of Economics
Democritus University of Thrace
University Campus, Panepistimioupoli Komotini, Greece

Abstract

Airport's serving a tourist destination is an essential counterpart of the tourist demand supply chain, and their productivity is related to the region's attractiveness and is enhanced by the air transport business. In this paper, the evaluation framework to prioritize the scheduled flights connecting two tourist airports is constructed. The analysis based on the rating of available yield seats offered in a corridor connects two tourist regions, which are adjusted towards origin-destination attractiveness, air carriers' operational characteristics and demand response per flight serving this route. By adopting a holistic system of system approach, the flight schedule between two tourist airports is reviewed and airports connectivity is weighted according to air transport network characteristics. The evaluation methodology, based on inventory control theory (yield seats), introduced a modeling framework easy to use MIS data from airports and air carriers and applied in relevant DSS system. The numerical application deals with the connection between the main airports in Greece and Cyprus which both are very attractive tourist destinations in the Mediterranean region, and therefore, air transport sector has a large contribution to national economy. The modelling framework is structuring to provide an essential tool for planners, managers, researchers and analysts towards tourist airports connectivity in terms of air transport network's resilience, attractiveness, productivity and efficiency.

Keywords: Airport Connectivity, Flights Scheduling, Air Connectivity Rating, Yield Seats, Connectivity Evaluation.

1. INTRODUCTION

Air transport development is on the top of the agenda for governments, authorities and stakeholders, especially, for economies heavily depending on tourism, such as the Mediterranean region in Europe, where air transport provides connectivity to national and international markets. Therefore, air transport is recognized as a key driver towards income generation, social stability, sustainable business development and economy enlargement [1]. The impact of air transport on the regional economy is of great importance, because it reflects to the economic profile of the region it serves and, in many cases, acts as a key driver of the socioeconomic development in regional or national scale. It is noteworthy that regions accessible to air transport services and connectivity to international markets, achieving essential economic benefits in terms of unemployment, business productivity, and per capita income. Especially, for the tourism regions where the domestic income heavily depended on air transport and tourism supply chain performance. For those regions any decision on improving air connectivity is very crucial towards economic system resilience and social coherence.

Air connectivity is a catalyst for economic growth, employment, trade and mobility in Europe, especially for south European countries. The concept of cohesion is more crucial when reflects on the notion of connectivity. Increasing connectivity enables local economies to grow by attracting foreign direct investments and creating new jobs. In addition, promotes the mobility of citizens in remote regions in Europe [2], [3]. Furthermore, the contribution of tourism and air transport to regional development stimulate the research interest [4], [5] providing evidence that the selection of the final tourist destination is related to air transport performance, transport infrastructures and supply chain management. For high demanded tourism destinations, the business sectors of air transport and tourism are interlinked. References [6], [7] highlight the relationship between tourism and air transport and conclude that any changes in aviation efficiency are closely linked to tourism development. So, this concept stimulates the interest of researchers promoting efficiency of the network and performance of the airport [8], [9].The key objective of this paper is to develop an evaluation framework of the scheduled flights serving tourist airports. Taking into consideration the air transport network's operational characteristics and the airport services performance outputs, the available yield seats of the arrival flights are correlated with the available yield seats of the departure flights which are adjusted in terms of supply chain characteristics including destination attractiveness, carrier operational characteristics and demand response. The methodology framework, based on the inventory theory control (yield seats) and the numerical example, promotes the use of modeling formulation. The results would be useful for the planners and managers in air transport, promoting outputs to support decisions towards network efficiency, pricing policy and flight schedule optimization.

The paper layout is organized in six sections. After the introduction, in the second section the relationship between air transport and connectivity growth, especially in tourist regions, is noted and a reference is made to the architecture of airline networks. Third and fourth section deal with the methodology framework and the modeling formulation to improve air connectivity. In section five, the key features and the results of the application are presented, while in the last sections, the key conclusions are drawn, and the references are situated.

2. BACKGROUND RESEARCH AND LITERATURE

2.1 Air Connectivity and Economic Growth Linkage

Aviation is a customer-driven business sector. While there is no single definition of air connectivity, it can be viewed as the ability of a network to move passengers, cargo and mail involving the minimum of transit points, which makes the trip as short as possible with optimal user satisfaction at the minimum price possible [10]. Improved air connectivity is a key driver for social and economic development and its importance depends on the location and its accessibility to markets [11]. In graph theory, connectivity of a given airport could be represented as the average minimum path length required to reach it from other airports in the network. This connectivity index, whether a simple average or weighted by the route frequency or number of offered seats, has been widely adopted to measure the connectivity of entire airport networks [12].

According to IATA [13], air passenger demand worldwide has experienced a 3.7% annual compound average growth rate over the last decade. The spectacular growth in the international air transport market and the accompanying development of new markets has greatly contributed to improved global connectivity. Air connectivity is essential to unlock a county's economic growth potential, in part because it enables the country to attract business investment and human capital. Many authorities and professional bodies place on the top of their agenda the contribution of air connectivity to economic development and they promote that investment prioritization and feasibility in air transport industry should be based on evaluation of changes in connectivity and network capacity [10]. Especially, for airports, ACI [2] has placed air connectivity at the core of its aviation strategy, which itself is part of its plan for growth, investment and jobs.In 2017, overall average airport connectivity in Europe increased by +3.8%, reflecting significant airline capacity expansion. Most of the connectivity gains came from the EU market at 4.3%, where Cyprus, Latvia, Lithuania, Malta and Portugal achieved double-digit growth. Conversely, connectivity in the non-EU market grew at a much slower pace at +1.4% - mainly due to connectivity losses in Turkey (-6%) and Norway (-2%) as well as limited gains in Switzerland (+1%) (2). Furthermore, according to ICAO's long-term traffic forecasts, total passenger traffic of Europe is expected to grow by around 3.0% annually up to 2032 and by 2040 is expected to grow to just over 16 million flights in the most-likely scenario [10, 14].

