UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa

Titulació:

Màster Universitari en Enginyeria Aeronàutica

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Enunciat TFM:

European second tier airports connectivity analysis: Study case considering potential long-haul low-cost flights

REPORT

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ABSTRACT

European air transport market and its growing tendency has led to an environment where all airports are facing fierce competition to attract connecting passengers and airlines. The potential development of long-haul low-cost carriers will be held by second tier airports, airports one step below hubs, in the future years. For this reason, the thesis aims to analyse the European second tier airports in terms of connectivity along with its evolution during the 2009-2017 period. The impact of long-haul low-cost flights into the connectivity values of European second tier airports will also be studied.

To fulfil the objectives of the thesis, a connectivity analysis is done in terms of passenger accessibility and airport centrality applying the Netscan model. Once the different types of connectivity values are determined, a clustering is done to group similar airports. The historical connectivity levels are analysed following the previous clustering. Then a study case is done by comparing connectivity analysis results with the introduction of long-haul low-cost phantom flights.

The main findings of the thesis conclude that there are significant differences between European second tier airports in terms of connectivity. Munich's performance is better than all other second tier airports, even compared to airports with higher number of passengers like Barcelona, London Gatwick or even than major hubs like Madrid. European second tier airports are primarily focused on intra-European operations. The historical data of European second tier airports reveals that the period 2009-2017 has been satisfactory in terms of connectivity, growing 19% in direct connectivity and more than 30% for other types of connectivity. The study case exposes that it is too early to determine the implications of long-haul low-cost operations in terms of connectivity on the European market since most results are inconclusive.

Keywords:

Air transport, EU market, Netscan model, Phantom Flights, Hub, Non-Hub

El mercat europeu del transport aeri i la seva tendència creixent han conduït a un entorn on hi ha una gran competència entre tots els aeroports per atraure passatgers en connexió i aerolínies. El potencial desenvolupament de vols *long-haul* operats per companyies de baix cost succeirà en els aeroports secundaris, els aeroports un pas per sota dels grans hubs europeus, en els propers anys. Per aquest motiu, aquesta tesi pretén analitzar els aeroports europeus de segon nivell en termes de connectivitat, juntament amb la seva evolució durant el període 2009-2017. També s'estudiarà l'impacte dels vols *long-haul* de baix cost en els valors de connectivitat dels aeroports europeus secundaris.

Per aconseguir els objectius marcats, en aquesta tesi es fa un anàlisi de connectivitat en termes d'accessibilitat de passatgers i centralitat aeroportuària aplicant el model Netscan. Un cop determinats els diferents tipus de valors de connectivitat, es fa una *clustering* per agrupar aeroports similars. Els nivells històrics de connectivitat s'analitzen seguint els grups del *clustering*. A continuació, s'estudia el cas de com varia la connectivitat amb la introducció de vols *long-haul* de baix cost i comparant els resultats de l'anàlisi de connectivitat.

Les principals conclusions de la tesi conclouen que hi ha diferències significatives entre els aeroports europeus de segon nivell en termes de connectivitat. El rendiment de Munic és millor que la resta d'aeroports de segon nivell, fins i tot en comparació amb aeroports amb un nombre més elevat de passatgers com Barcelona, Londres Gatwick o Madrid, un hub de primer nivell. Els aeroports europeus secundaris es centren principalment en operacions intra-europees. Les dades històriques dels aeroports europeus de segon nivell revelen que el període 2009-2017 ha estat satisfactori en termes de connectivitat, creixent un 19% en connectivitat directa i més d'un 30% en altres tipus de connectivitat. El cas exposa que és massa d'hora per determinar les implicacions de les operacions de baix cost a llarg termini en termes de connectivitat al mercat europeu, ja que la majoria dels resultats no són concloents.

Paraules clau:

Transport Aeri, Mercat europeu, Model Netscan, Vols fantasma, Hub, Non-Hub

ACKNOWLEDGEMENTS

First, I would like to recognise my appreciation to the deputy director for master's studies at ESEIAAT and my thesis director, Dr Daniel Garcia Almiñana. He has offered his support and expertise in the process of recognition of this thesis and accepted to be the director when I was in a complex position.

Secondly, I would like to express my best and deepest gratitude to the APM course director and my thesis co-supervisor, Dr Pere Suau-Sanchez. His excellent guidance and support during all the wonderful year and more specifically throughout this thesis. His deep knowledge and constant availability helped me solve any issues that arouse.

Thirdly, I would want to appreciate the effort and knowledge of every lecturer and employee who works in Air Transport Management in Martell House at Cranfield University. They have an extraordinary course, from an academic point of view as well as the personal touch. The massive knowledge assimilated from both lecturers and guest lectures is really appreciated and it will certainly benefit me in my career.

Finally, I want to thank my family for their encouragement, understanding and support to do the MSc in Airport Planning and Management and spend all year in Cranfield. I could not have achieved it without their effort and support.

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LIST OF ABBREVIATIONS

AGP	Malaga Airport
AMS	Amsterdam Schiphol Airport
AOC	Air Operator Certificate
ARN	Stockholm Arlanda Airport
ASK	Available Seat Kilometre
ATH	Athens International Airport
BCN	Barcelona El Prat Airport
BRU	Brussels Zaventem Airport
CAGR	Compound Average Growth Rate
CDG	Paris Charles de Gaulle Airport
CNU	Number of Connectivity Units
CPH	Copenhagen Kastrup Airport
DUB	Dublin Airport
DUS	Düsseldorf Airport
FCO	Leonardo da Vinci Fiumicino Airport
FRA	Frankfurt Airport
FSC	Full-Service Carrier
GVA	Geneva International Airport
HAM	Hamburg Airport
HEL	Helsinki Airport
LCC	Low-cost Carrier
LGW	London Gatwick Airport
LHLC	Long-haul Low-cost
LHR	London Heathrow Airport
LIS	Lisbon Airport
MAD	Madrid Barajas Airport
MAN	Manchester Airport
MaxCT	Maximum Connecting Time
MCT	Minimum Connecting Time
MUC	Munich Franz Josef Strauss Airport
MXP	Milan Malpensa Airport
OD	Origin and Destination

ORY	Paris Orly Airport
OSL	Oslo Gardermoen Airport
PMI	Palma de Mallorca Airport
STN	London Stansted Airport
TXL	Berlin Tegel Airport
VIE	Vienna International Airport
ZRH	Zürich Airport

1 INTRODUCTION

1.1 Background

Commercial air transport is growing every year and it is expected to double in twenty years, from 3,800 million of passengers worldwide in 2016 to 7,200 million in 2035 (IATA, 2017). The European growth rate will be about 2.5% annually. Even though the growth rate in Europe is slightly behind compared to other regions like Asia-Pacific or North America, with 4.7% and 2.8% each, the rapid growth of commercial aviation demand is not corresponded by the European airports capacity development. Big European hubs are having problems increasing its capacity due to environmental constraints or surface availability, as it has been seen in the case of the third runway for London Heathrow. So, the upcoming increase in the demand must be faced by second tier airports, airports one step below hubs, in the future years. On one hand, Big European hubs are mainly operated by full-service carriers (FSC) with strong market shares. On the other hand, the rest of the airports, without being a primary hub of major European FSCs, have developed a fierce competition to attract connecting passengers and airlines to increase their route network while trying to remark its differentiation.

The introduction of long-haul low-cost (LHLC) flights opens a wide range of opportunities for second-tier airports. Hubs' priority are long-haul flights from FSCs and the top five European hub airports prefer not to have low-cost carriers. FSCs control most slots of the top five European hubs and they do not want to lose them since LHLC flights represent one of the biggest threats in the upcoming years. But for second tier non-hub airports, they could mean the chance to become a hub and have an important increase in number of passengers. The LHLC operations aim to end with the typical "hub and spoke" structure since they can have profitable routes between secondary airports. Norwegian expansion and the introduction of LEVEL by IAG show a bright future for these types of flight. As Ryanair modified and reshaped the intra-European markets, these companies can restructure the long-haul market and it will also modify the current airport classification.

1.2 Aim and Objectives

The intention of this thesis is to study and analyse European second tier airports in terms of connectivity. Calculation of the connectivity of each airport for different years will be carried out to study the evolution of European second tier airports. Top five European hubs and regional airports are excluded. Finally, the thesis will also analyse the effects of the long-haul low-cost flights on the distinct types of connectivity of those airports. To pursue the aim of these thesis, the subsequent objectives are to be accomplished:

- To analyse the evolution of second tier European airports connectivity over time and the differences between them and the major European hubs.
- To evaluate the current state of long-haul low-cost carriers and to determine its potential impact in European second tier airports.

1.3 Scope and Limitations

The thesis studies European airports to do a connectivity analysis. The selected airports are the ones handling over 15 million passengers per year within the European market, excluding Turkey and Russia. The biggest European hub airports, which are London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, Frankfurt Airport and Madrid Barajas, are excluded.

The analysis, with its recommendations for each type of airport, focuses on the airports connectivity and it is not going to consider physical factors such as the airport's terminal dimension, number or runways or its length. Political factors are also not going to be considered.

1.4 Thesis Structure

The thesis has been structured to accomplish the objectives mentioned above while having a logical flow for the reader. The thesis is grouped into five chapters and is structured as follows:

Chapter 1 – Introduction: the first chapter presents background and problem statement about the topic of the thesis. It defines the core aim and objectives that the author wishes to achieve during the thesis research. Also, the research scope and limitations are presented along with a summary of the structure.

Chapter 2 – Literature Review: the second chapter describes previous research done related to the thesis. It will provide the current understanding of the subject and it will support the arguments presented at the conclusion. Literature review will be based on three main topics: Aviation network structure, airport connectivity and its different types and long-haul low-cost flights.

Chapter 3 – Methodology: This chapter consists of the airport selection and the different methodologies that will be used on the thesis. Three methodologies are explained along with its criteria and characteristics: The first one for the different airports' selection, the next one for the calculation of the connectivity values and the last one for the creation of long-haul low-cost phantom flights.

Chapter 4 – Results and Discussion: the fourth chapter is the central part of the thesis since it provides an answer all the objectives stated in Chapter 1. It consists of an analysis of all gathered data following the previous methodologies applied and interpretation and discussion of results with the goal to answer and fulfil the aim and objectives of the thesis. Chapter 4 is divided into the connectivity analysis of the current state of European second tier airports, then it will study the connectivity of the previous analysed airports for the last decade and its evolution. Finally, long-haul low-cost phantom flights will be studied and its outcome will be compared with the previous results and determine which airports are more affected by them.

Chapter 5 – Conclusions: the closing chapter of the thesis summarises the main outcomes of the research and it compares these results with the aim, objectives and limitations from Chapter 1. It also highlights suggestions for further research.

2 LITERATURE REVIEW

2.1 EU-Aviation Network Structure

The liberalization of the European aviation market started on 1997 and it produced major consequences. Flag carriers from leading countries started to function as European airlines, using hub-and-spoke networks from its main hub. Low-cost carriers (LCC) chose an alternative strategy and they focused on point-to-point markets from mainly regional or non-hub airports leading to the deconcentration of intra-European traffic (Burghouwt, 2007). Janic (1997) pointed out that it disabled any impediment that carriers could have to operate on the different EU domestic markets. Bel and Fageda (2010) agreed with both articles as it concluded that there was a *clear tendency towards deconcentration in European airports. Malighetti et al. (2008)* disagreed since they believed that hub-and-spoke network forced the European market towards a higher concentration. Suau-Sanchez *et al.* (2014) had a different opinion as they stated: "the exact manner in which European deregulation has affected the spatial concentration/deconcentration of airline traffic is unclear". It is considered that the terms "hub-and-spoke network" and "point-to-point networks" are known for the readers. But hub-and-spoke networks were defined as "concentrated around one or more hub airports where passengers can transfer to connecting flights within a limited time window" (Burghouwt, 2007). Point-to-point networks were defined by Cook and Goodwin (2008) as a structure that "connects each origin destination via a non-stop flight".

2.1.1 Types of Airport

Previous literature indicate the existence of several criteria in classifying the different types of airports. Burghouwt (2007) considered three criteria to classify the hub types. With these three ones, the article was able to identify nine distinct types of hubs. The first criterion is the size of the Origin and Destination (OD) market of each airport. On one hand, a *traffic hub* primary source of passengers is its own OD traffic and its local market. The possible transfer traffic the *traffic* *hub* can connect is also considered, but it is not a primary factor for its traffic generation. On the other hand, a *wayport hub* severely depends, more than 60% on connecting passengers and transfer traffic. The following criteria for airport differentiation consist of the quantity and quality of the connections offered to connecting passengers. In this segment, there are two types of hub with opposing characteristics, the *hinterland hub* and *directional hub*. A hinterland hub connects international routes with short-haul flights, where the short-haul purpose as feeder flights. The directional hub, also named hourglass hubs, transfers long-haul routes to other long-haul flights through itself. An optimal geographical location is important for this model, in order to minimize detours and connect markets far away from each other. The hourglass hub can multi-directional as well as uni-directional, east-west or north-south flows. Moreover, it also exists the option of a regional hub, which specializes in connecting short-haul routes with short-haul flights via itself. Hub airports that are able to offer the three types of connections are all-round hubs. Last criteria segments different types of hubs depending on their geographical focus. On one hand, *eurohubs* are the airports which exclusively focus on flights to other EU destinations. On the other hand, *global hubs* are defined as hubs that cover a large number of destinations, intra-EU and to other destinations worldwide.

Rodríguez-Déniz *et al.* (2013) stated that typically airport classifications are based on homogeneous groups. It also remarks that the most commonly employed method is the hierarchical clustering methods. They are applied to a wide range of topics that can be used to classify an airport. Rodríguez-Déniz and Voltes-Dorta (2014) classification ranged from terminal size and geometry benchmarking (Adikariwattage *et al.*, 2012) to connectivity analysis as Ivy (1993) or Burghouwt and Hakfoort (2001) going through productivity (Sarkis and Talluri, 2004). Suau-Sanchez *et al.* (2014) pointed out that the main criteria for the different airport categorisations is the total traffic of passengers. However, the method does not consider different type of passengers, OD or connecting passengers, and their influence over the airport classification. Suau-Sanchez *et al.* (2014) added a simpler and more transparent approach concerning airport categorisation. Suau-Sanchez *et al.* (2014) modified Rodríguez-Déniz *et al.*

(2013) classification and they classify the airports regarding their traffic generator "ODi" importance and their connecting passengers' contribution. Firstly, the traffic generator is computed as the sum of passengers that are originated in airport "A" or that airport "A" is its final destination divided by the market size "P". The second is the ratio calculated by transfer passengers divided by the market size "P". Suau-Sanchez *et al.* (2014) methodology was able to split the different types of hubs into seven groups by determining the "market size, traffic generation, level of connectivity and enplanements in domestic, international and total markets".

2.2 Airport Connectivity

2.2.1 Connectivity Definition

"Connectivity is a composite measure of the number of destinations, the frequency of services and the quality of the connections, in the case of hubbing or indirect services" (ACI, 2017). Burghouwt *et al.* (2009) considered connectivity to be the outcome of the all possible and reachable destinations structured as a network at a singular airport. Malighetti *et al.* (2008) previously defined connectivity as "the degree to which nodes in a network are connected to each other via links". Goedeking (2010) additionally pointed out that "the most fundamental indicator of connectivity is the absolute number of online hits by an airline at a given airport or system wide". Previous articles indicated, therefore, that the airport connectivity was meant to be a measurable result. And it ought to be obtainable by analysing the carrier network and it is a continuously variable since it modify depending on airline network changes and airport infrastructure developments. Zaharia (2014) suggested that the airport connectivity has no formal definition, nevertheless he points out a simplistic definition by affirming that it is conventionally defined as the number of direct flights or number of destinations offered by a particular airport.