The linkage between transport and tourism sectors is widely acknowledge [15]. Tourism plays an important role in the regional economic development, and in some cases, it significantly contributes to regional economic development, representing the main source of income [16]. Despite the high competition in aviation industry, the volatility and cyclicality in economic environment and the slow innovation in aviation sustainable development, air transport achieve the highest shares of market in tourism demand [16]. Mediterranean tourism activities in MENA have undergone enormous growth during the last decade, which in turn has significantly increased the demand for air travel, and placed under discussion the adequacy of the available infrastructures [17], [1]. International tourist arrivals (ITA - overnight visitors) reached a total of 1,235 million in 2016. This was 46 million more than in 2015, or an increase of 3.9%. The global pace of growth was slightly more moderate than in 2015 (4.5%), but in line with UNWTO [15] long-term forecast of 3.8% per year for the period 2010 to 2020. According to Euro-Control [14], the Mediterranean region is expected to achieve an annual growth rate more than 4% in the next decade.

2.2 Air Connectivity Network Features

An air transportation network consists of the nodes (airports) and the edges depicting the flight routes which directly link two airports [18]. An airline's network is the set of city-pairs that the airline connects via non-stop flights. The choice of network structure is one of the most important strategic decisions of an airline [19]. The most widespread forms of networks are the point-to-point and Hub and Spoke (H&S) systems, with most large airlines operating some combination of the two. A hub-and-spoke network is a route where an airline not only transports passengers between two points but also connects the passengers of distant points via its hub. In contrast, in a point-to-point network, all cities are connected with each other through non-stop flights.

2.1.1 Point to Point Network Structure

On the other hand, point-to-point route planning connects each origin and destination via a non-stop flight. In this approach, total travel time is reduced by eliminating the intermediate stop and there is the possibility of better allocation and use of airline and airport staff [20]. The PP network for airlines is operated by a simple fleet with a limited variety of types of aircraft which are very cost-efficient. According to [21], the considerable cost reduction of LCCs comes from an intensive use of the aircraft: the aircraft of an LCC is in the air, on average, more hours a day compared with the traditional carriers. This generates higher productivity of aircraft and crew. Moreover, lower maintenance costs, due to simpler fleets and lower landing/ground handling fees negotiated with secondary airports without congestion problems, cause also relevant differences in the production process.

2.1.2 Hub and Spoke Network Structure

In a hub-and-spoke network, an airline concentrates most of its operations in one airport, called the hub. All other cities in the network (i.e., the spokes) are connected to the hub by non-stop flights such that travelers between two spoke cities must take a connecting flight to the hub [19]. The H&S network planning aims to maximize the of the number of city pairs to cover all traffic demand. An H&S network design focuses on the connectivity within hubs which is typically implemented by concentrating the flights' landing and takeoff time at the hubs [22]. Reference [20] highlight that the H&S route structure planning became the post-deregulation principle aiming to serve network destinations with the fewest routes of any alternative planning. For example, five destinations require only four routes with one hub and four spoke cities but ten routes are required if the same destinations are connected with a point-to-point system. Thus, is assumed that the H&S system is optimized when providing air service to a wide geographic area and many destinations.

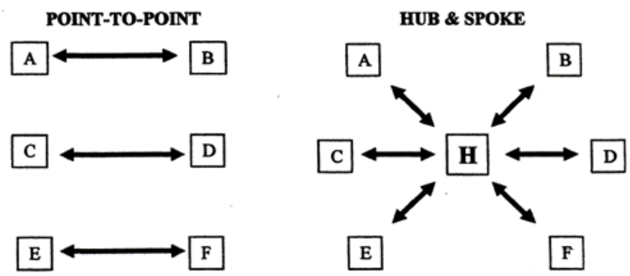

FIGURE 1: Depiction of point-to-point and Hub & Spoke network planning, [20].

2.1.3 Connectivity Optimization

There are many researchers that highlight evaluation methods used to solve the robustness of air transportation network. The most widely used evaluation method is by computing the algebraic connectivity [8]. In reference [18] the algebraic connectivity to air transportation networks is introduced for the first time. They chose the algebraic connectivity as the robustness metric and solve the optimization problem. The flight routes addition/deletion problem is formulated based on the weighted air transportation network.

Optimization problems have been applied to different fields such as transportation systems resource constrained projects [23] and sensor networks. Such problems are characterized by the presence of one or more objective maximizing or minimizing functions and various restrictions that must be met so that the solution is valid.

Furthermore, the use of linear programming is very useful in order to solve optimization problems [11].When working with linear restrictions and objective functions, optimization problems can be resolved with algorithms such as the Simplex which limits the study of this type of problem. Certain non-linear problems can be optimally resolved by using algorithms such as Lagrange multipliers [24].

In previous researches allocation models divided in two different categories: single-airport slot allocation models and network-wide slot allocation models [25], [26]. Especially single-airport slot allocation models have been recently investigated in research. Many researchers such as, [27], [28] focused on developing optimization models to determine the capacity targeting to minimize delays, maximize airline profitability and maximize passenger welfare. Such models have been applied for a single day of operations at some of the busiest airports [29].

Finally in terms of the temporal dynamics of airline networks, many researchers have considered weighted networks based on the number of flights from schedules [30], such as the investigation of air deregulation in Korea's aviation market concluding that the pattern flight schedules patterns clustered [31], the survey of the quality of direct connections from a temporal perspective conducted by [32]. And the examination of the performance of a dual-hub network via indirect connectivity analyzed in [33].Furthermore, many researchers measuring connectivity of network carriers have investigated that alliance strategies in the aviation market strengthened connectivity [34], [35].