2.2.2 Connectivity Usages and Importance

The connectivity measures are described by Burghouwt *et al.* (2009) described as a quantification of the airline networks and the airports and regions performances. These measurements and values permit industry professionals and experts to monitor and benchmark the airline networks, airports and regions performances and compare it with previous results or competitors. SEO economic research (2016) pointed out that connectivity also can be used to monitor and assess the "impact of certain network changes, such as alliances, codeshares and better minimum connecting times (MCT)”. Also, connectivity analysis delivers the required evidence in order to develop improvement strategies for the airports’ competitive position (Burghouwt *et al.*, 2009). This judgement was supported by ACI Europe (2014) by stating that the airports network connectivity ought to be a key element of an airport business development plan. Furthermore, ACI Europe (2014) claimed that it was required an in-depth comprehension of its connectivity for both the management and economic team. Burghouwt *et al.* (2009) shared the same point of view by affirming that connectivity values allow airports, airlines and policy makers to control and handle the network performance over time and evaluate the impact of several procedures to preserve or boost network connectivity performance. Finally, Burghouwt *et al.* (2009) stated that connectivity is a significant factor for passengers when deciding its destination and carrier and the connectivity values should be required to be considered in airports’ disaggregated forecasts and business models. Homsombat *et al.* (2011) agreed with the previous article by affirming: “airlines tend to favour flying into large hubs thus that there will be more connection opportunities for passengers”.

2.2.3 Different Types of Connectivity

Burghouwt and Redondi (2009) recognised that the previous literature differentiates between two connectivity standpoints: direct and indirect connectivity or passenger accessibility and hub connectivity or airport centrality. On one hand, the drive of the passenger accessibility perspective is to assess the quantity and quality of direct and indirect connections at a particular airport as an origin. On the other hand, hub centrality purpose is to estimate the total connecting opportunities available for a specific airport. Rodríguez-Déniz *et al.* (2013) supported the previous article by affirming that hub-and-spoke networks contain two important indicators for hubs: connectivity and OD traffic generation. The connectivity indicator quantifies the importance of the "H" airport doing the function of a hub and connecting different city-pairs through the airport "H" while the OD traffic generation indicator gauge the importance of an airport as a traffic generator for the airport of origin "A" and airport of destination "B". In the same article, Rodríguez-Déniz*et al.* (2013) recognised "flow centrality" as the last important factor and its definition is to "measure the proportion of the total network flow that travels through airport H", therefore airport centrality and hub connectivity are described as the same concept.

There are different types of connectivity and they can be categorized in different ways. Burghouwt (2007) and SEO economic research (2014) followed the same types of connectivity values as the ones applied in the Netscan connectivity model. It is explained in the section 3.2.2 and it is applied for both passenger accessibility and airport centrality, as it can be seen in Figure 2-1. Goedeking (2010) only contemplated the passenger accessibility perspective and focus on direct and indirect connectivity. In Figure 2-1, direct connectivity is referred as the connectivity of a non-stop flight between two airports. Indirect connectivity is defined as the route between the airport of origin "A" and the destination airport "B" while connecting at a hub airport "H". Hub connectivity is established as the connectivity of airport of "A" to connect passengers from airport "B" towards airport "C". Finally, onward connectivity from airport "A" is the indirect connectivity following step since it consists of multiple airports "H" providing transfer flights to multiple indirect destinations. Onward connectivity is the sum of all the possible indirect connections.

ACI (2017) suggests a new type of connectivity, the airport connectivity. It is defined as the sum of direct connectivity and indirect connectivity. It affirms that is "the most comprehensive metric for airport connectivity".

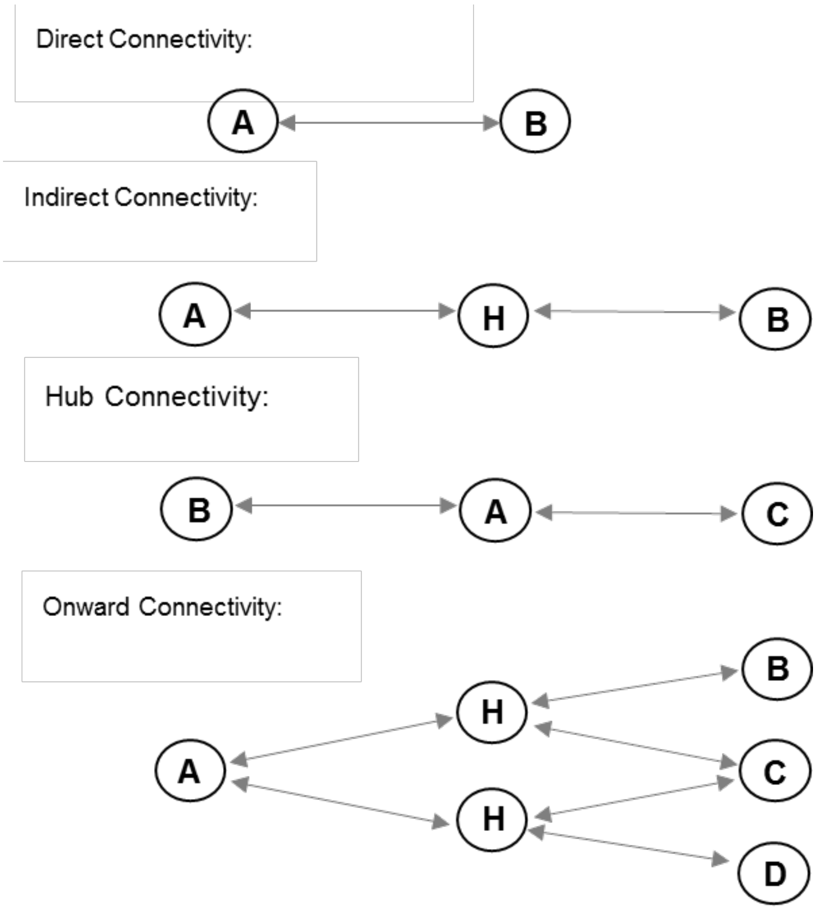

Figure 2-1 - Different types of connectivity

(Adapted from SEO economic research, 2014).

2.2.4 Methods to Determine Connectivity

Burghouwt and Redondi (2009) performed a detailed study of ten connectivity models. Two of them are subdivided, the shortest path length and the quickest path length, for accessibility and centrality. As shown in Table 2-1, there is a brief description for every possible model. The article also remarks that there are many variations of the mentioned connectivity models to add more complexity to the study.

Table 2-1 - Summary of connectivity models (Burghouwt and Redondi, 2009).

Model	Short Definition
Hub Potential	Incoming * outgoing frequency
Doganis & Dennis Connectivity	Number of connections. Indirect connections meet conditions of minimum and maximum connecting time and routing factor.
Bootsma Connectivity	Number of connections. Indirect connections meet conditions of minimum and maximum connecting time and are classified as excellent, good or poor.
Weighted Number of Connections (WNX)	Number of direct and indirect connections weighted by their quality in terms of transfer of detour time. (Continuous value)
Netsan Connectivity Units	Number of direct and indirect connections weighted by their quality in terms of transfer of detour time relative to a theoretical direct flight.
Danesi Connectivity	Number of direct and indirect connections weighted by their quality in terms of transfer of detour time. (Discrete Value)
Shortest Path Length Centrality	Number of connections of O-D quickest paths. The quickest path is the path involving the minimum number of steps from O to D.
Shortest Path Length Accessibility	Average number of steps to reach any other airport in the network.
Quickest Path Length Centrality	Number of connections lying on O-D quickest paths. The quickest path is the path involving the lower travel time from O to D.
Quickest Path Length Accessibility	Average travel time to reach any other airport in the network.
Gross Vertex Connectivity	Sum of all possible paths with three or fewer flight segments, weighted by a scalar value.
Number of Connections Patterns	Number of statistically significant patterns of incoming and outgoing flights.

Despite the existence of many models, there is not a specific model which is the most suitable for each situation, as the models are determined by the authors of the article and many models can fit the research objectives. Burghouwt and Redondi (2009) conclusions were that for brief and not specific analyses at an aggregate level, the hub potential and Doganis & Dennis models were the ones who adapted most to the situation while Netscan connectivity units' model was for a more detailed analysis. Bootsma connectivity and weighted number of connections is aimed for studies that focus on "local measures, continuous measurement of connection quality, impacts of flight schedule coordination on connectivity, individual Origin-Destination (OD) market level and connectivity of small airports" (Burghouwt and Redondi, 2009). The SPL and QPL are recommended for analysis who aimed to study routes with more than two stops in long-haul markets. The last model, the number of connection patterns is used for analysis that require recognizing conditions between statistically significant and non-significant patterns since it applies statistical conditions.

Arvis and Shepherd (2011) created a new method to measure connectivity named air connectivity index. The model consists on a "minimalist gravity model" based on four principles: realistic, intensive, dimensionless and global. Its model cannot be only based on a particular region, it requires and incorporates information of the full network. It measures key features of the total network, such as "its hub-and-spoke structure and the number and strength of flight connections" (Arvis and Shepherd, 2011).

2.3 Long-Haul Low-Cost Flights

LCC business model has been worldwide exported, with very prosperous cases in all the major markets. Low-cost airlines are short-haul oriented in almost everywhere. Nevertheless, the concept of LHLC flights was developed many years ago. The first person to seriously think about a potential LHLC carrier was Freddie Laker in 1971. He wanted to create an intercontinental carrier with low fares to travel from Europe to America with the name of Skytrain (Calder, 2002). Skytrain started its operations on September 1977 with a daily service between London Gatwick and JFK in New York with DC-10s. Skytrain had a really important success at the early stages due to the really low fares compared to the rest of airlines, but when the competition reduced its fares, they took back part of the market share and Skytrain finally went bankrupt in February 1982 (Calder, 2002). One year after the bankruptcy of Skytrain, PEOPLExpress tried to emulate the Skytrain model, in 1983. PEOPLExpress was a profitable domestic airline based in Newark, USA, and it operated transatlantic services from its hub to London Gatwick with a 747 aircraft, but it suffered from fierce competition with predatory pricing from other established transatlantic carriers, Newark capacity constraints and an excessive fleet expansion (Calder, 2002). At the end, Texas Air bought PEOPLExpress in 1986. After PEOPLExpress there was a time without European LHLC carriers, until Zoom Airlines launched in 2002. It was a LHLC carrier that operated flights from Canada to UK using high density seating in 757s and 767s. In 2006, Flyglobespan launched similar services with the same type of aircraft. Zoom Airlines declared bankruptcy in August 2008 due to the economic downturn of 2008, high fuel prices and from low demand and Flyglobespan in 2009 due to the same reasons (CAPA, 2009).

2.3.1 Actual Long-Haul Low-Cost Carriers

2.3.1.1 Norwegian

Norwegian Air Shuttle ASA, trading as Norwegian and with IATA code DY, started its operations in 1993 in Norway. In 2002, Norwegian became a low-cost carrier connecting Norway and other Scandinavian countries to European destination, changing its previous main strategy of being a regional carrier (CAPA, 2013). The airline established an extensive short-haul network and when it was consolidated, Norwegian started to operate LHLC flights. To start the LHLC operations, they created a subsidiary in Ireland named Norwegian Air International Limited with a new AOC and a new IATA CODE D8 to reduce its cost. In 2015, Norwegian opened a new subsidiary in UK with a new AOC and a new IATA CODE DI to benefit from the bilateral traffic rights of UK (CAPA, 2015).

The first long-haul routes started on May 2013 with 787-8s from Oslo and Stockholm to New York J.F. Kennedy International Airport. It is using a really efficient aircraft fleet composed of 787s giving the carrier a competitive advantage compared to its rivals (CAPA, 2017d). Norwegian, with the establishment of long-haul flights from Barcelona starting in June 2017 (CAPA, 2016), it will have long-haul flights from twelve different airports in Europe: Stockholm, Barcelona, Belfast, Bergen, Paris Charles de Gaulle, Copenhagen, Dublin, Edinburgh, London Gatwick, Cork, Oslo and Shannon. The destinations are mainly to USA such as New York JFK, Los Angeles, Fort Lauderdale, Newark, Boston, Hartford

Bradley, Orlando, Oakland, Providence and New York Stewart. But there are flights to other regions like Marrakech, Tel, Bangkok and Singapore (Sources: OAG).

2.3.1.2 LEVEL

International Airlines Group (IAG) announced on March 17th, 2017 that he was launching a new long-haul low-cost airline branded LEVEL based in Barcelona with flights to Los Angeles, Oakland, Buenos Aires Ezeiza and Punta Cana. The first flight was on June 1st, 2017 from Barcelona to Los Angeles. The aircrafts used for all LEVEL flights are two new A330 with a seat configuration of 293 tourist and 21 premium seats. LEVEL will have a traffic feeding from Vueling since they are from the same group. For this reason, LEVEL is based in Barcelona since it is where Vueling has its main base. Willie Walsh, IAG CEO, stated that "LEVEL is an exciting new IAG airline brand which will bring a stylish and modern approach to flying at prices that are even more affordable. It will benefit from having the strength of one of the world's largest airline groups behind it." (CAPA, 2017b). LEVEL fares started from €99, a really competitive price in the long-haul market. LEVEL expansions plans include opening bases in Rome Fiumicino and Paris Orly, as well as increasing the frequencies and destinations from Barcelona (CAPA, 2017a).

2.3.2 Viability of Long-Haul Low-Cost Business Model

The low-cost business model is attached to core principles and the two most essential are simplicity and OD demand. Both concepts are focused on revenue maximisation and cost reduction. All policies applied to reduce costs by LCCs in staff management, airport operations and high aircraft utilization and strategies to maximise the revenue such as high load factors, charge for everything extra and high seating density, follow from these two main principles.

The long-haul low-cost business model cannot meet all these policies and strategies and for these reasons it will not follow some of the core principles of the low-cost business model. The most critical principal to follow is the simplicity of the model. Long-haul flights require for a more complex crew training and management and the airport choice is more constrained since the OD demand should be higher or have an important short-haul network to connect everybody or have links with other airlines through alliances, ties-up or other types of agreements. Both solutions are opposed to the principle of simplicity. The aircrafts cannot have as high seat density as short-haul aircraft since there are requirements for entertainment and comfort on board. The segments in which the low-cost business model gain cost advantages represent a reduced fraction of the entire expenses. The historical European LHLC carriers have all failed due to the competition from FSC and consolidated carriers, fuel costs and the lack of necessary demand from targeted sectors of passengers.

But not everything is as bad as it looks for the future of European long-haul low-cost carriers like Norwegian or Level. EU established a policy about the prohibition of predatory pricing so the established carriers cannot compete arduously and reduce heavily its air fare (Rosenblatt *et al.* 2013). In terms of fuel costs, new generation of aircrafts are focused on reducing the fuel consumption and Tembleque-Vilalta and Suau-Sanchez (2016) affirmed that “the economics of new aircraft technology can indeed turn an unfeasible route into a feasible one”. New aircrafts like the 787 and A350 have more fuel efficiency and it has an important reduction on the total costs. Moreover, there are some airlines that have succeeded in implementing a long-haul low-cost business model in other parts of the world like Asia-Pacific (Morrell, 2009). Companies like Air Asia X and Cebu Pacific are good examples of it. Their structure and status as part of a bigger organisation, like LEVEL being part of IAG, or their big and well stablished short-haul flights, like Norwegian, provide them with solutions for traffic feeding issues. Moreover, fuel costs, which represent a big part of the total costs, cannot be reduced by LHLC carriers and they are compensated by severely decreasing other expenses and maximizing the income by establishing new sources of ancillary revenue. All profitable and viable LHLC carriers’ structure consist of a hybrid model that adapts the core LCC business model doctrines.

3 METHODOLOGY

3.1 Airport Selection

3.1.1 Conditions to Select Airports

The thesis aims to study the connectivity of the European second tier airports, as the title suggests. But before the thesis focus on the connectivity analysis methodology, it is important to define which airports will be studied. For this reason, it is important to define the conditions which will determine if an airport will be studied or not.

The first conditions are the ones specified in the scope of the thesis, 1.3. As the title specify, the thesis focus on European airports. But there is not a clear definition of what "European" means. The author considers the term "European" as the countries inside the European Union and EFTA. The countries currently members of EFTA are Iceland, Liechtenstein, Norway and Switzerland (EFTA, 2017). Then it is time to specify which airports are second tier airports. The author considers that there are only five first tier airports in Europe: London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, Frankfurt Airport and Madrid Barajas. The bottom limit is defined as 15 million passengers. The first airport after this limit is London Luton Airport, with 14.65 million, and London Luton Airport is not considered in the same tier as London Gatwick Airport and London Stansted Airport.

3.1.2 Final Selected Airports

After applying both conditions and searching for data of all potential selected airports[1], there are 24 airports that meet both criteria and will be studied in the connectivity analysis.

[1] (AENA, 2017; UK Civil Aviation Authority, 2017; ADV German Airport Statistics, 2017; Aeroports de Paris Group, 2017; ASSAEROPORTI, 2017; Copenhagen Airports, 2017; Dublin Airport Authority, 2017; Zurich Airport, 2017; AVINOR, 2017; Swedish Airport Statistics, 2017; Vienna Airport, 2017; Aeroportos de Portugal, 2017; Brussels Airport, 2017; Airport, 2017; FINAVIA, 2017; Geneve Aeroport, 2017; Prague Airport, 2017).

Table 3-1 – Selected Airports. (Source: Author).

Code	Airport	Country	Passengers
BCN	Barcelona El Prat Airport	Spain	44,154,693
LGW	London Gatwick Airport	United Kingdom	43,119,628
MUC	Munich Franz Josef Strauss Airport	Germany	42,261,309
FCO	Leonardo da Vinci Fiumicino Airport	Italy	41,744,769
ORY	Paris Orly Airport	France	31,237,865
CPH	Copenhagen Kastrup Airport	Denmark	29,043,287
DUB	Dublin Airport	Ireland	27,907,384
ZRH	Zürich Airport	Switzerland	27,666,428
PMI	Palma de Mallorca Airport	Spain	26,253,882
OSL	Oslo Gardermoen Airport	Norway	25,787,691
MAN	Manchester Airport	United Kingdom	25,637,054
ARN	Stockholm Arlanda Airport	Sweden	24,682,466
STN	London Stansted Airport	United Kingdom	24,320,071
DUS	Düsseldorf Airport	Germany	23,521,919
VIE	Vienna International Airport	Austria	23,353,016
LIS	Lisbon Airport	Portugal	22,449,289
BRU	Brussels Zaventem Airport	Belgium	21,818,418
TXL	Berlin Tegel Airport	Germany	21,253,959
ATH	Athens International Airport	Greece	20,017,530
MXP	Milan Malpensa Airport	Italy	19,420,690
HEL	Helsinki Airport	Finland	17,184,681
AGP	Malaga Airport	Spain	16,672,776
GVA	Geneva International Airport	Switzerland	16,532,690
HAM	Hamburg Airport	Germany	16,224,154

3.2 Calculation of Connectivity values

3.2.1 Election of Netscan Model

In this section, the reasons behind the election of the Netscan model will be presented and it will continue with the accurate method to use the Netscan model. This thesis aims to measure and evaluate both the current connectivity levels of the airports selected in the section 3.1 and the historical connectivity between the years 2009 and 2017 to be able to analyse the evolution in this period. Following the thesis objectives, a model is required that is able to perform an in-depth connectivity model. This factor excludes the hub potential and the Doganis & Dennis connectivity models, without market analysis that considers socioeconomically factors of the different regions. The study only focuses on direct flights and single indirect flights, meaning that only one stop in a hub airport is accepted and a maximum of two steps per route are considered. Bearing in mind all these previous considerations, the model which is the most suitable for this thesis is the Netscan model.

Netscan model was developed as an innovative technique to determine the competitiveness of an airport in comparison to other airports by Veldhuis (1997). Previous literature before mainly focused on the total number of passengers or aircraft movements as indicators to evaluate the rank of each airport, while the Netscan model from Veldhuis (1997) considered factors like connections quality and availability. The model utility and usefulness was defined by Suau-Sanchez and Burghouwt (2012) as a method that is able to measure connectivity from two standpoints: the passenger's perspective, which is measured when analysing direct and indirect connections, and the airport's perspective, which is measured when studying hub connectivity. Another vital factor to choose the Netscan model above any other one, is the proven applicability and ability to produce sound results of this model. This argument can be checked in different articles like Burghouwt *et al.* (2009) and Suau-Sanchez and Burghouwt (2012) and the connectivity performance of different airport over time was successfully achieved by both articles.

3.2.2 Netscan Model

As mentioned in 3.2.1, Veldhuis (1997) recognised that the passengers final decision in which airport does the passenger wants to connect is affected by the number of possible destinations and the conditions of the available alternatives. For this research, the conditions of the alternative destinations are quantifiable factors, like the number of frequencies and time of travel, which Netscan considers as significant for connecting passengers' options. Goedeking (2010) defined four criteria that the potential connection must satisfy to be, realistic, competitive and feasible:

- Detour
- MCT
- MAXCT
- Bidirectionality

The first criterion is the detour between the sum of both legs of the connection compared to the direct connection or the theoretical time the direct flight would take. Connections via a hub airport obviously induce a larger detour time than direct connections travel time. Detour was defined by Burghouwt (2007) as "the difference in travel time between a direct and indirect flight" and it is measured as a detour ratio. Goedeking (2010) also analysed passenger behaviour based on passenger booking data and the article conclude that passengers tend to accept greater detour ratios on short-haul flights, values ranging from 1.35 to 2.5, while there is less margin for detour in long-haul flights, with an acceptable detour ratio below 1.2.

The second criterion is the minimum connecting time (MCT). Every airport requires an amount of time to transfer an arriving passenger and its luggage to its departure flight feasibly and successfully. Taking this concept in consideration, any connectivity model should only do the potential connection if the time between the arrival flight and the departure flight is higher than the MCT. Dennis (1994) pointed out that the "level of MCT is broadly influenced by the airport's efficiency of processing both passengers and baggage". Every airport is required to publish updated MCT times, since they vary per airport and the nature of the connection. MCT's are different whether the connection is domestic-domestic, domestic-international, international-domestic or international-international. Goedeking (2010) considered other factors that affect MCT like the type of airline, the terminal composition and the final destination. He also affirms that regional or small airports offer smaller MCT than major hub airports. Suau-Sanchez *et al.* (2017) take in consideration the "self-connectivity" and they determined the MCT of this kind operation as the traditional MCT plus one hour.

The third criterion is the maximum connecting time. This condition is not related to any airports' issue, it is just a factor to point out that the connecting time is not too long for the passenger to reconsider that route. The MaxCT also has the purpose to be a time ceiling. Due to this fact, the difference between the MCT and MaxCT creates a time-lapse and the model only will consider the potential connections that can happen in that range.

The fourth and last criterion is the bidirectionality. The passenger should be able to have a return route to its origin airport with a considerable frequency in order to consider the route viable and feasible. Goedeking (2010) established this frequency at least one flight per week.

All the conditions mentioned are also integrated in Suau-Sanchez and Burghouwt (2012), but the article distinguished between two main conditions of the Netscan model: the connection quality and the availability of connections. The connections availability is the number resulting from the available direct connections plus the indirect ones to/from/through a particular airport. The quality of the connection quality is determined by establishing a quality index to each route, proper explained in the following section, 3.2.2.1.

3.2.2.1 Connection Quality

The obtainment of the connection quality is achieved by assigning a quality index to every indirect connection and that is in proportion of a theoretical direct connection quality. The mathematical formulae are explained on 3.2.3. The quality index only is assigned to indirect connections since direct connections have a connection quality of the unit. The indirect connection quality index ranges from 0 to 1 without being possible to have the exact value as 1 since the quality of indirect connections cannot be the same as direct connections. Detour and the subsequent transfer time are considered inconvenient for the travellers and it has the additional threat of losing the connecting flight or the loss of baggage, reducing the quality index. A null quality connection value will determine that the travel time is too long compared to the theoretical direct travel time or other factors are not acceptable, making the potential connection not feasible. The theoretical direct travel time is established with the origin and destination airports position on the globe and the assumed flight speed plus the time required for take-off and landing.

3.2.2.2 Connection Availability

The connection availability is the sum of direct and indirect connections from or to an airport if the study focuses on the passenger accessibility or the indirect connections through the airport if the airport centrality is being analysed. Direct flights can be obtained from flight schedule data. Achieving the indirect connections is not as immediate as the direct connections. Indirect connections are made by connecting two direct flights, one incoming and one outgoing, that follow the four criteria of Goedeking (2010), but with some alterations. The Netscan model algorithm builds indirect connections on operational criteria that make the connection viable. The major adjustment is on the MCT criterion. Goedeking (2010) defined that every airport has a particular MCT depending on the type of connection. In order to do the Netscan algorithm efficient, it is established one MCT limit for every nature of the connectivity for all airports. It is established a MCT of 30 min for the domestic-domestic and 45 minutes for the rest types of connectivity. The MaxCT condition is established as 480 minutes, 8 hours, and the maximum circuitry allowed, the routing factor of the great circle distance is 200. This means the sum of the distance of both flights is the double as the theoretical distance of the direct connection. Following all these criteria, it is possible to determine all the potential indirect connections. But there is another criterion based on the airlines. The potential indirect connection can only be considered if both flights are operated by the same carrier, labelled by OAG as online connections, between carriers from same alliance or with code-share agreements, labelled interline connections, or between all possible options.

3.2.2.3 Number of Connectivity Units

Once the connection quality and the connection availability are known, it is needed a value to be able to compare different airports. Netscan measures the number of connectivity units by doing the sum of all the products of the quality index of each possible route by its frequency. The obtained number is a close approximation of the total connectivity of the airport on the market studied and selected by the author.

3.2.3 Netscan Mathematical Definition

Once all the criteria are clear and how Netscan model works, it is time to explain the Netscan mathematical model. After the application of the following formulae, the outcome is the measure of the quality index, described in 3.2.2, and CNU value from a certain airport. Even though Netscan method was developed by Veldhuis (1997), the formulae was slightly modified by Burghouwt *et al.* (2009).

$$NST = \frac{40 + 0.068 * GCD\ km}{60} \quad \textbf{(3-1)}$$

$$MXT = (3 - 0.075 * NST) * NST \quad \textbf{(3-2)}$$

$$PTT = FLT + (3 - 0.075 * NST) * TRT \quad \textbf{(3-3)}$$

$$QLX = 1 - \frac{PTT - NST}{MXT - NST} \quad \textbf{(3-4)}$$

$$CNU = QLX * NOP \tag{3-5}$$

Where:

NST: Non-Stop travel Time (hours).

GCD km: Great Circle Distance (kilometres).

MXT: Maximum perceived travel Time (hours).

PTT: Perceived Travel Time (hours).

FLT: Flying Time (hours).

TRT: Transfer Time (hours).

QLX: Quality index of a connection.

NOP: Number of Operations.

CNU: number of Connectivity Units.

The NST time is the theoretical travel time of a potential non-stop route between two airports. It is measured by multiplying the GCD in kilometres between the airports of the OD city-pair and the inverse of the average flight speed plus the take-off and landing required average time. Then it is divided by 60 to get the result in hours, instead of minutes. It is used to compare the indirect travel time with the theoretical direct flight. The MXT is the travel time limit that a potential connection is believed to still be viable compared to the potential non-stop flight. The quality of the connection will be 0 if the PTT value is higher the MXT. The MXT is defined be three times the value of a direct flight, but the factor is reduced as long as the flight time increased. The PTT considers time of flight and transfer time as factors. The transfer time is multiplied for a factor to increase its value, due to the fact that passengers perceive transfer time as a loss of time. This consideration is what makes that indirect flights do not have a quality index of 1 since it is what make the travel time much higher than the NST. The final equation is the total number of operations inside one route per week multiplied by the quality index, which is determined by all previous factors, and the outcome is the CNU.

3.3 Data Obtainment

Once the airports are selected and the Netscan model is chosen and explained, it is time to get the data to run the previous formulae. This thesis studies the passenger accessibility and the hub centrality for the 24 chosen airports in 3.1 for the period 2009-2017. For these years, data is going to be obtained every two years: 2009, 2011, 2013, 2015 and 2017. A reference week is needed to be able to compare all years, and the chosen one is the third week of May. The moths which are similar to the average of the year are May and September. May was chosen in order to be able to have reliable data from year 2017. To get all this data, the OAG connections analyser database is used. Microsoft Excel is used to recollect and group all data obtained. It is also used to calculate CAGR (Compound Average Growth Rate) The study needs two different types of settings, one for the passenger accessibility and one for hub centrality.

The first setting created aims to get the data of the direct and indirect connectivity. Note that every OAG connections analyser has to be run for every airport and for every year. Direct and single options are selected for the trip type in order to select both connectivity types. The studied airport must be selected on the origin space and left blank the Gateway 1 and 2 since all the airport hubs are considered in this study. The other considerations have been previously explained. The first setting is:

- Trip type: Direct, single
- Type of operation: Operating flights, published carrier
- Carrier: Blank
- Origin: The studied airport
- Gateway 1: Blank
- Gateway 2: Blank
- Destination: Blank
- Equipment: Blank
- Equipment Group: Blank
- Connecting type: Online

- Max. Circuity: 200
- Service type: Passengers
- Restriction Rule: IATA
- MaxCT: 8 hours
- MCT: 30 min for domestic-domestic and 45 min for the rest.
- Phantom flights: No
- Period: 3rd week of May

The second setting is done in order to get the hub connectivity data. The major change is that the origin is blank and the studied airport is on the gateway 1 option. The gateway 2 option is still blank. The only selected option for the airport type is the single since two or more flights are needed for the availability of gateways. The second setting is:

- Trip type: Single
- Type of operation: Operating flights, published carrier
- Carrier: Blank
- Origin: Blank
- Gateway 1: The studied airport
- Gateway 2: Blank
- Destination: Blank
- Equipment: Blank
- Equipment Group: Blank
- Connecting type: Online
- Max. Circuity: 200
- Service type: Passengers
- Restriction Rule: IATA
- MaxCT: 8 hours
- MCT: 30 min for domestic-domestic and 45 min for the rest.
- Phantom flights: No
- Period: 3rd week of May

It is important to remark that the Max. Circuity value in this study is considerably high. There are two main reasons behind this decision. On one hand, it is to make sure that all possible connections are incorporated. Since the Netscan model has a quality index, the value will be 0 if the circuitry is too high and most routes will be unattractive, but for some routes the quality index will be positive, meaning that the route is feasible. On the other hand, it is due to the fact that the selected airports in the 3.1 are second tier airports. They are not regional airports, but the number of direct connections of the selected airports is not as big as the top European hubs. If the OD city-pairs are not inside the catchment of important airports, the passengers are more pleased to accept bigger circuity.

3.4 Long-Haul Low-Cost Phantom flights

Once the connectivity of the 24 airports is studied and its evolution through the period 2009-2017, the thesis aims to study the effects that the LHLC flights will produce on the European second tier airports. As explained in 2.3.1, Norwegian and IAG, with the creation of LEVEL, have invested a lot of resources in order to develop successful long-haul low-cost carriers. Even though both LHLC carriers are still in the initial stages in this type of operations, the early results are very promising for both companies and they both have ambitious expansions plans. Norwegian started its long-haul operations from Barcelona in June 2017 (CAPA, 2016) and it has planned to launch three now long-haul routes from London Gatwick to Denver, Seattle and Singapore starting in September 2017 (CAPA, 2017e). LEVEL started its operations in June 2017 and it is already planning on expanding to two other airports like FCO and ORY in 2018. The early positive results from LEVEL has made possible to increase the frequency on the Barcelona – Buenos Aires Ezeiza route from three to five times a week, starting on 29th October 2017 (CAPA, 2017c).

3.4.1 Creation of Long-Haul Low-Cost Phantom Flights

In order to be able to establish and determine how the long-haul low-cost operations are going to affect and modify the connectivity of the 24 selected airports. One big issue appears when it is time to obtain the data of the long-haul low-cost flights. The data to do the current connectivity analysis and its evolution through the period 2009-2017 is obtained in the 3rd week of May since May and September are the months which are similar to the average of the year and, as explained in 2.3.1, LEVEL started its operations on the 1st of June of 2017 and Norwegian also started its operations from Barcelona in June 2017. This means that if we evaluate the LHLC flights in the same period as the previous connectivity analysis, LEVEL and flights from Norwegian in Barcelona cannot be taken into consideration. May 2018 cannot be taken into consideration since schedules are not reliable before nine months to the date of the flight because airlines can modify its own schedule. Another point is that this thesis aims to study the connectivity of LHLC operations in the short-term since the long-term of LHLC flights depends on too many variables and it would require a forecast. Doing a forecast is out of the scope of this thesis.