3. METHODOLOGY FRAMEWORK AND HYPOTHESIS

This guideline is used for all journals. These are the manuscript preparation guidelines used as a standard template for all journal submissions. Author must follow these instructions while preparing/modifying these guidelines. This guideline is used for all journals. This guideline is used for all journals. These are the manuscript preparation guidelines used as a standard template for all journal submissions. Author must follow these instructions while preparing/modifying these guidelines. This guideline is used for all journals. This guideline is used for all journals. These are the manuscript preparation guidelines used as a standard template for all journal submissions. Author must follow these instructions while preparing/modifying these guidelines. This guideline is used for all journals. This guideline is used for all journals. These are the manuscript preparation guidelines used as a standard template for all journal submissions. Author must follow these instructions while preparing/modifying these guidelines. This guideline is used for all journals.

3.1 Hub Network Architecture For Improving Connectivity

The research question of this paper deals with the prioritization of inbound flights, based on their available yield seats, from a tourist region (Airport i) compared with the accessibility to available seats of outbound flights from a busiest hub airport (Hub Airport j). The optimization framework based on a hub and a spoke air transport network (i, j), ultimately examines the possible optimum allocation of connections, based on the availability of yield seats of each flight, between tourist airport i and a hub tourist airport j for improving the connectivity to tourist market of airport i. Reference (20) giving the H&S system definition, explains that in this system passengers departing from any non-hub (spoke) city bound to another spoke in the network are first flown to the hub where they connect to a second flight to their final destination.

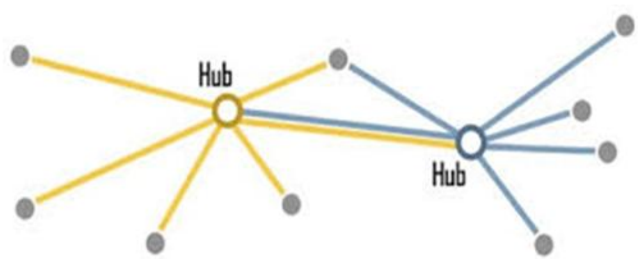

FIGURE 2: Depiction of Air Connectivity between Two Tourist Airports. [36].

In this approach, the fact that the availability of the yield seats of each flight depends on many factors related to the airport characteristics, the air carrier operational characteristics and the demand of each flight is taken into consideration. Thus, some significance coefficients are introduced which imply the above connection. The modeling formulation is based on the classification of each flight depending on its available yield seats, in order to maximize the connecting flights for the flights arriving from airport i. This formulation is very beneficial for island tourist destinations, where the dependency of airport i from airport j is essential. In other words, the connectivity of airport i depends on the flights connecting with airport j, which provides a much higher number of flight connections through airport j with the tourist market.

3.2 Definitions and Key Assumptions

The modeling formulation based on the inventory control theory, whereby an optimization structure based on the availability of the yield seats of each flight is developed, and the existing schedule services are evaluated over time.

The assumptions adopted regarding the operation characteristics of connection flights at airports A and B are:

- Only scheduled flights are taken into consideration;
- For all selected data in this research, there is no any restriction to connected flights;

- The seat configuration of each aircraft depends on the airline. However, for the purpose of this research the promoted by the manufacture seat capacity is taken into consideration. For instance, the available yield seats for the Airbus A320 is 180, [37];
- For LCCs, where the seat configuration includes higher volume of yield seats (higher seat capacity than traditional carriers) and two additional seat rows are taken into consideration (available yield seats: 192).

4. MODELLING FORMULATION

This section is divided into two different sub-sections. In sub-section 'Available yield seats adjustment' the accessibility to available yield seats of the departures k from Airport j, based on the weighted coefficients is calculated, while in sub-section 'Connection flights rating zones'the classification in connectivity zones of each flight r from Airport i to Airport j is analyzed.

4.1 Available Yield Seats Adjustment

The influence of the significance coefficients on the adjusted number of available yield seats of each departure k from airport j in a specific day is presented in the following equation:

$$WS_{j,k} = (AS^{\,a\times b\times f})_{j,k} \qquad (1)$$

Where:
k= index that refers to each departure from Airport j to any destination and k ∈ ℕ;
r= index that refers to each arrival from Airport i to Airport j and r = 0, 1, 2, 3… n;
n= the last arrival from Airport i to Airport j, during a specific day;
$\boldsymbol{WS_{j,k}}$ = adjusted number of available yield seats of each departure k from airport j in the same specific day;
$\boldsymbol{AS_{j,k}} =$ = number of available yield seats of each departure k from airport j for each flight r that arrive from airport i in a specific day;
$\boldsymbol{a_{j,k}}$=Weighted coefficient that determines the attractiveness of the destination of each departure k, based on the type of its airport;
$\boldsymbol{b_{j,k}}$=Weighted coefficient that is linked to the uniqueness of the destination and the air carrier operational characteristics;
$\boldsymbol{f_{j,k}}$= Weighted coefficient that represents the load factor of each departure k and receives values from 0.00 to 1.00.

The values of the coefficients a and b based on the airport characteristics and the air carrier operational characteristics respectively, are shown in the Tables below.

<u>Values of coefficient $\boldsymbol{a_{j,k}}$</u>

According to [38] the categorization as provided by Munich Airport was identified as the most suitable starting point for statistical assessments since it reflects operational characteristics of airports in qualitative statements except passenger number ranges. The categorization of airports and the corresponding values of coefficient $\boldsymbol{a_{j,k}}$ are presented in the Table 1:

Annual pax (Million)	**Airport Category**	**Attractiveness coefficient $\boldsymbol{a_{j,k}}$**
>40	International Hubs	1.00
(15 , 40]	Secondary Hubs	0.75
(5 , 15]	International O&D	0.50
≤5	Regional O&D	0.25
Local to regional service area (usually ≤ 1)	Secondary O&D	0.00

TABLE 1: Values of Attractiveness Coefficient $\boldsymbol{a_{j,k}}$.