For these reasons, it is decided that the chosen phantom flights will be the ones that Norwegian and LEVEL have scheduled for the third week of August. The number of flights that are operated for Norwegian and LEVEL in August can be considered as the possible scenario that the LHLC routes and frequencies will have as an average in the short-term. Some routes scheduled in August were already operated in May 2017 and these flights will not be created as phantom flights, they only will be included if there is any variation on their schedule or their frequency. The data to create these phantom flights of Norwegian is extracted from the OAG Schedules Analyser database. The LEVEL phantom flights will be added manually. The setting that are in the capacity report established are:

- Date: Week – 14th August 2017 – 20th August 2017.
- Types of Flights: Operating flights, published carrier and non-stop.
- Carrier Name: D8, DI & DY.

- Origin: Region – EU1 (Western Europe) and EU2 (Eastern/Central Europe).
- Destination: Add Exclusion – Region – EU1 (Western Europe) and EU2 (Eastern/Central Europe).
- Equipment: Blank.

3.4.2 Addition of phantom flights to the connectivity analysis.

The OAG Schedules Analyser database gives all the scheduled flights within these limits, but the study only is interested in the flights departing from our selected airports. There are six airports that meet both criteria, which are ARN, BCN, CPH, DUB, LGW and OSL. The final phantom flights with all its detailed specifics can be found in Appendix A.

Once the phantom flights are created, it is time to add them with the previous data from the 24 selected airports. The thesis wants to study how the passenger accessibility connectivity as well as the hub centrality in the 24 selected airports will be modified since the implementation of the long-haul low-cost flights. To accomplish this objective, the study needs to run again the OAG connections analyser database with both settings of 3.3, but with one modification. In both settings, the phantom flights option is disabled and it is needed to be accepted for both. Previously, it is needed to enter into the OAG database all the phantom flights, detailed in Appendix A. To do this procedure, it is necessary to go "My OAG", then to "Customize" and after "Phantom Flights". Finally, it is necessary to submit all phantom flights in .csv or enter them manually.

4 RESULTS & DISCUSSION

4.1 Budget Summary

All hypothesis considered for the budget of this thesis are detailed in the budget document. The total costs estimated for this thesis amount 15,820 euros.

Table 4-1 – Budget (Source: Author).

Personnel costs	Hours	Cost per hours (euros)	Cost (euros)
Student	300	25	7,500
Director	20	100	2,000
Total Personnel costs			**9,500**

Non-personnel costs	Cost
OAG license	5,000
Microsoft Office license	120
Laptop amortization	300
Office leasing	900
Total Non-Personnel costs	**6,320**
Total Costs	**15,820**

4.2 Connectivity Analysis for 2017

4.2.1 Direct Connectivity

The first type of connectivity analysis is the direct connectivity. Direct connectivity measures the number of operations and frequencies to the different destinations that a particular airport offers. As shown in Figure 4-1, the European second tier airports have a direct connectivity where most of them varied in the range of 1,500 to 2,500 CNU and the total average is 2169.6 CNU. The airport with higher direct connectivity is MUC, with 4008 CNU, and the airport with lower CNU value in terms of direct connectivity is AGP with 1283. MUC has a direct connectivity three times higher than AGP.

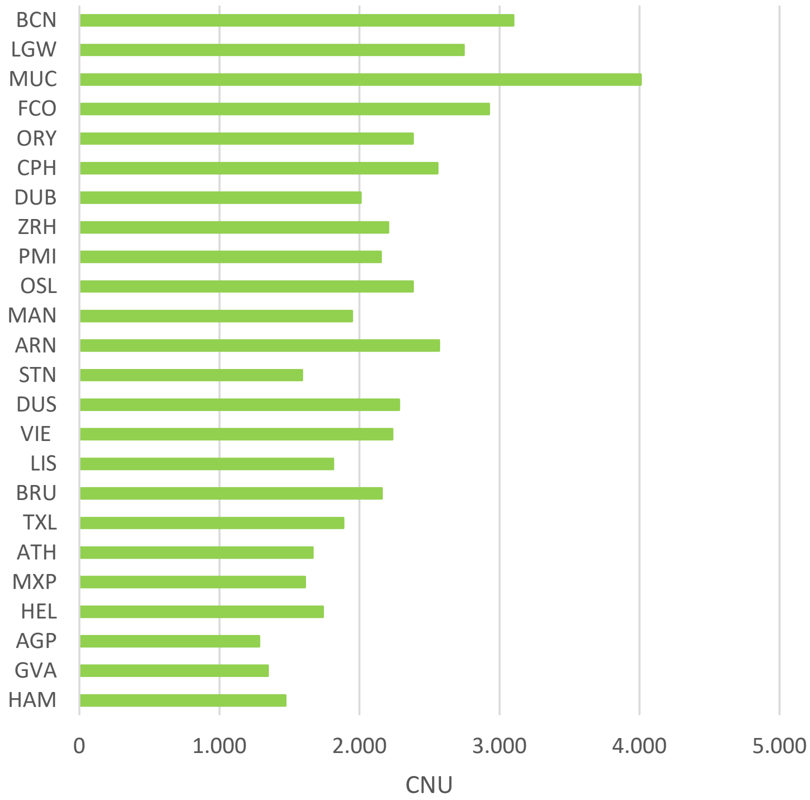

Figure 4-1 - Direct connectivity for the reference week of 2017

(Source: Author's based on OAG Data).

The airports are ordered following the number of passengers they had on 2016, detailed in the section 3.1.2. For this reason, it can be noticed a trend where the airports at the top have a higher direct connectivity than the low bottom. The first quartile, the first six airports, average a direct connectivity of 2953.25 CNU while the last quartile average is 1519.5 CNU. The top 6 airports almost double its direct connectivity compared to the last six. In terms of number of passengers, the top 6 airports had an average of 38,593,592 passengers in 2016, more than double compared to the last 6 airports, that they average 17,674,420 passengers.

4.2.2 Airport Connectivity

As detailed in subsection 2.2.3, airport connectivity is the sum of all the direct and indirect connectivity (ACI, 2017). It is the most comprehensive metric for airport connectivity and represents the global picture of the passenger accessibility from a particular airport. With the airport connectivity and direct connectivity, it is possible to determine the indirect connectivity. The Figure 4-2 represents the airport connectivity for the selected airports. The European second tier airport with a better passenger accessibility is Munich Airport, followed by Fiumicino and Barcelona. Munich Airport has an airport connectivity of 8700 CNU, which means that its indirect connectivity is higher than its direct connectivity, 4008 CNU from previous subsection. Fiumicino with an airport connectivity of 7722 CNU and its direct connectivity of 2925 CNU, is the airport with more indirect connectivity with 4797 CNU. It can be seen that airports with an important hub in the same city and they are relegated to be a secondary airport of the city, like LGW, ORY and STN, have a relatively low airport connectivity compared to other second tier airports. While LGW and ORY have a medium-high direct connectivity, their indirect connectivity is low. While these three airports average an indirect connectivity of 456.9 CNU, the rest airports average 2559.5 CNU, more than five times higher. This is due to the fact that big hubs like LHR and CDG attract almost all FSC carriers and secondary airports are relegated to be used by LCC carriers. LCC carriers like EasyJet or Ryanair do not offer transfer flights to its passengers since they work with point-to-point networks. For this reason, they cannot be considered for indirect connectivity. Airports who are really LCC oriented like PMI and AGP are also affected by the same situation. The airport connectivity has a bigger difference between the first and the last compared to the direct connectivity. MUC has a direct connectivity three times higher than AGP, but MUC airport connectivity is more than five times higher than STN.

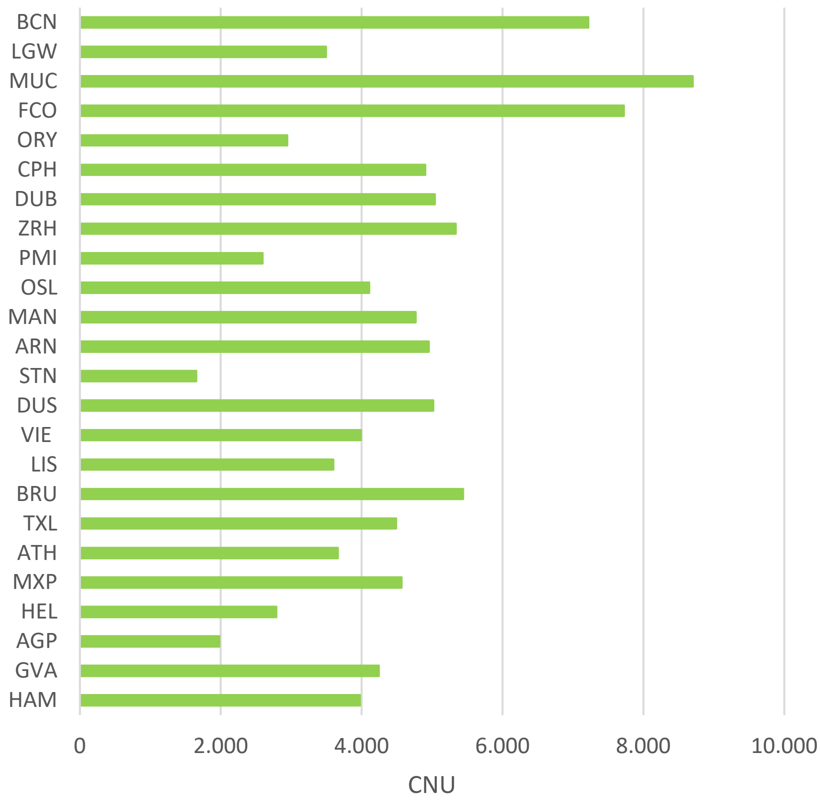

Figure 4-2 – Airport connectivity (direct + indirect connectivity) for the reference week of 2017

(Source: Author's based on OAG Data).

Another graph to explain the passenger accessibility is the Figure 4-3. It represents the direct and the indirect connectivity on both axes. Three groups can be differentiated from the Figure 4-3. The first group has the three airports with biggest indirect connectivity. The second group includes most airports and the last group includes the airports commented on the previous graph as the ones with low indirect connectivity plus Helsinki Airport. The first group has the airports with more direct and indirect connectivity of all. There is a wide gap between these airports and the rest. The airports from the bottom group are the ones affected by being secondary airports from cities with big hubs and airports with primarily LCC carriers. The reason why HEL is in the third group is due to the fact that it has a reduced number of frequencies to the major European hubs compared to the rest of airports. Suau-Sanchez and Burghouwt (2012) state that second tier airports really benefit from their frequencies to major hubs to boost their indirect connectivity. Table 4-1 shows the frequencies to the major hubs from representative airports of each group. The results of Table 4-1 validate Suau-Sanchez and Burghouwt (2012) affirmation. All three airports from first group have more than 100 flights weekly to the major hubs. Having much more frequencies than the airports from other groups. The airport representative from third group, HEL and LGW, are the ones with fewer frequencies. HEL is not near a major hub and it is not an airport primarily used by LCC, but he has much fewer frequencies compared to the airports from second group. BRU has the same frequencies as LGW, but BRU is the primary airport of Brussels and it has many FSC carriers flying to it since LCC mainly use Charleroi Airport.

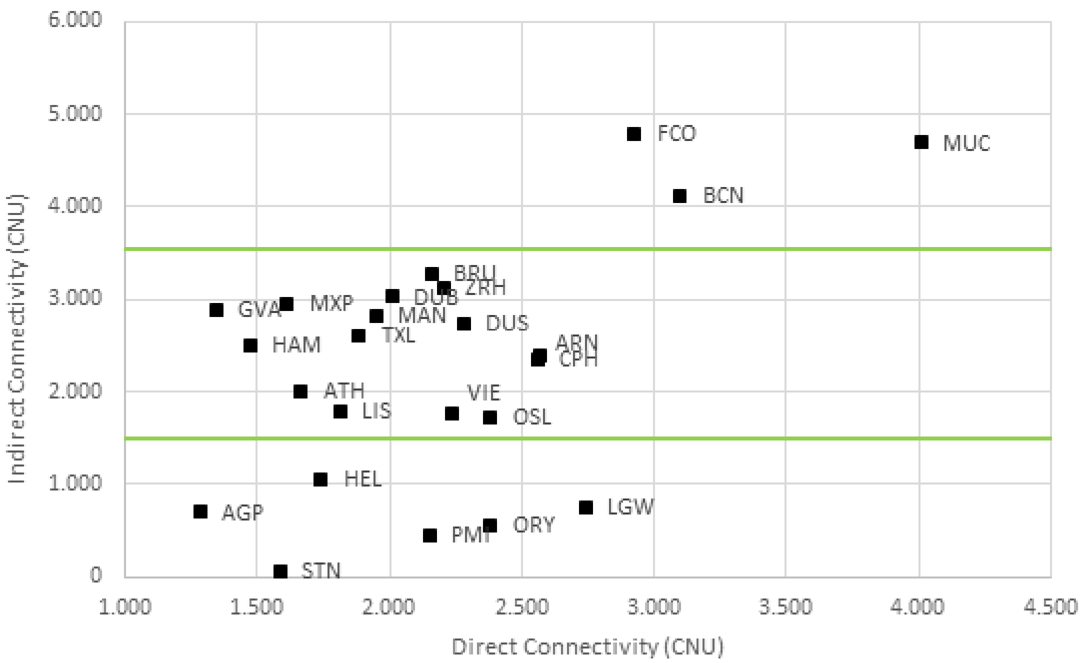

Figure 4-3 – Indirect connectivity compared to direct connectivity

(Source: Author's based on OAG Data).

Table 4-2 Frequencies to European hubs.

(Source: Author's based on OAG Data).

Flights to Hubs	AMS	CDG	FRA	LHR	MAD	Total
MUC	33	44	48	42	18	**185**
FCO	27	25	16	19	22	**109**
BCN	24	29	10	10	74	**147**
BRU	11	5	17	18	20	**71**
VIE	26	17	33	17	9	**102**
OSL	24	10	17	28	2	**81**
HEL	16	13	15	17	2	**63**
LGW	39	10	0	0	22	**71**

4.2.3 Hub Connectivity

Once the passenger accessibility is explained, it is time to focus on the airport centrality. As it can be seen in Figure 4-4, the results of the airport centrality are different from previous graphs. MUC has a big hub connectivity, with a value of 12861.04 CNU. It is more than three times its direct connectivity and 2.5 times its direct connectivity. These values are similar to the major European hubs' figures, as it will be shown later. The following airports are ZRH, HEL, VIE and FCO that they vary in the range of 4,000 to 7,000 CNU, but far from MUC. All these five airports have a FSC based at them, but Lufthansa, the biggest FSC in Europe, is based as his second hub in MUC. 7 airports, PMI, MAN, STN, MXP, AGP, GVA and HAM, have almost no hub connectivity since they do not have any major carrier established at their airport that it is not a LCC. It is also remarkable that major airports like BCN, LGW and ORY, which were in the top 5 of number of passengers, have low values of hub connectivity. ORY and LGW have a reduced value for the same reason they had a small CNU for the indirect connectivity. BCN has a considerable share of FSC on their schedule, but they are not based at the airport. They just fly to BCN due to the big OD market from the city.

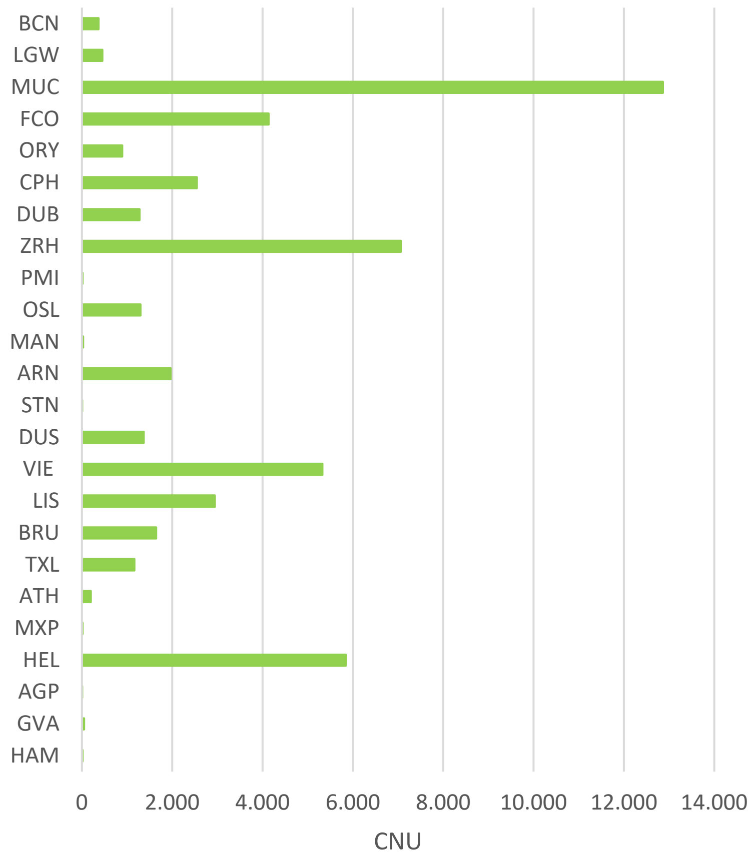

Figure 4-4 – Hub Connectivity for the reference week of 2017

(Source: Author's based on OAG Data).

As it can be seen in Figure 4-5, MUC has a really significant difference over the European second tier airports. It is close to double the second airport, ZRH, in the terms of hub connectivity and it has close to 1000 CNU more than the second airport, BCN, in terms of direct connectivity. For this reason, Figure 4-6 is done. A clustering is done in order to set the airports into different groups in reasons of similarity of direct and hub connectivity values. This clustering will be used in all the further study to analyse different topics in reduced groups. There are airports that are not considered in any cluster, MUC, FCO and LIS, because their conditions do not fit in any group and they will be treated separately. The cluster is shown in for a better clarity.

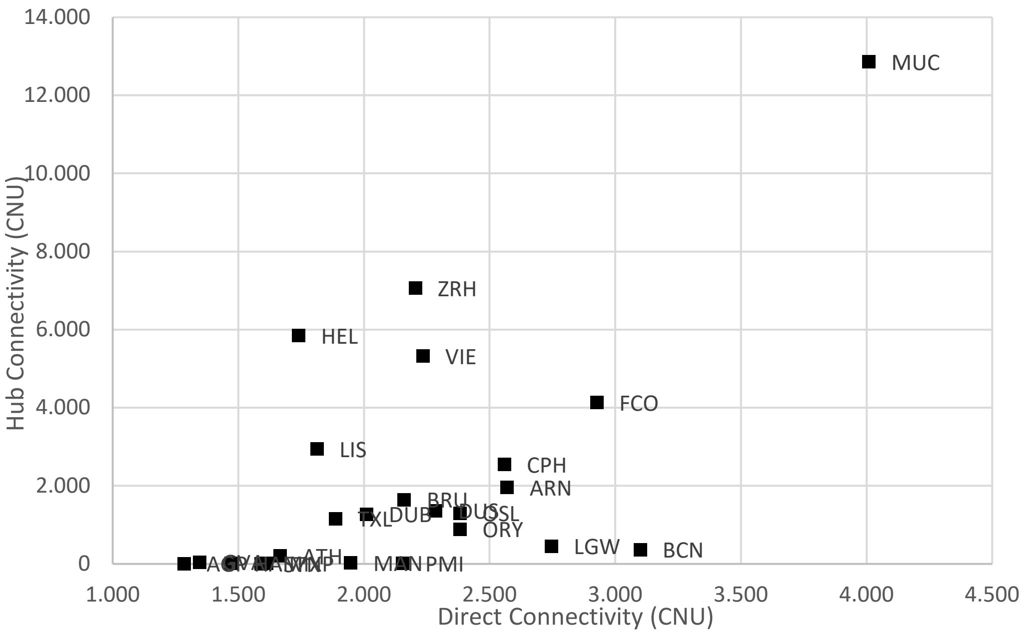

Figure 4-5 - Hub connectivity compared to direct connectivity

(Source: Author's based on OAG Data).

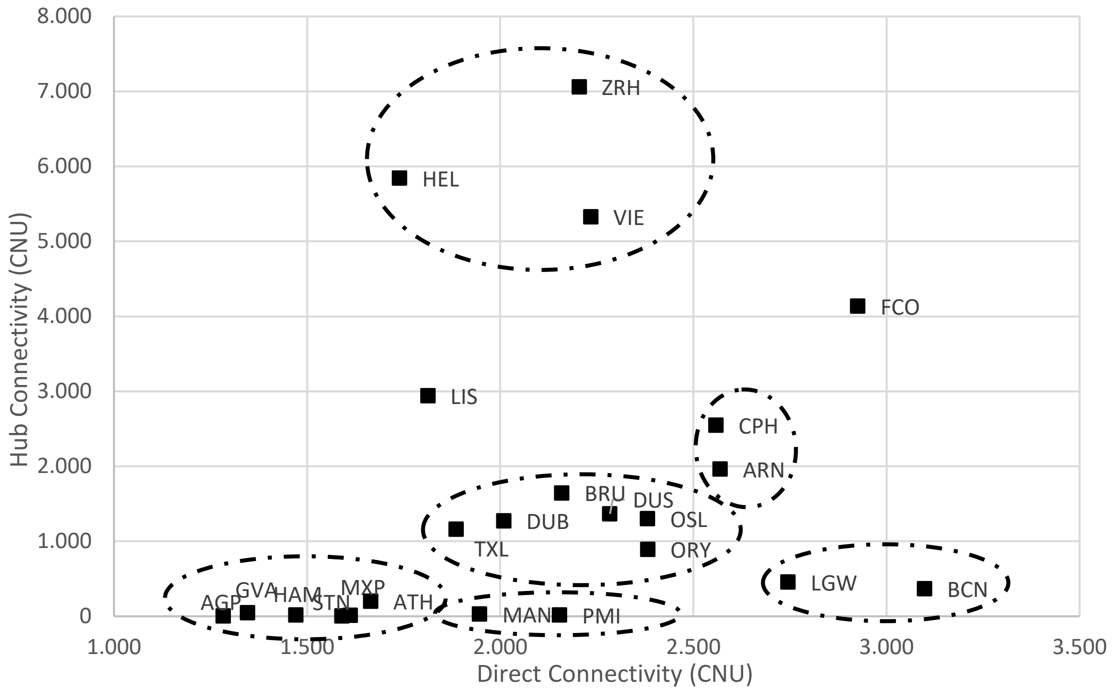

Figure 4-6 – Figure 4-5 excluding MUC

(Source: Author's based on OAG Data).

Table 4-3 – Clustering of Airports (Source: Author)

Class	1	2	3	4	5	6	7	8	9
Airports	MUC	FCO	BCN	CPH	ZRH	ORY	PMI	LIS	ATH
			LGW	ARN	VIE	OSL	MAN		MXP
					HEL	DUS			STN
						BRU			HAM
						DUB			GVA
						TXL			AGP

4.2.4 Major Airlines

Once the passenger accessibility and airport centrality are studied, the thesis will analyse the top airlines that use the selected airports. The results are shown in Figure 4-7, for both Frequencies and ASK. Both factors are studied since they offer distinct perspectives to the dominance of the major airlines in the market of European second tier airports. The frequencies ranking is in relation to direct connectivity. The greater number of frequencies relates to more direct connectivity since the connectivity is not affected by the distance of the flight. The ASK ranking shows the airlines with more passenger carrying capacity. While ASK has a linear relation to the direct connectivity, it also affects the indirect connectivity since the long-distance flights increase the possible hub airports to connect and it increase the number of final destinations. It is seen that Ryanair and EasyJet are in the top position for both frequencies and available seat kilometre top 30 ranking. They are the biggest LCC in Europe and Ryanair is the largest airline in the continent by number of passengers (Airports in Europe, 2017). They are followed by Lufthansa, the first FSC in the list. On one hand, the frequency ranking includes more LCC airlines than the top 30 ASK carriers and they have more predominance. LCC carriers like Germanwings, Flybe and Transavia are in the frequency top 30 while they are not in the ASK ranking. Other LCC carriers, like Vueling and Eurowings, drop positions and importance when compared to the other ranking. On the other hand, the top 30 carriers by ASK to reveal more importance of full-service carriers, especially the foreign full-service carriers. The three major airlines from USA and the Middle East (Delta, American, United, Emirates, Qatar and Etihad) are all on the top 30 ranking by ASK and they are not on the frequency. The biggest alteration in position is done by Emirates, it is not on the frequency ranking, but it is on the sixth position on the ASK ranking. British Airways, Air France and KLM are far from Lufthansa since they do not have any principal hub on any of the selected airport, while Lufthansa has its second hub in MUC.

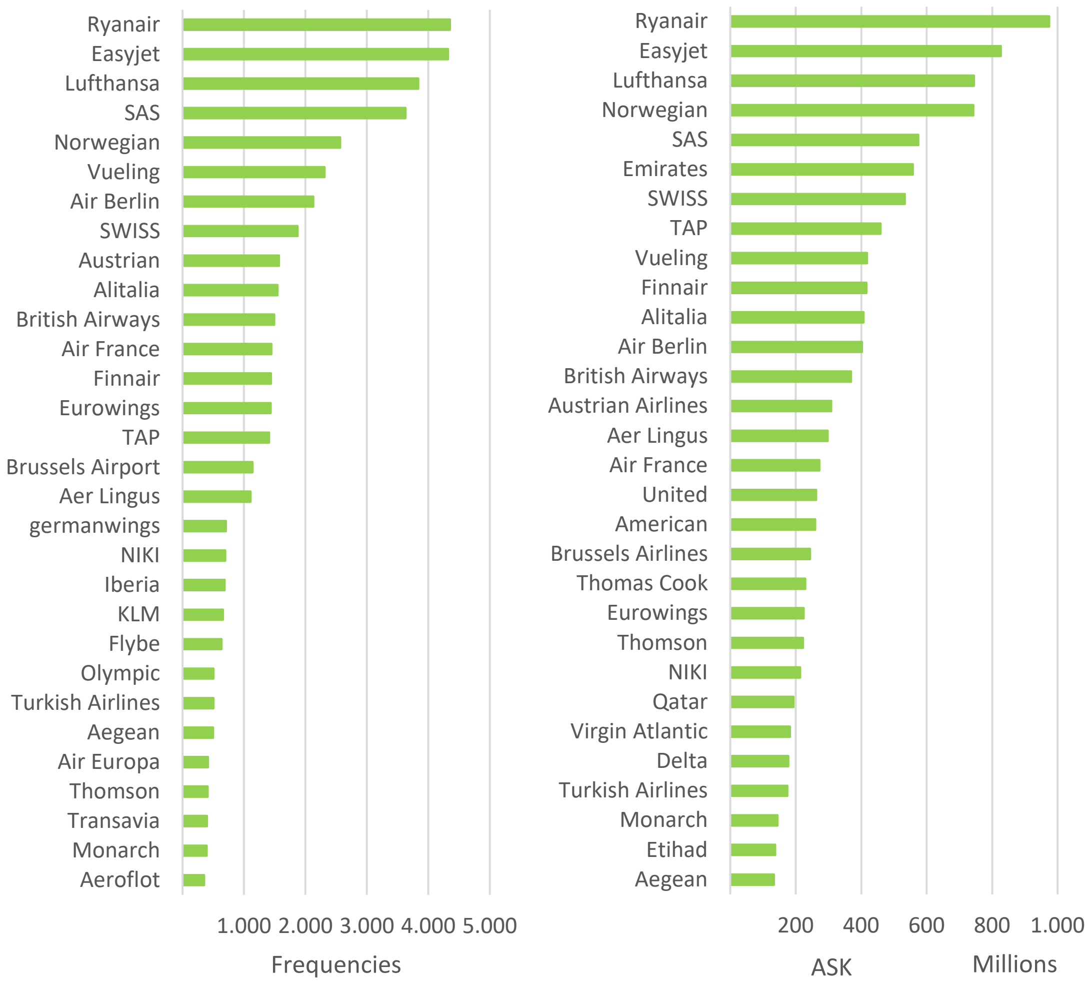

Figure 4-7 – Airlines ordered by frequencies and ASK the reference week of 2017 (Source: Author's based on OAG Data).

4.2.5 Principal destinations

To finish the connectivity analysis for 2017, the major destinations are analysed for the selected airports. Figure 4-8 represents the ratio of flights to other European destinations compared to the total frequencies the airport has. The European second tier airports are primarily focused on having intra-European frequencies. Most airports have over 90 percent of flights to other European airports and some of them like PMI, AGP, STN or HAM almost exclusively have intra-European operations. Airports like ORY, FCO and MXP are the ones with fewer flights to other European airports and they still have more than 80% of them. There is a total of 52895 flights on the third week of May from the selected airport and 48474 are to inside EU, which represents 91.64%. It is also noticeable that airports from the North of Europe have higher ratio compared to the ones in southern countries.

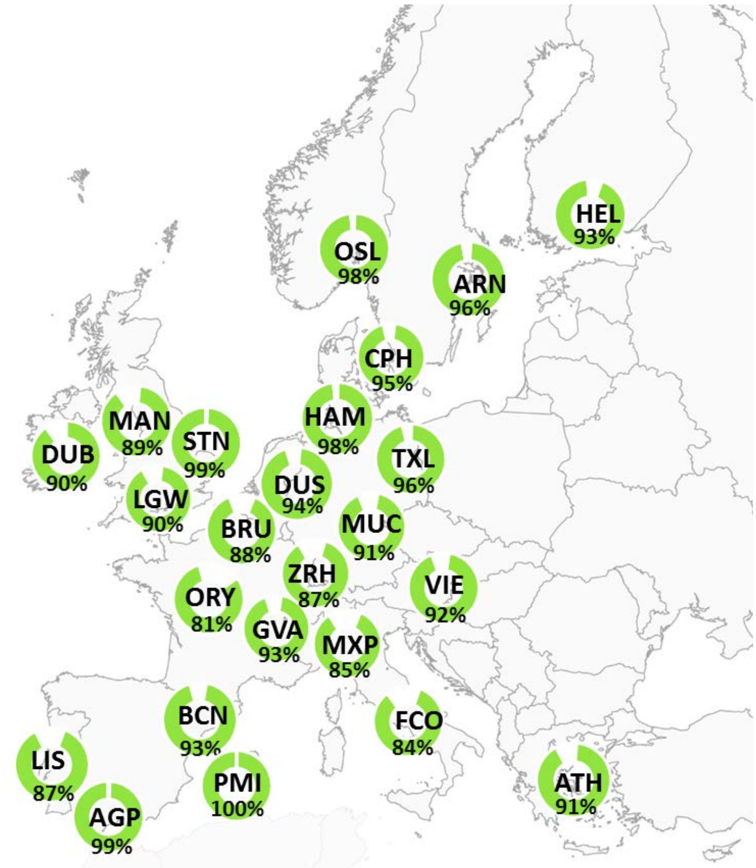

Figure 4-8 – Ratio of European destinations by selected airports

(Source: Author's based on OAG Data).

Figure 4-9 represents the proportion of flights to other regions from the selected airports and it implements a scale to show the number of frequencies to outside Europe. It is complemented with the Figure 4-8 since the values from the following graph represent the portion that is left to achieve 100% on the previous one. It is noticeable that Oceania is not represented in the graph since there is no direct flight to the region from any of the airports. The airports with more flights to other regions are FCO and ORY, with 471 and 459 each, followed by MUC with 375. ZRH with 305 flights is the last airport in the group of over 300. On one hand, FCO, MUC and ZRH have a similar distribution of flights. Flights to North America and Middle East represent around 60% of the flights, with a low proportion of flights to Latin America and the rest is distributed between Africa and Asia, with the Asian market having slightly more impact.