Values of coefficient b:
If there is direct flight from Airport i, then:

$$b_{j,k} = 0.00 \quad (1)$$

If there is not direct flight from Airport i, then the values of the coefficient $b_{j,k}$, according to the air carrier operational characteristics, appear in the following Table 2:

Air carrier operational characteristics	$\boldsymbol{b_{j,k}}$
Base carrier to final destination	1.00
Base carrier to Airport j	0.75
Non-base carrier to Airport j and final destination	0.50
Low cost carrier	0.25
Charter flight	0.00

TABLE 2: Values of Attractiveness Coefficient $\boldsymbol{b_{j,k}}$.

Once the values of the above factors have been determined, the accessibility of the passengers coming from Airport i to Airport j at the available yield seats of the connection flights departing from Airport j is calculated.

Based on the above assumptions, the solution of this prioritization problem is addressed with the aid of the following objective function, depending on the above 2 cases:

i. If d_t>60min, then:

$$\mathrm{FC_r^d} = \frac{\sum_{t_r}^{t(r+1)} \mathrm{WS_{j,k}}}{\mathrm{S_{i,r}}} \qquad (2)$$

ii. If d_t≤60min, then:

$$\mathrm{FC_r^d} = \frac{\sum_{t_r}^{t(r+1)} \mathrm{WS_{j,k}}}{\mathrm{S_{i,r}} + \mathrm{S_{i,(r+1)}}} \qquad (3)$$

Where:
$\boldsymbol{S_{i,r}}$ **=** number of available yield seats of each flight r arrives from airport i over the same day; $\boldsymbol{d_t}$= time between two consecutive arrivals from airport i.

$\boldsymbol{t_r}$= The minimum connection time for each flight r that arrives from Airport i to Airport j.

The values of t_r are defined as follows:

i. For base carrier and network carriers the t_r is taken 60min, because the baggage handling system support connected flights procedurally, meaning no need for the passenger to check again the baggage for the next flight.
ii. Otherwise $\mathrm{t_r}$ is taken 90min.

Min and max values for factor $\boldsymbol{FC_r^d}$ are defined as following:

If $\sum_{t_r}^{t_{(r+1)}} \mathrm{WS_{j,k}} = \mathrm{S_{i,r}}$, then:

$$\min \mathrm{FC_r^d} = 1 \qquad (4)$$

If $\sum_{t_r}^{t_{(r+1)}} \mathrm{WS_{j,k}} > \mathrm{S_{i,r}}$, then:

$$maxFC_r^d = \frac{\sum WS_{j,k}^t}{S_{i,t}} \qquad (5)$$

Where:

$\boldsymbol{WS_{j,k}^t}$= Adjusted number of available yield seats of departures k from airport j for the longest time t between two consecutive arrivals from airport i;

$\boldsymbol{S_{i,t}}$= number of available yield seats of the flight that arrives from airport i for the same time t.

4.2 Connection Flights Rating Zones

In order to solve the prioritization problem, equation (6) is used, where the variable μ_r is defined. A scale from 0.00 to 5.00 is adopted. The max $\boldsymbol{FC_r^d}$ is considered to be equal with the value 5.00, then for each flight r that arrives form airport i to Airport j, $\boldsymbol{VC_r}$ is calculated as:

$$\mathrm{VC_r} = \frac{\mathrm{FC_r^d} \times 5.0}{\mathrm{MaxFC_r^d}}, \qquad (6)$$

Where:

$\mathrm{VC_r}$= Variable that shows the connectivity of each flight r; and

$\mathrm{VC_r} \in [0.0\,,5.0]$.

The values for the variable $\mathrm{VC_r}$, in the scale from 0.00 to 5.00 for each flight r that arrives from airport i, depend on the value of the variable $\mathrm{FC_r^d}$ and the corresponding assessment and prioritization of each flight, and are placed into four different zones as presented in Table 3.

Intervals of VC_r	**Connectivity rating zones**
(3.5 , 5.0]	High attractive zone
[2.5 , 3.5]	Comfort attractive zone
[1.0 , 2.5)	Moderate zone
(0.0 , 1.0)	Poor attractive zone

TABLE 3: Depiction of the zones based on the value of the variable $\boldsymbol{VC_r}$.

Depending on the value of $\mathrm{VC_r}$, each flight r is assigned to a connectivity zone. Each zone symbolizes the accessibility of the passengers of this flight to the connecting departures k of Airport j.

5. NUMERICAL APPLICATION

5.1 Case Study Features

Mediterranean region is one of the most attractive tourism destinations in the world, accounting for approximately more than a third of ITA [2]. For decades, the Mediterranean destinations have provided, along with other attractions, the traditional sun, sand and sea product, essentially for the North European markets. The northern part of Mediterranean tourism market is much more mature, although, recently a widespread development in the south part is occurred [36]. According to [7], recent years, the contribution of the airports for the Mediterranean countries to the national GDP is essential. This is particularly noticeable in destinations with high percentage of air transport ITAs like the islands of Cyprus and Malta. It is also highlighted that Greece due to the dispersion of tourist destinations, the intense seasonality and many airports, has the highest share of airport contribution to the national GDP in comparison with other Mediterranean countries.

Based on the above, Greece and Cyprus are considered among the top Mediterranean tourism destinations. The busiest airports of each island are of vital importance with a strategic position. In this section, analysis on air connectivity features between Athens International Airport (the main hub airport in Greece) and Larnaca International Airport (the busiest airport in Cyprus) is given in order to highlight the optimum air connectivity allocation between the two airports.