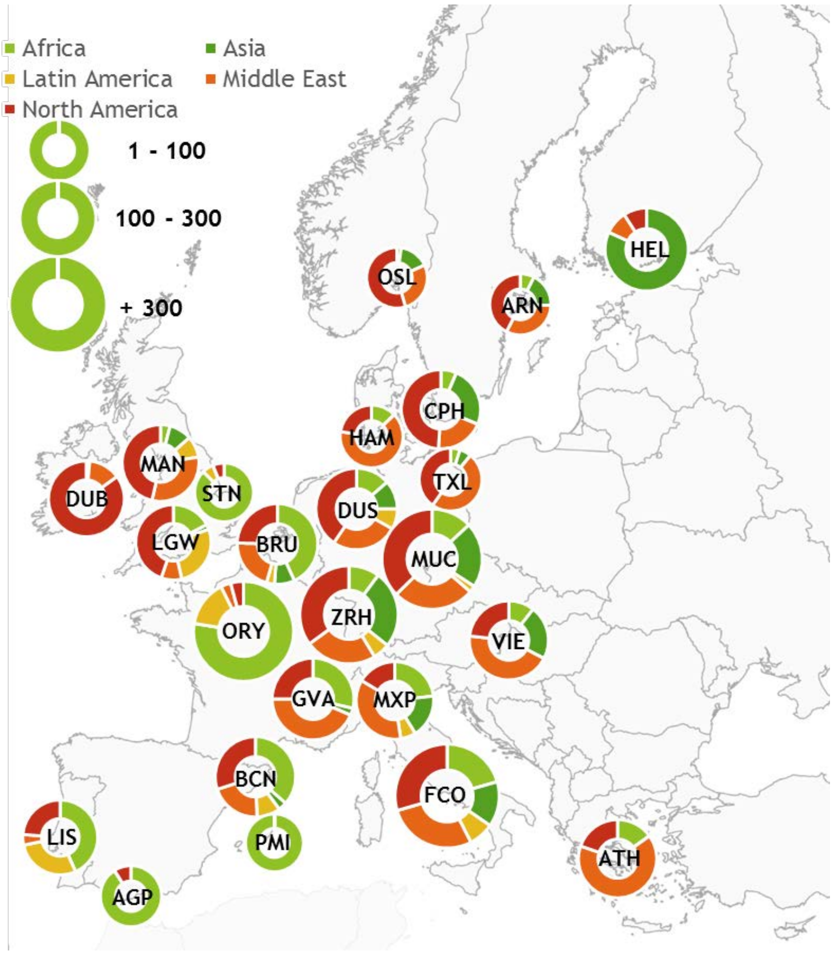

Figure 4-9 – Destinations per region and number of flight outside Europe

(Source: Author's based on OAG Data).

On the other hand, ORY has 77.6% of its flights to the African continent and 15% to Latin America. The other regions have marginal portions of the flights outside Europe from ORY. Many African countries have historical links with France due to the colonialism and France has overseas departments in Latin America in Guiana, Guadeloupe and Martinique. France keeps and have economic interests and social relations to make these routes still available.

The second group are most of the selected airports. LIS is in a comparable situation as ORY in terms of proportions since the Portugal and Paris have similar history in terms of colonialism. All airports between 100 and 300 frequencies, excluding HEL, have most of its flights to Middle East and North America and the sum of both market shares range from 50%, in BCN or BRU, to 99% like DUB. HEL almost exclusive have frequencies to Asia since it is very well connected to the Asian market and its location makes the airport an efficient option as a hub airport between EU and Asia. It is noticeable that the number of frequencies to other regions for each airport varies depending on their position in most cases. Airports located at the western countries have more market share of North America than the eastern Countries and southern airports have more flights to Africa than the northern ones. ATH, VIE or MXP have high portion of Middle East frequencies since they are in the south-eastern part of the selected airports. Asia flights are also affected by this trend since as most the airport is located at the east, more Asian market share it has. At last, the third group of airports are the ones who almost exclusively had intra-European flights. PMI had a 100% share of intra-European flights because it only has 1 flight to Africa. HAM, TXL, OSL and ARN have similar market shares and their flights to other regions are almost focused on Middle East and North America.

4.2.6 Difference between top tier hubs and second tier hubs.

After knowing the results for the different sections of the connectivity analysis for 2017, it is clear that some airports have better performance on the overall picture than the rest of the airports. MUC is the second-tier airport with better connectivity since it is in first place in direct, airport and hub connectivity and second in indirect connectivity. BCN has a good connectivity in terms of passenger accessibility, it is second in direct connectivity and third in indirect and airport connectivity. FCO has also very good results in terms of passenger accessibility. It is third in direct connectivity, second in airport connectivity and first in indirect connectivity. It also has quite good airport centrality results, being fifth in terms of hub connectivity. ZRH has decent values in passenger accessibility since it is fifth in indirect and airport connectivity, but it has satisfactory results in hub connectivity, being second and just below MUC.

MUC, BCN, FCO and ZRH are the airports with better performance compared to the European second-tier airports, but it is unclear how they perform compared to the top European hubs. This subsection aims to show the difference between the major European hubs and the top second tier airports. Figure 4-10 represents the hub connectivity and the direct connectivity on both axis and it analyses 9 airports. The four second tier airports with better performance and the major European hubs. It is clear that there is a considerably big margin between both tiers. BCN and FCO should increase by 50% its direct connectivity and ZRH by over 100 % to have similar values than the major European carriers.

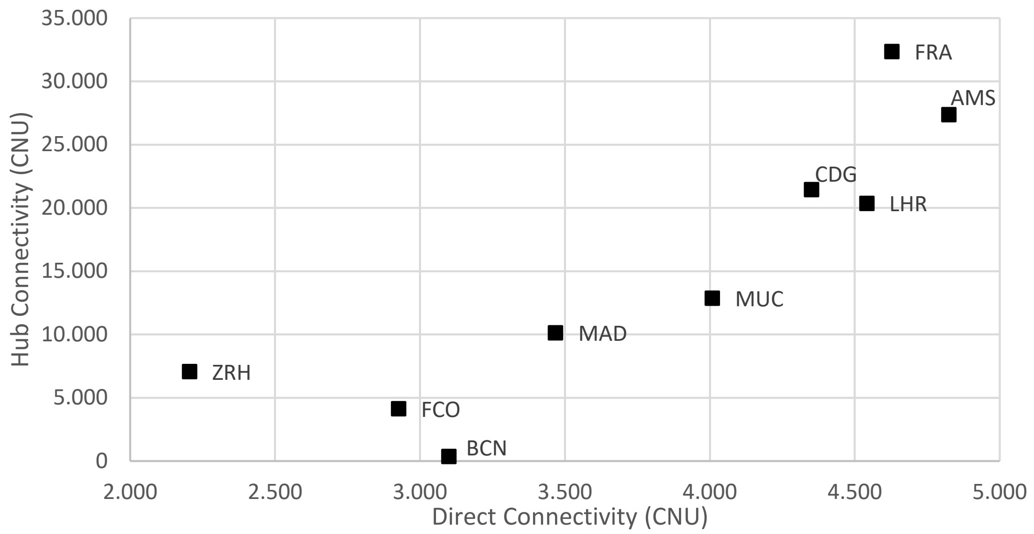

Figure 4-10 – Comparison between major EU hubs and second tier airports (Source: Author's based on OAG Data).

But the main difference between both types is on the hub connectivity. Top European hubs are the main bases the major FSC and for this reason, its hub connectivity is really high compared to the second-tier airports like BCN, FCO and ZRH. The only airports who are close to each other from different categories are MAD and MUC. MUC has better direct connectivity and hub connectivity than MAD. This is due to the fact that Lufthansa, which has its second hub in MUC, is much bigger and has more passengers than Iberia, with its main hub in MAD (Airports in Europe, 2017). Another important factor is their location. On one hand, Munich is in the relatively centre of Europe, making it easier for other European citizens to connect there to go to almost all regions. On the other hand, Madrid is located in the south-west of Europe, which induces in high detours to connect in Madrid to eastern regions for EU citizens. For this reason, Madrid is specialized in connections to Latin America. Even though MUC has better performance than one of the major European hub, it is still a second tier hub since MUC must be compared with FRA since they are from the same country and Lufthansa has its hub in both. Nowadays, MUC is far from FRA since FRA has 2.5 times more hub connectivity than MUC and over 600 CNU in direct connectivity.

4.3 Evolution of Connectivity for the period 2009-2017

Once the connectivity analysis has been done for the year 2017, it is time to study the evolution of the selected airports. The studied period will be from 2009 to 2017. Table 4-3 shows the evolution of the diverse types of connectivity values for the whole European second tier airports' market. It is possible to see a growing trend during this period. The direct connectivity of the selected airports has grown 19.02% during all period while the hub connectivity has a growth rate of 31.65%. The type of connectivity type which grows more is the indirect, a 43.17%. The year with more growth was 2011, with the connectivity values having an average growth of 8% CAGR. 2013 had a major decrease except for the indirect, who had a light increase of 1.33%. 2015 and 2017 had a considerable growth, but not as high as 2011, since they don't achieve two-digit growth.

Table 4-4 – Connectivity for the period 2009-2017

(Source: Author's based on OAG Data).

Connectivity	2017	2015	2013	2011	2009
Direct	52,070	49,413	46,146	48,620	43,749
CAGR	2.65%	3.48%	-2.58%	5.42%	-
Indirect	55,119.24	49,695.11	45,430.89	44,250.25	38,500.03
CAGR	5.32%	4.59%	1.33%	7.21%	-
Hub	51,444.56	47,379.93	43,188.86	51,551.12	39,076.96
CAGR	4.20%	4.74%	-8.47%	14.86%	-
Airport	107,189	99,107.96	91,575.74	93,870.51	82,248.91
CAGR	4.00%	4.03%	-1.23%	6.83%	-

4.3.1 Munich Airport, Rome Fiumicino Airport and Lisbon Airport

MUC, FCO and LIS are the only airports that cannot fit in any of the clusters, as detailed in Table 4-2. For this reason, its evolution is explained in the same subsection. MUC, shown in Table 4-4, evolution is similar to the whole European second tier markets. It is remarkable the indirect connectivity growth MUC had in 2011, almost doubling the growth of the market. 2013 had important decreases as the average. The growth in 2015 and 2017 is below average and it had an important decrease in hub connectivity in 2015. As bigger the airport is, the growth rates are smaller since it means higher increases.

Table 4-5 – MUC Connectivity for the period 2009-2017

(Source: Author's based on OAG Data).

MUC	2017	2015	2013	2011	2009
Direct	4,008.53	3,705.27	3,647.42	3,924.32	3,569.73
CAGR	4.01%	0.79%	-3.59%	4.85%	-
Indirect	4,691.92	4,074.64	3,679.23	3,680.03	2,822.57
CAGR	7.31%	5.24%	-0.01%	14.18%	-
Hub	12,861.04	12,382.20	12,979.28	16,917.6	14,583.96
CAGR	1.92%	-2.33%	-12.41%	7.70%	-

Table 4-6 - FCO Connectivity for the period 2009-2017

(Source: Author's based on OAG Data).

FCO	2017	2015	2013	2011	2009
Direct	2925.767	3173.466	2803.413	3227.694	2695.49
CAGR	-3.98%	6.40%	-6.80%	9.43%	-
Indirect	4796.578	4224.548	3759.224	3684.396	3068.258
CAGR	6.56%	6.01%	1.01%	9.58%	-
Hub	4135.075	4362.5	4321.255	4789.665	1035.648
CAGR	-2.64%	0.48%	-5.02%	115.05%	-

Table 4-7 - LIS Connectivity for the period 2009-2017

(Source: Author's based on OAG Data).

LIS	2017	2015	2013	2011	2009
Direct	1812.908	1540.381	1384.047	1307.382	1201.004
CAGR	8.49%	5.50%	2.89%	4.33%	-
Indirect	1786.139	1536.227	1265.573	1349.892	1198.681
CAGR	7.83%	10.18%	-3.17%	6.12%	-
Hub	2939.885	2347.173	2309.344	2199.556	1738.882
CAGR	11.92%	0.82%	2.47%	12.47%	-

FCO connectivity evolution is shown in Table 4-5. It had an amazing growth in 2011 due to the fact that Alitalia switched its main hub from MXP to FCO (Italy Magazine, 2009). It had an incredible growth in the hub connectivity, 115.05%, and a growth around 10% in direct and indirect connectivity. In 2013 had an important decrease in direct and hub connectivity, higher than the average of the whole market. FCO had satisfactory results in 2015, with 6% CAGR growth in direct and indirect connectivity. FCO has had an important decrease of direct and hub connectivity while the average second tier airports had considerable increases. This is due to the fact that Alitalia had a bankruptcy in 2017, affecting FCO (FlightGlobal, 2017).

LIS has had a huge growth during the period 2009-2017. The direct connectivity has grown a 51%, the indirect connectivity a progress of 49% and the hub connectivity, 69%. While the average market decreased its connectivity on 2013, LIS had growth rates for direct and hub connectivity. For the years 2015 and 2017 it has had growths much higher than the average, except the hub connectivity for the year 2015.

4.3.2 Cluster 1

Cluster 1 represents the evolution of the two airports with more passengers during the year 2016, BCN and LGW. They are big OD traffic generators, but its hub connectivity is low. Figure 4-11 represents the historical evolution of the airport connectivity for both airports for the period 2009-2017. BCN had an incredible decrease during the period of 2009-2015. The hub connectivity in 2015 is the 4.7% of the value of 2009. This happened due to two major reasons. Iberia stopped to use Barcelona airport as a secondary hub and Spanair, a Spanish carrier based in Barcelona, ceased its operations in 2012 (CAPA, 2012). In 2017, BCN had a considerable growth in hub connectivity due to the considerable evolution of Vueling and Norwegian started to use BCN as a base. LGW has had a considerable decrease in hub connectivity during this period. It has reduced its hub connectivity over 35% during the last 8 years.

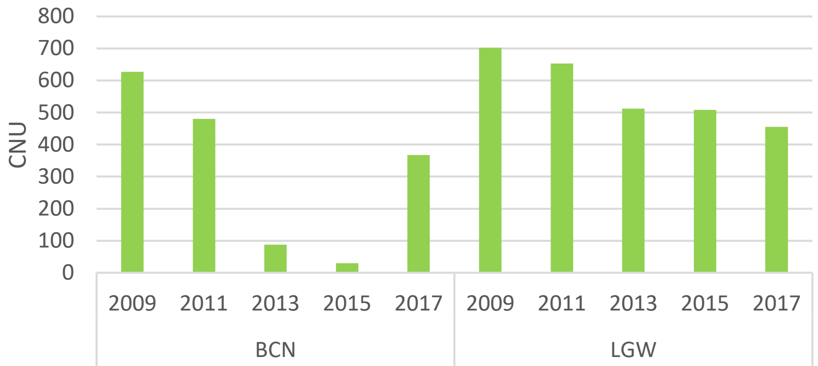

Figure 4-11 – Cluster 1 Hub Connectivity Evolution

(Source: Author's based on OAG Data).

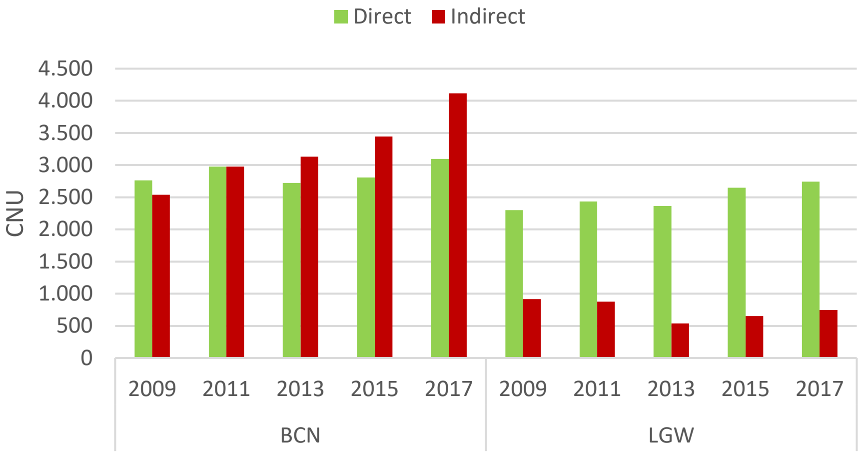

Figure 4-12 - Cluster 1 Direct and Indirect Connectivity Evolution

(Source: Author's based on OAG Data).

While BCN hub connectivity was severely affected between the years 2009-2015 and LGW had a considerable constant decrease year after year, its direct and indirect connectivity was not as affected. As shown in Figure 4-12, direct connectivity for BCN and LGW follow similar patterns as the average European second tier airports' market. An increase in 2011, followed by a decrease in 2013 and an upsurge in 2015 and 2017. BCN indirect connectivity has increased every year, with special rise in 2017. LGW indirect connectivity diminished during the total period and its lower value was in 2013. The growth of direct connectivity while having stable indirect connectivity means that the rise has been produced by LCC in LGW during the period 2009-2017.