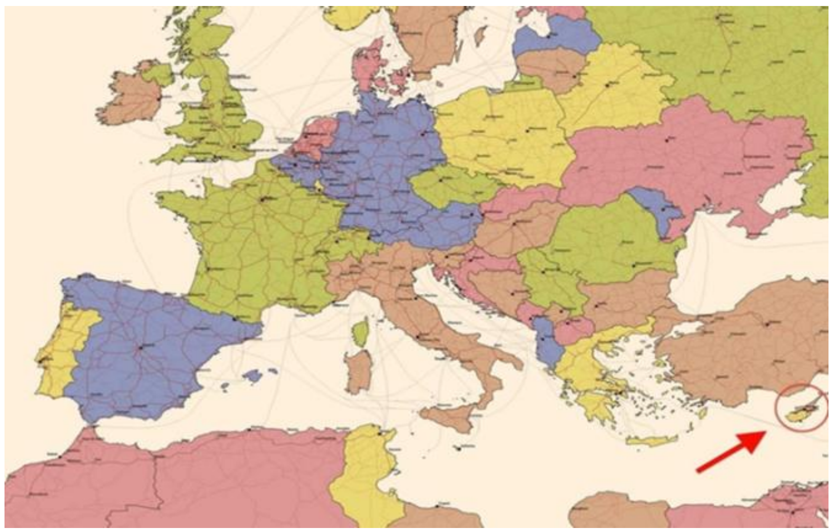

FIGURE 3: Geographical location depiction of Larnaca/Cyprus and Athens/Greece [11].

Athens International Airport (ATH) in 2017 recorded an all-time high performance, with 21.7 million passengers (surpassing previous year traffic by 1.7 million (+8.6%). This outcome was mainly driven by the strong growth of the international market (+1.5 million or +12%), whereas the domestic market presented a slow rise of 2.4% due to capacity reduction in the winter periods [39]. Larnaca International Airport (LCA) in 2017 accommodated 7.7 Mio total numbers of passengers, with 65 airlines having operated to 110 destinations in 40 countries; thus, it is assumed that Athens International Airport serves as a hub airport, where Larnaca Airport serves as a spoke [40]. The monthly passenger traffic of the two airports in the last five years (2013-2017), is shown in Figure 4 and Figure 5. Based on these data, it is observed that, as tourist airports, they present their maximum passenger traffic in the summer months. Furthermore, their passenger traffic has been rising steadily over the past few years, indicating that they are very promising and crucial infrastructures for both countries.

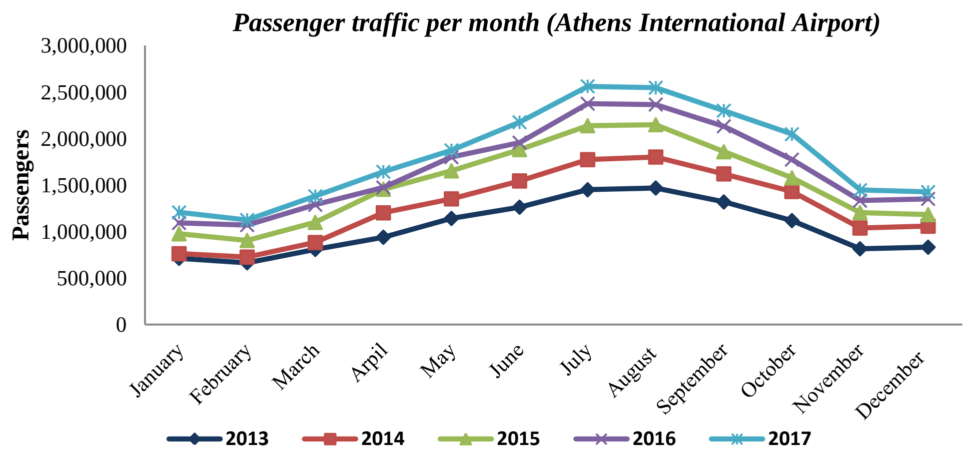

FIGURE 4: Depiction of the monthly passenger diet at Athens International Airport, (2013-2017) [39].

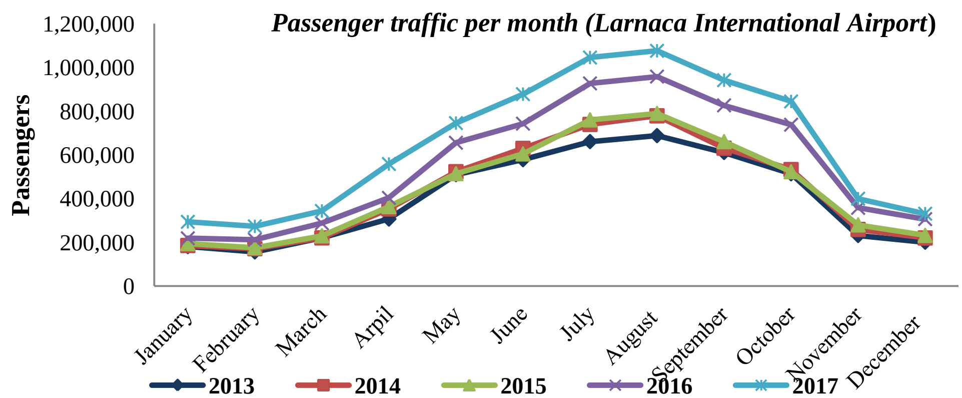

FIGURE 5: Depiction of the monthly passenger traffic at Larnaca International Airport, (2013-2017) [40].

Observations on data analytics on the specific window sample highlight that there is daily direct flight from Larnaca Airport to Athens International Airport. There are four carriers serving the direct connection between Larnaca and Athens, and a high diversification in fares is observed.