4.3.3 Cluster 2

Cluster number two is formed by two airports, CPH and ARN, with strong direct connectivity while having a significant hub connectivity. In Figure 4-13, CPH hub connectivity had massive growth during the period 2009-2013 and it later had a stable period during the years 2013-2017. This enormous growth was due the apparition and evolution of Norwegian and the also progress of SAS. ARN enormous growth during all the period is due to the introduction of Norwegian, but mainly because SAS multiplied its operations for five times in that period.

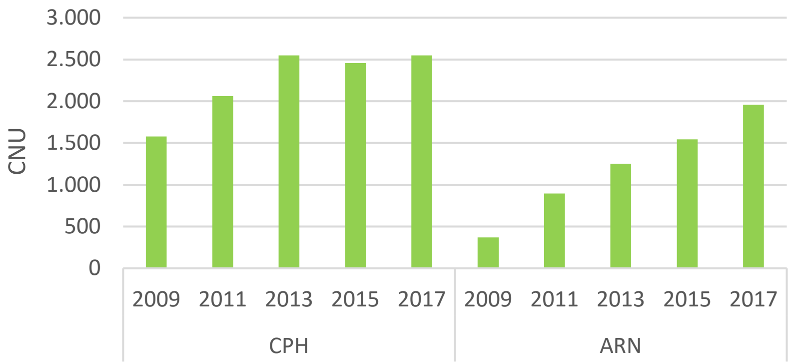

Figure 4-13 - Cluster 2 Hub Connectivity Evolution

(Source: Author's based on OAG Data).

Figure 4-14 represents the direct and indirect connectivity for CPH and ARN. CPH has had a direct and indirect connectivity growth like to the average European second tier airports, but with smaller improvement in the direct connectivity for 2015 and 2017. The growth in both years was close to 4%. The progress in 2011 was high since the direct connectivity grew by 10% CAGR. ARN direct and indirect connectivity growth has been similar to the average European second tier airports. ARN direct connectivity grew considerably, 21% CAGR, in 2011. Both airports direct connectivity rise was due to Norwegian success.

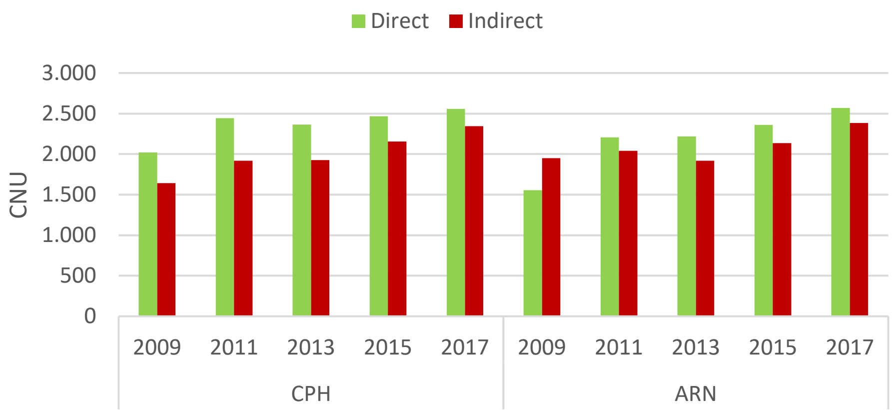

Figure 4-14 - Cluster 2 Direct and Indirect Connectivity Evolution

(Source: Author's based on OAG Data).

4.3.4 Cluster 3

The third cluster represents three airports with very high airport centrality, just below MUC, and a standard direct connectivity. Figure 4-15 represents the evolution of hub connectivity for ZRH, VIE and HEL. ZRH had important hub connectivity rises, higher than the average, in 2011 and 2013, but then it had a decline in 2015. VIE had a drastic result in 2013, reducing its value to a 25% of its previous result. That year Austrian Airlines, based in VIE, was bought by Lufthansa group, but then it recovered in 2015, when its hub connectivity was the 87% of its value in 2011. HEL had a significant increase of 57% in 2011 due to the large growth of Finnair. HEL has grown two times more than the average on 2015 and 2017.

Figure 4-15 - Cluster 3 Hub Connectivity Evolution

(Source: Author's based on OAG Data).

Figure 4-16 represents the direct and indirect connectivity for ZRH, VIE and HEL. Indirect connectivity follows the same pattern for ZRH and VIE than the average of European second tier airports, but not the direct connectivity. Direct connectivity improved in 2011 in both airports and then its value was reduced in 2013 and then it stayed stable. Both airports main carriers, SWISS for ZRH and Austrian Airlines for VIE, were bought by Lufthansa in 2013. It is logic that Lufthansa prefers to focus all their resources in their hubs, FRA and MUC, than in other airports. Direct and indirect connectivity results in HEL follow the same pattern as the average airport but the growth in 2011 was much higher, 35% for direct and 61% for indirect, due to the satisfactory results of Finnair, the Finnish flag carrier and based in HEL, and then they had an important decrease in 2013, -16% in direct and -23% in indirect.

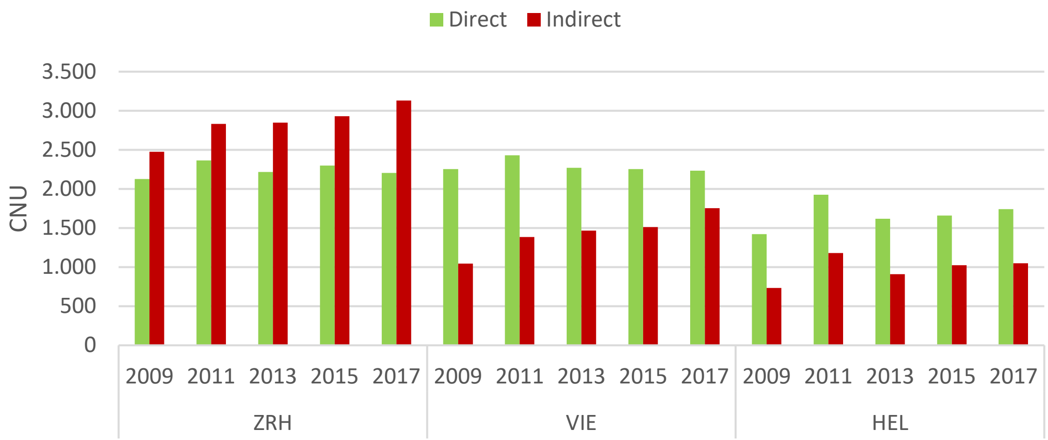

Figure 4-16 - Cluster 3 Direct and Indirect Connectivity Evolution

(Source: Author's based on OAG Data).

4.3.5 Cluster 4

The fourth cluster represents the airport with the same direct connectivity as cluster 3, but its hub connectivity is moderate. ORY has underperformed in the period 2009-2017 since its hub connectivity is lower in 2017 than in 2009, even though it has grown 24% from the year 2015. OSL has performed similar

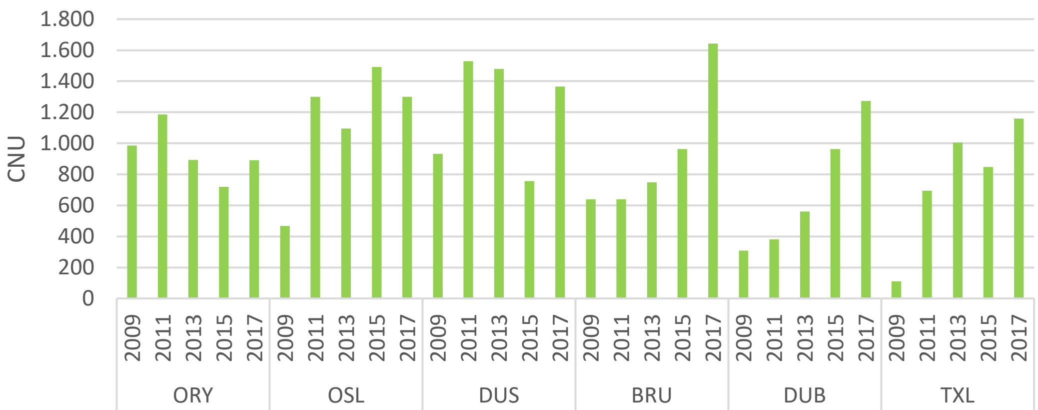

Figure 4-17 - Cluster 4 Hub Connectivity Evolution

(Source: Author's based on OAG Data).

as the average second tier airport and its considerable growth in 2011 is due to the same reason as ARN and CPH, the progression of Norwegian. DUS and TXL hub connectivity evolution is similar. They had important growths in 2011, both over 600 CNU, and their hub connectivity had considerable decline in 2015 due to the problems and passenger loss of Air Berlin. DUS was more affected since Lufthansa focused on its main hubs. DUB has had an excellent evolution during this period, with the average growth of 44%, due to the progression of Aer Lingus. BRU also had an excellent period with rises around 20% in 2013 and 2015, but in 2017 it has increased 71% since Brussels Airlines, based in BRU, have had excellent results after being bought by Lufthansa.

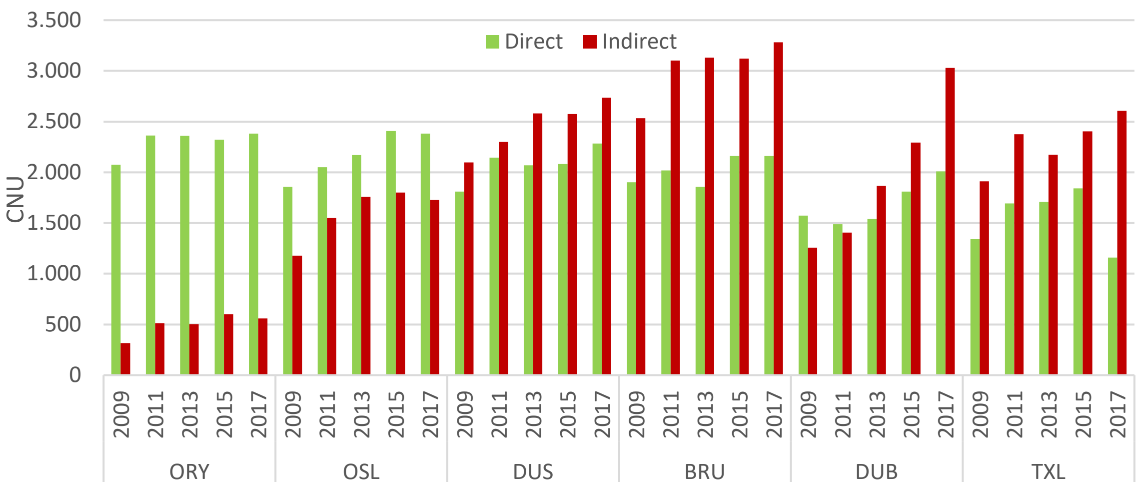

Figure 4-18 - Cluster 4 Direct and Indirect Connectivity Evolution

(Source: Author's based on OAG Data).

ORY direct connectivity evolution during the period 2009-1017 is like its indirect connectivity, considerable growth in 2011 as the selected airports' market and then stable for the rest of years. OSL follow the same pattern as CPH and ARN for the same reasons, the consolidation and expansion of SAS and Norwegian. DUS, BRU and TXL have alike evolution of direct and connectivity results since they follow the same progress as the average of the selected airports. The direct connectivity of TXL in 2017 is the only result that diverges, due to the bad results of Air Berlin. DUB has also had an excellent period in terms of passenger accessibility. Indirect connectivity has grown an average of 25% each year and direct connectivity has risen 14% in 2015 and 2017.

4.3.6 Cluster 5

The fifth cluster is composed of PMI and MAN, with the same level of passenger accessibility as cluster 3 and 4, but with reduced airport centrality. As shown in Figure 4-19, hub connectivity in MAN is low and it is irrelevant for the airport. PMI has had an almost constant decrease of 100 CNU during all the period. In 2009, PMI was the Spanish hub for Air Berlin. They connected second tier German airports with several destinations in Spain. Air Berlin reduced its services in PMI since it preferred a point-to-point network.

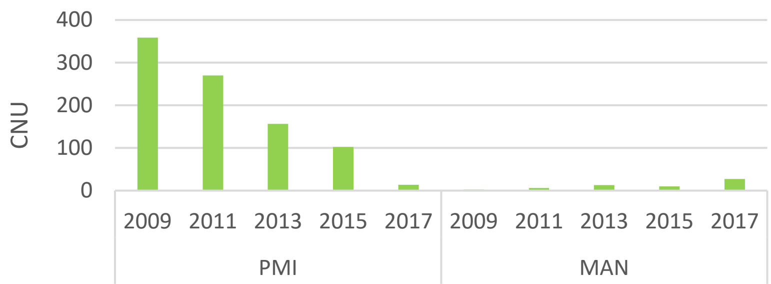

Figure 4-19 - Cluster 5 Hub Connectivity Evolution

(Source: Author's based on OAG Data).

PMI indirect connectivity is low since it is primarily a LCC oriented airport. Its direct connectivity follows the same pattern as the average selected airports. MAN direct and indirect connectivity evolution has been inside standard levels during 2009-2017, but in 2017 the direct connectivity grew 19%.

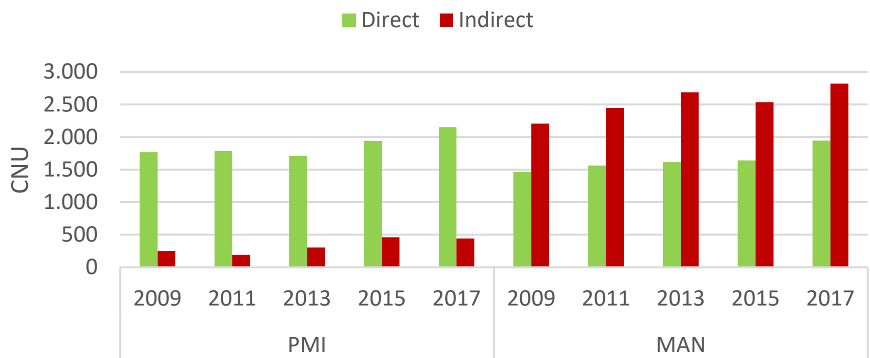

Figure 4-20 - Cluster 5 Direct and Indirect Connectivity Evolution

(Source: Author's based on OAG Data).

4.3.7 Cluster 6

The sixth and final cluster is for the selected airports with few passenger accessibility and airport centrality results. Figure 4-21 shows that STN and AGP almost have no hub connectivity since they are mainly LCC oriented airports. MXP has reduced hub connectivity since Alitalia left MXP to FCO. Its hub connectivity reduced around 80% in 2013. HAM low hub connectivity has also been affected for the deficient performance of Air Berlin and the focus of Lufthansa in their dual hub strategy. GVA small hub connectivity values derived from the fact that SWISS always has considered ZRH as its main hub. ATH is the only airport in this cluster with considerable hub connectivity during the years 2009-2017, but both ATH and Aegean Airlines, the main Greek carrier, were heavily affected by the Greek economic situation.

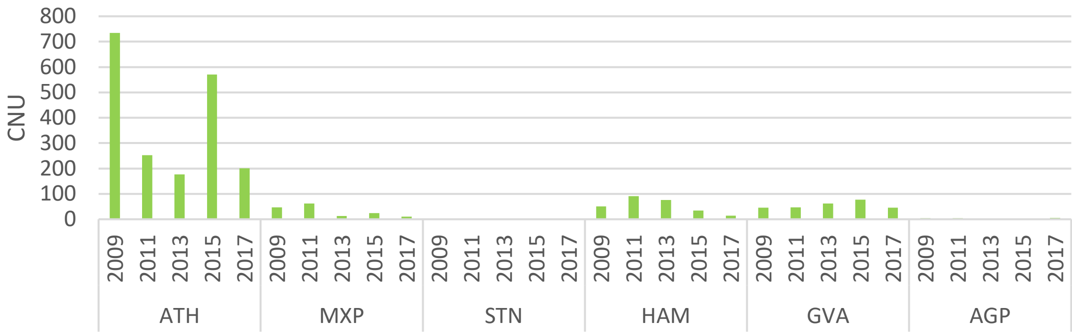

Figure 4-21 - Cluster 6 Hub Connectivity Evolution

(Source: Author's based on OAG Data).