The specific time window adopted is the second week of July 2017 (period12-7-2017 to 19-7-2017). The next step is to analyze how passengers may use this hub-and-spoke network. In order to optimize how this hub and spoke network may be used, a specific time window, thus a specific everyday day (Thursday 13th July) and a weekend day (Saturday 15th July) were selected to illustrate the results.

5.2 Results

The key results of the classification of flights arriving from Larnaca, based on their available seats, compared with the accessibility to available yield seats of the connecting scheduled international flights from Athens, are depicted in Table 4 and Table 5:

Flight Details			**Number of Yield Seats**		**Variables**	
Flight ($F_{i,j}$)	**Arrival Time at ATH**	**Flight Number**	**Available Seats of $F_{i,j}$**	$\sum_{t_r}^{t_{(r+1)}} S_{j,k}$	FC_r^d	VC_r
F1	6:55	A3 901	174	245	1.41	3.51
F2	8:30	CO 712	156	72	0.46	1.14
F3	9:20	0B 5161	170	33	0.19	0.47
F4	9:50	A3 911	174	350	2.01	5.00
F5	13:00	A3 903	174	230	1.32	3.28
F6	14:45	0B 5261	170	180	1.06	2.64
F7	15:35	CO 716	156	210	1.35	3.36
F8	17:30	A3 905	174	188	1.08	2.69
F9	20:00	0B 5361	170	146	1.16	2.89
F10	22:45	A3 909	174	94	0.54	1.34

TABLE 4: Prioritization of flights arriving from Larnaca to Athens based on the value of variable (Thursday, 13th July, 2017).

Flight Details			**Number of Yield Seats**		**Variables**	
Flight ($F_{i,j}$)	**Arrival Time at ATH**	**Flight Number**	**Available Seats of $F_{i,j}$**	$\sum_{t_r}^{t_{(r+1)}} S_{j,k}$	FC_r^d	VC_r
F1	6:55	A3 901	174	287	1.65	3.93
F2	9:15	0B 5161	170	46	0.27	0.64
F3	9:45	A3 911	174	225	1.29	3.07
F4	12:15	A3 903	174	193	1.11	2.64
F5	13:10	CO 720	156	328	2.10	5.00
F6	17:30	A3 905	174	286	1.64	3.90
F7	20:20	CO 722	156	112	0.72	1.71
F8	22:45	A3 909	174	77	0.44	1.05

TABLE 5: Prioritization of flights arriving from Larnaca to Athens based on the value of variable VC_r (Saturday, 15th July, 2017).

As depicted in the above Tables, the higher values of the variable FC_r^d results for flight $F_4$the typical everyday day and for flight $F_5$the weekend day. Therefore, for these flights, the variable VC_r will receive its maximum value which is equal to 5.00 in both cases. The prioritized flights are placed graphically in the different zones defined in Table 3. The graphic depiction of this classification for the specific time window is given in Figure 6 and Figure 7.

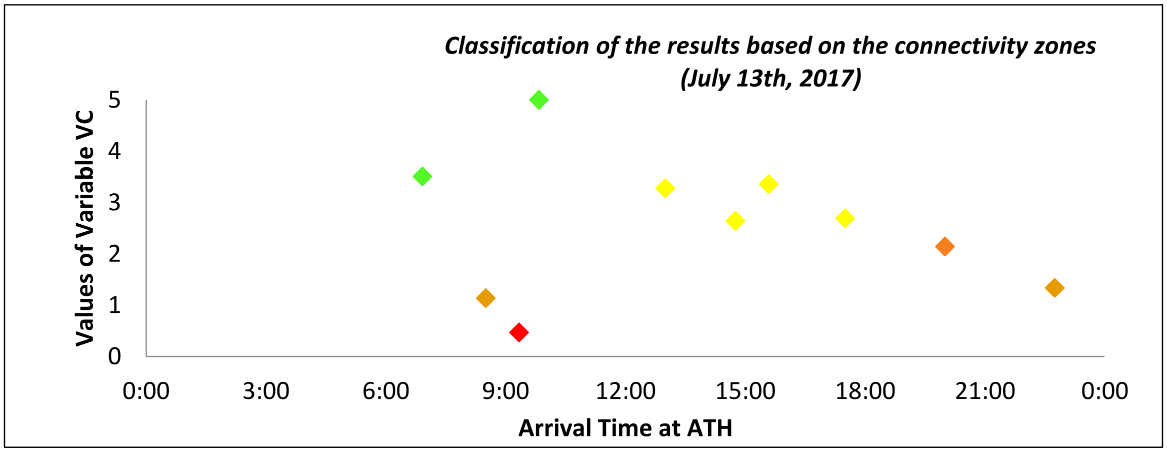

FIGURE 6: Depiction of the classification in different zones (July 13th, 2017).

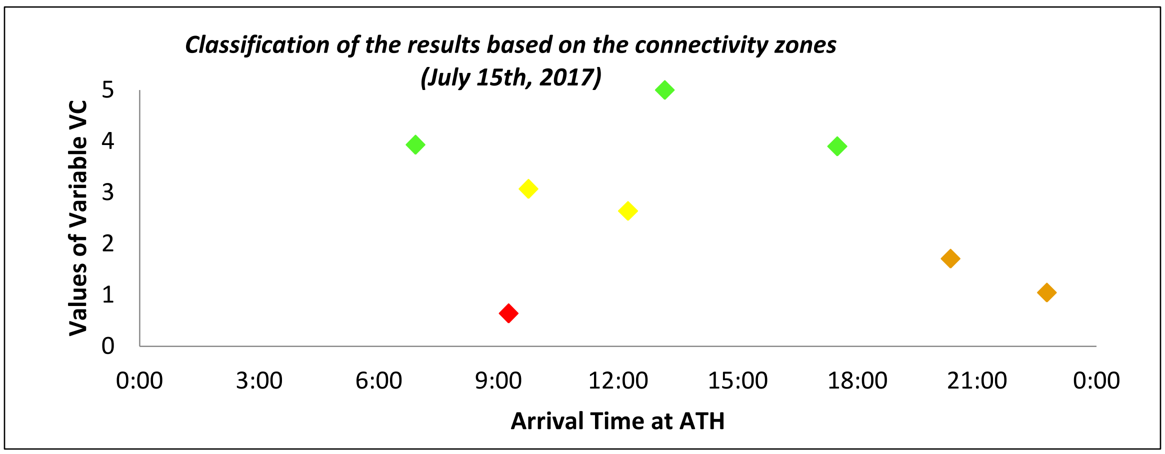

FIGURE 7: Depiction of the classification in different zones (July 15th, 2017).

According to the above results, the key messages could be summarized as:

- The typical daily, most flights are high in rank and they are placed in comfort and high connectivity zones;
- This is mainly due to the superiority of international flights in relation to the domestic flights from Athens airport during most hours of the day, as well as the high load factor due to the summer tourist season. This results in high values of the respective coefficients;
- Therefore, in the morning and late evening (flights F2, F3 , F9 and F10) a significant lack of connectivity is observed, because of the large number of domestic flights which correspond to low rates of the coefficients and in particular of $\boldsymbol{a_{j,k}}$;
- On the weekend, a higher percentage of flights in high connectivity zone is observed and there is a better distribution during the day;
- In both cases, the last flight at a late hour is not improving the connectivity and the only reasonable reason to exist is to serve the business traffic between Cyprus and Greece.

The recommendations to air carriers, for the best allocation of arrival time for this air corridor, in order to increase connectivity, between Larnaca International Airport and Athens International Airport could be summarized as:

- Afternoon and late evening hours are highly competitive time windows for air carriers to provide additional services;
- The yield pricing should be connected with the value $\mathrm{VC_r}$ and the connectivity zones resulting from it.
- The above could be a crucial tool for better distribution of flights schedule between the two airports. The increase in connectivity would be a key feature of economic growth and resilience in these tourist regions, which are of vital importance for the development of the Mediterranean region.

6. CONCLUSIONS

Tourism and regional socioeconomic development are based on the optimization of air connectivity between hub and spoke airports serving tourist destinations. Airports serving tourism destinations develop hub and spoke networks to provide optimum connectivity between popular origins and destinations. The main airports of Greece and Cyprus, two top Mediterranean tourism destinations, are both hubs of vital importance with a strategic advantage in the surrounding area. In this research paper, an overview of the existing air connectivity between the two countries and specifically between Athens International Airport as the main airport in Greece and Larnaca International Airport as the main airport in Cyprus is analyzed. In order to capture these characteristics, a combined measure which assesses the base level of connectivity, based on the availability of seats of each flight, leads to the prioritization of flights that arrive from Larnaca to Athens.

In portraying the air transport sector in these countries, this research assesses possible concerns in relation to current and potential future air connectivity gaps between the two main hub airports. The assessment concept and methodology provided is an essential tool for the management of airports and airlines, as well as for planners, analysts and researchers. The application results are essential for comparisons with other destinations and provide key messages regarding the importance of air connectivity in remote tourist destinations especially in the Mediterranean region.

7. REFERENCES

[1] D. Dimitriou. '*Comparative evaluation of airports productivity towards tourism*. International Journal of Cogent Business and Management, 5 (1464378), 2018, 1-15.

[2] ACI. '*Airport Industry Connectivity Report 2017'*. pp. 3, 9-11, 2017.

[3] D. Dimitriou , J. Mourmouris , M. Sartzetaki. '*Economic impact assessment of mega infrastructure pipeline projects*.' Journal of Applied Economics, pp.4310-4322, 2015.

[4] G. Benedetti, L. Gobbato, G. Perboli,, F. Perfetti. '*The Cagliari Airport impact on Sardinia tourism: a Logit-based analysis*.' Procedia – Social and Behavioral Sciences, 54(4), 1010-1018, 2012.

[5] J. Khadaroo, B. Seetanah. '*Transport infrastructure and tourism development.*' Annals of Tourism Research, Vol 34(4), pp. 1021-1032, 2007.

[6] T. Bieger, A. Wittmer. '*Air transport and tourism – Perspectives and challenges for destinations, airlines and governments*.' Journal of Air Transport Management 12, pp. 40-46, 2006.

[7] D. Dimitriou. '*Mobilities, Tourism and Travel Behavior – Contexts and Boundaries'*, Edited by Leszek Butowski, ISBN: 978-953-51-3727-6, Print ISBN: 978-953-51-3726-9, Publisher. In Tech, pp.143-159.

[8] P. Wei, L. Chen, D. Suna, '*Algebraic connectivity maximization of an air transportation network: The flight routes' addition/deletion problem'.* Transportation Research Part E: Logistics and Transportation Review Vol. 61, January 2014, pp. 13-27.

[9] D. Dimitriou, M. Sartzetaki, A. Karagkouni. '*Rating Framework to Evaluate Connection Flights at Tourist Airports*.' International Journal of Modern Research in Engineering & Management (IJMREM), Vol.1(7), pp.01-06, 2018.

[10] ACI, CANSO, IATA, ICAO, ICCAIA, 2017. '*Aviation Benefits Report 2017'*.pp.15, 54-55.

[11] D. Dimitriou. '*An Optimization Modelling to Evaluate Flights Scheduling at Tourist Airports Engineering and Technology'*, International Journal of Industrial and Systems Engineering, Vol:11, No:11, 2017, pp. 2730-3734, 2017.

[12] N. Antunes Ribeiro, A. Jacquillat, A. Pais Antunes, A. R. Odoni, J. P. Pita. '*An optimization approach for airport slot allocation under IATA guidelines'* Transportation Research Part B: Methodological, Volume 112, June 2018, Pages 132-156.

[13] R. Redondi, P. Malighetti, S. Paleari. '*New Routes and Airport Connectivity',* Journal: Networks and Spatial Economics, 11 (4), pp.713-725, 2011.

[14] IATA, 2016. '*Annual Report 2016'*. pp. 10-14.

[15] Euro-Control. '*European aviation in 2040 - challenges of growth',* report 2018, pp.19-23.

[16] UNWTO. '*Tourism Highlights Report'*, United Nations World Tourism Organization. pp.4-7, 2017.

[17] D. Dimitriou. '*Climate Change Implications in Aviation and Tourism Market Equilibrium, Climate Change Adaptation, Resilience and Hazards'*, Springer, pp.409-424, 2016.

[18] D. Dimitriou. '*Quantitative evaluation taxonomy for transport infrastructure projects',* International Journal of Research Science and Management 4(3), pp.34-40, 2017.

[19] E. Vargo, R. Kincaid, N. Alexandrov, '*Towards Optimal Transport Networks, Systemics, Cybernetics and Informatics',* 8 (4), pp. 59-64, 2010.

[20] V. Aguirregabiria, J. Chun-YuHob, '*A dynamic game of airline network competition: Hub-and-spoke networks and entry deterrence',* International Journal of Industrial Organization Vol. 28, Issue 4, July 2010, pp. 377-382.

[21] G. N. Cook, J. Goodwin. '*Airline Networks: A Comparison of Hub-and-Spoke and Point-to-Point Systems',* Journal of Aviation/Aerospace, Education and Research, 17 (2), 2008.

[22] M. Franke*, 'Competition between network carriers and low-cost carriers—retreat battle or breakthrough to a new level of efficiency?',* Journal of Air Transport Management, 10 (2004), pp. 15-21.

[23] M. Alderighi, A. Cento, P. Nijkamp, P. Rietveldc, '*Network competition—the coexistence of hub-and-spoke and point-to-point systems',* Journal of Air Transport Management, Volume 11, Issue 5, September 2005, PP. 328-334.

[24] X.L. Zheng, L. Wang, '*A multi-agent optimization algorithm for resource constrained project scheduling problem'* Exp. Syst. Appl., 42 (15–16), pp. 6039-6049, 2015.

[25] L. Castelli, P. Pellegrini, R Pesenti, '*Airport slot allocation in europe: economic efficiency and fairness',* Int. J. Revenue Manage., 6 (1/2), pp. 28-44, 2012.

[26] L. Corolli, G. Lulli, L. Ntaimo, '*The time slot allocation problem under uncertain capacity',* Transp. Res. Part C, 46, pp. 16-29, 2014.

[27] P.B. Swaroop, M. Zou, M. Ball, M. Hansen, *'Do more us airports need slot controls? A welfare based approach to determine slot levels*', Transp. Res. Part B, 46 (9), pp. 1239-1259, 2012.

[28] V. Vaze, C. Barnhart, '*Modeling airline frequency competition for airport congestion mitigation airline frequency competition in airport congestion pricing',* Transp. Sci., 46 (4), pp. 512-535, 2266 (69-77), 2012.

[29] A. Jacquillat, R. Odoni, '*An integrated scheduling and operations approach to airport congestion mitigation',* Oper. Res., 63 (6), pp. 1390-1410, 2015.

[30] G. Bagler, *'Analysis of the airport network of India as a complex weighted network*', Phys. A Stat. Mech. its Appl., 387, pp. 2972-2980, 2008.

[31] Y. Zhang, D.K. Round, '*China's airline deregulation since 1997 and the driving forces behind the 2002 airline consolidations'*, J. Air Transp. Manag., 14, pp. 130-142, 2008.

[32] S.-L. Shaw, F. Lu, J. Chen, C. Zhou, '*China's airline consolidation and its effects on domestic airline networks and competition',* J. Transp. Geogr., 17, pp. 293-305, 2009.

[33] W.K. Li, C. Miyoshi, R. Pagliari, '*Dual-hub network connectivity: an analysis of all Nippon Airways' use of Tokyo's Haneda and Narita airports',* J. Air Transp. Manag., 23, pp. 12-16, 2012.

[34] P. Malighetti, S. Paleari, R. Redondi, '*Connectivity of the European airport network: "self-help hubbing" and business implications',* J. Air Transp. Manag., 14, pp. 53-65, 2008.

[35] P. Suau-Sanchez, G. Burghouwt, '*Connectivity levels and the competitive position of Spanish airports and Iberia' network rationalization strategy'*, 2001-2007, J. Air Transp. Manag., 18, pp. 47-53, 2012.

[36] J. Yang, Y. Zhuang. '*An improved ant colony optimization algorithm for solving a complex combinatorial optimization problem*', Appl. Soft Comput., 10 (2), pp. 653-660, 2010.

[37] Airbus, https://www.airbus.com/aircraft/passenger-aircraft/a320-family/a320ceo.html.

[38] G. Öttl, P. Bock. '*An approach to airport categorization – category definition and quantification for air traffic related simulation purposes'*, Journal of Aerospace Operations, Vol: 1, No: 1-2, pp.155-170, 2011.

[39] Athens International Airport, https://www.aia.gr/userfiles/675393df-ab1a-4b77-826c-f3096a3d7f12/Pax_EN-2018-May.pdf.

[40] Hermes airports, http://www.hermesairports.com/en/larnakahome/corporate-and-business/aeronautical-activities/passenger-traffic.