STN and AGP also have almost no indirect connectivity, due to being primarily a LCC oriented airport. They both had constant results during 2011 and 2013 and they have grown considerably in 2015 and 2017. ATH indirect connectivity has evolved as the average, but not the direct connectivity. It heavily decreased during 2011 and 2013 due to the Greek economic situation. It has recovered part of the direct connectivity, but not as the 2009 direct connectivity value. MXP direct connectivity has been stable for all period due to the positive effect of the economy growth and the negative effect of Alitalia dehubbing. HAM and GVA direct and indirect connectivity has followed the same evolution as the average, except GVA had positive results in 2014 for both direct and indirect.

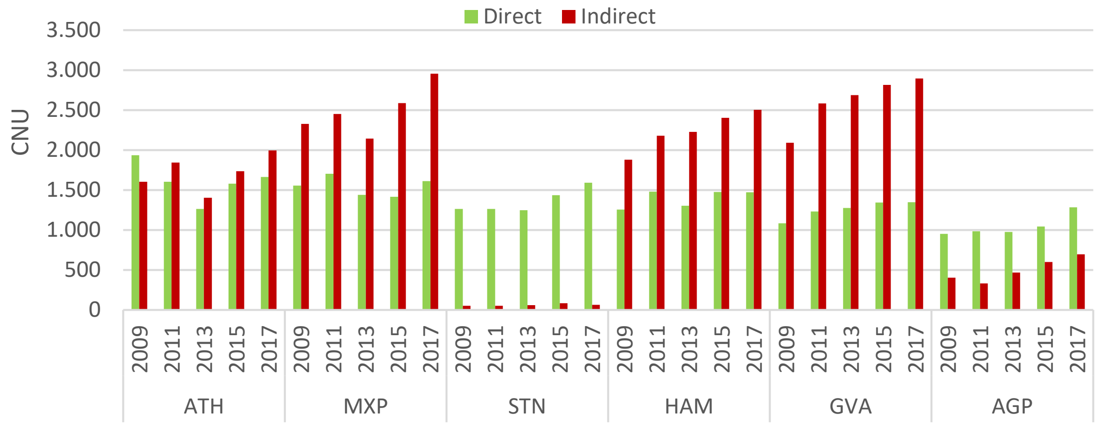

Figure 4-22 - Cluster 6 Direct and Indirect Connectivity Evolution

(Source: Author's based on OAG Data).

4.4 Long-Haul Low-Cost Connectivity Study Case

Once the connectivity analysis and its evolution during the 2009-2017 period for the selected airports is completed, it is time to apply the methodology explained in section 3.4. The long-haul low-cost connectivity study case consist of applying the LHLC phantom flights, detailed in Appendix A, into the results from the connectivity analysis from section 4.1. It is mentioned that the LHLC phantom flights created is conservative since they are the flights from the peak season of 2017 and no forecast is done for the rise of long-haul low-cost carriers in the mid-term.

The phantom flights are only applied to the six selected airports that has LHLC flights: ARN, BCN, CPH, DUB, LGW and OSL. Due to this fact, Table 4-7 only includes six airports out of the 24 selected ones. The increase of direct connectivity in CNUs is equal to the number of frequencies created as phantom flights for each one of the airports during one week since the quality of every non-stop direct flight is equal to the unit. The last column is the percentage that the LHLC phantom flights represent to the total number of direct flights of a particular airport. It was previously commented that the total number of phantom flights added to the data was conservative and it is demonstrated since all airports, except LGW, have an increase in their total flights that vary in the range of 0.60 and 0.70%. LGW has a higher ratio, a growth of 1.11%, than the other airports, but it is still low.

Table 4-8 – Hub and direct connectivity increase due to phantom flights (Source: Author).

Airports	Hub (CNU)	%	Direct (CNU)	%
ARN	44.65	2.28%	17	0.66%
BCN	72.33	19.67%	20	0.60%
CPH	37.66	1.48%	18	0.70%
DUB	1.04	0.08%	13	0.60%
LGW	2.69	0.59%	33	1.11%
OSL	95.31	7.33%	15	0.63%

Table 4-7 also shows how it is affected the hub connectivity for the introduction of LHLC phantom flights. Four airports have a considerable increase, ARN, BCN, CPH and OSL, due to the phantom flights while the other two airports, DUB and LGW, have a reduced hub connectivity growth. The hub connectivity is higher than the direct connectivity in some cases since these airports have many frequencies that can connect with the LHLC phantom flights. The airport with more hub connectivity created by phantom flights is OSL. Norwegian is based in OSL and the maturity of its network lets many frequencies connect on Norwegian's LHLC flights. Since OSL has moderate hub connectivity and it belongs to cluster 4, the LHLC phantom flights increase its hub connectivity up to 7.33%. BCN hub connectivity is heavily affected by the LHLC phantom flights since it represents almost a hub connectivity growth of 20%, because Vueling has its main hub in BCN and it provides the feeding and the transfer passengers to LEVEL operations. The growth rate is that big since BCN had low level of airport centrality. CPH and ARN, both from cluster 2, have similar hub connectivity gains and growth rates. It is noticeable that ARN hub connectivity rise is higher even though it has one less phantom flight. The main reason behind it is that Norwegian has more market share on ARN than in CPH while SK has much more impact in CPH than in ARN. Lastly, LGW and DUB rise in hub connectivity are residual since Norwegian still has not developed a strong short-haul network on those airports. Norwegian considers the OD traffic and the self-connectivity in both airports to make its profitable. 5.2Appendix A

Table 4-9 – Indirect connectivity increase due to phantom flights (Source: Author).

Airports	Indirect	%
AGP	0.668	0.10%
ARN	11.684	0.49%
ATH	0.918	0.05%
BCN	2.235	0.05%
CPH	7.476	0.32%
DUB	0.712	0.02%
FCO	2.588	0.05%
GVA	0.404	0.01%
HAM	1.866	0.07%
HEL	3.565	0.34%
MUC	0.276	0.01%
ORY	0.465	0.08%
OSL	10.020	0.58%
PMI	0.879	0.20%
VIE	0.562	0.03%

Table 4-8 indicates the indirect connectivity originated from the LHLC phantom flights. The selected airports that do not appear on the table is because the phantom flights do not affect its indirect connectivity. LGW, the airport with more phantom flights, has no increase in indirect connectivity since the lack of Norwegian's short-haul network from LGW. The airports with more growth of the indirect connectivity are ARN, CPH and OSL even though the increase is low since they vary in the range of 0.32% and 0.58%. They are the airports with a more mature network of short-haul flights of Norwegian. HEL rise in indirect connectivity is in the same range as the three previous airports since HEL has many connections to them.

5 CONCLUSIONS

5.1 Findings of the Study

The aim of the thesis was to study and analyse the second-tier European airports in terms of connectivity. In order to achieve this purpose, the thesis was divided into subsequent objectives to be accomplished.

The first part of the thesis was to provide an insight into the definition of connectivity and why it is important and used in air transport. It was also planned to determine the different methods to quantify connectivity and its subsequent operational criteria. Previously, a brief introduction was done analysing the different opinions whether the liberalisation of EU aviation market has led to a concentration or deconcentration of the network. Then, there were different classification of airports regarding their nature, whether they focus on OD traffic or in connecting passengers, as well as the quality of the connections and their geographical focus. Then, there was a review of different authors' perspective on the meaning and the usefulness of connectivity followed by the different connectivity types and models. Connectivity analysis have gained importance since hub-and-spoke and point-to-point networks have been developed. Netscan model was chosen as the most suitable model since it was required a methodology that was able to perform an in-depth connectivity model without the need of market analysis for each airport. Netscan model also has proven applicability in several analyses. Netscan model different criteria´s values were considerably high to make sure all possible connections were incorporated since the quality index would determine if the route was feasible or not.

The first objective consisted in analysing the evolution of second tier European airports connectivity over time and the differences between them and the major European hubs. First, it was studied the connectivity in the European second tier airports' market for 2017. The direct connectivity on the majority of European second tier airports varied in the range of 1,500 to 2,500 CNU. Larger airports like BCN, LGW and FCO were around 3000 CNU while MUC, the airport with better performance in almost all sections, had 4008 CNU. In airport connectivity, the difference between airports was higher than in direct connectivity. MUC had an airport connectivity of 8700 CNU while STN had 1653 CNU, 5 times smaller. Airports with an important hub in the same city, like LGW, ORY and STN, had low airport connectivity compared to other second tier airports. Airports who were really LCC oriented were also affected by the same situation. European second tier airports really benefited from their frequencies to major hubs to boost their indirect connectivity. As higher frequencies and direct flights the airport had to major European hubs, higher indirect connectivity. Hub connectivity values were directly related whether the airport had a FSC based on it. The size of the FSC was also important. MUC, the airport with higher hub connectivity, was the second base of Lufthansa, the biggest FSC in Europe. ZRH, HEL, VIE and FCO also are the main hub of FSCs, but they carried less passengers than Lufthansa. Once all types of connectivity were studied, a clustering of airports was done to group them with similar airports. While carriers needed FSCs to increase its hub connectivity, European second tier airports´ market was dominated by Ryanair and EasyJet, since they were the first and second respectively in both frequencies and ASKs. European second tier airports were primarily focused on having intra-European frequencies. Most airports had over 90 percent of flights to other European airports and the average is 91.64%. It was also noticeable that airports from the North of Europe had higher ratio compared to airports in southern countries. Most flights outside EU were to North America and Middle East.

After the connectivity analysis for 2017 was finished, a comparison between the top second tier airports and the major EU hubs was done. BCN, FCO, ZRH were far from all major hubs, while MUC had better connectivity than MAD, but was far from the rest of EU main hubs. Then the evolution for the whole market and for every airport during the period 2009-2017 was done. Direct connectivity on the market has grown 19.02% while hub connectivity increased 31.65% during that time. The connectivity type which had grown more was the indirect, a 43.17%. The year with higher growth was 2011, with the connectivity values having a two-digit growth. 2013 had a major decrease except for the indirect, who had a light increase of 0.40%. 2015 and 2017 had a considerable growth, but not as high as 2011, since they don't achieve two-digit growth.

The second and final objective was to evaluate the current state of long-haul low-cost carriers and to determine its potential impact in European second tier airports. There had been some European LHLC carriers before Norwegian and LEVEL, but they all end up in failure. There had been two periods with LHLC airlines, the late seventies and the eighties and then the early 2000s. The first period failed due to airlines facing predatory pricing from established transatlantic carriers and an excessive fleet expansion, leading to bankruptcy. The second period faced similar problems and could not face the global economic crisis of 2008. LHLC business model has an increased complexity of operations, the structure change and it is more difficult to create demand compared to the LCC business model. For these reasons, LHLC business model consists of a hybrid model that adapts the core LCC business model doctrines. Norwegian and LEVEL, the actual LHLC carriers, have learned from the past failures and recent success of Asian LHLC carriers and for these reasons they have extensive short-haul feeding flights and they are using modern fuel-efficient aircrafts. The creation of LHLC phantom flights methodology was conservative and it only created 116 flights per week in the whole European second tier airport´s market. The methodology used was to get the total number of LHLC flights in the peak week and applied on the average week, since doing a forecast for the LHLC flights in short-mid-term was out of the scope. The airport whose direct connectivity has been more benefited is LGW, since 33 out of 116 would take off from it, representing 28.5% of the phantom flights and represent 1.11% of the total flights of LGW. The other airports varied in the range of 13 to 20 flights and they represented from 0.60% and 0.70% of their total flights. In terms of hub connectivity, the most benefited airports were OSL, BCN, ARN and CPH. The three Scandinavian airports are benefited from the Norwegian´s mature short-haul network from the three airports while BCN use Vueling flights to feed LEVEL operations. The hub connectivity values ranged from 37.66 to 95.31. Indirect connectivity rise was residual in all airports. LHLC flights were significant for these airports since the growth in hub connectivity is around three or four times higher per every extra direct flight.

5.2 Further Research Suggestions

Three main suggestions for further research can be derived from the scope of the thesis and it would provide added value to the field. The first main proposed research is to consider self-connectivity as a factor in the connectivity analysis. The actual thesis only considers online connections for the connectivity analysis in all sections. On one hand, self-connectivity would heavily increase the number of indirect connectivity and hub connectivity for all airports, but specially for airports with high factor of LCCs. On the other hand, self-connectivity it is not a popular option for passengers and it is uncommon since it has many inconveniencies to passengers. Alternatively, it could be studied how the connectivity on the selected airports would be modified if LCC considered the option to connect passenger or possible code-share agreements, like Ryanair providing the feeding for Norwegian.

Another possible research suggestion is to gather all the connectivity results from the thesis and do specific management recommendations to every selected airport. It would be useful for the airports to have a customized interpretation of the connectivity analysis results. To do this, it will be required a market analysis for each airport. As it is needed to do 24 brief market analyses, the author considers it was not possible to be done within this thesis and it was out of the scope.

The third and final recommendation is related to the LHLC flights. The study has been done in the early stages of LHLC operations in Europe and it is still has develop enough to have a mature network. This has been a limitation through the thesis and it has led to obtain meaningless results. The author proposes to repeat a similar study in the mid-term when the LHLC operations are more consolidated or to develop a forecast for the short-term and mid-term. The forecast proposal is out of the scope of the thesis since it would have required too many resources and it is included in the objectives of the thesis.

REFERENCES

ACI (2017) *Airport Industry Connectivity Report*.

ACI Europe (2014) *Airport Industry Connectivity Report 2004-2014*.

Adikariwattage, V. *et al.* (2012) 'Airport classification criteria based on passenger characteristics and terminal size', *Journal of Air Transport Management*. Elsevier Ltd, 24, pp. 36–41. doi: 10.1016/j.jairtraman.2012.06.004.

ADV German Airport Statistics (2017) *ADV Monthly Traffic Report*.

AENA (2017) *Informe 2016*.

Aeroportos de Portugal (2017) *Annual Report 2016*.

Aeroports de Paris Group (2017) *2016 Full Year Traffic*.

Airport, A. I. (2017) *Passenger traffic development 2016*.

Airports in Europe (2017) *Largest airlines Europe*. Available at: https://www.airportsineurope.com/flight-info/largest-airlines-europe/ (Accessed: 20 July 2017).

Arvis, J.-F. and Shepherd, B. (2011) 'The air connectivity index: measuring integration in the global air transport network', *World Bank Policy Research Working Paper*, 5722(June), pp. 1–61. doi: 10.1596/1813-9450-5722.

ASSAEROPORTI (2017) *STATISTICHE 2016*. Available at: http://www.assaeroporti.com/statistiche/ (Accessed: 15 June 2017).

AVINOR (2017) *TRAFFIC STATISTICS*. Available at: https://avinor.no/en/corporate/about-us/statistics/traffic-statistics (Accessed: 1 January 2017).

Bel, G. and Fageda, X. (2010) 'Intercontinental flights from european airports: Towards hub concentration or not?', *International Journal of Transport Economics*, 37(2), pp. 133–153.

Brussels Airport (2017) *BRUtrends 2016*.

Burghouwt, G. (2007) *Airline Network Development in Europe and its Implications for Airport Planning*. Ashgate, Aldershot.

Burghouwt, G. *et al.* (2009) 'Air network performance and hub competitive position: evaluation of primary airports in East and South-East Asia', 3(4), pp. 384–400.

Burghouwt, G. and Hakfoort, J. (2001) 'The evolution of the European aviation network, 1990-1998', *Journal of Air Transport Management*, pp. 311–31.

Burghouwt, G. and Redondi, R. (2009) *Connectivity in Air Transport Networks: Models, Measures and Applications*.

Calder, S. (2002) *No Frills, The Truth Behind The Low-Cost Revolution in the Skies*. Virgin.

CAPA (2009) *Long-Haul low-cost airline progress hampered by widebody prices and availability*.

CAPA (2012) *Spanair ceases operations on 28-Jan-2012*.

CAPA (2013) *Profile on Norwegian Group*.

CAPA (2015) *Norwegian Group receives UK operatin license, to establish 'Norwegian UK' subsidiray*.

CAPA (2016) *Norwegian announces new Trans-Atlantic services from Barcelona*.

CAPA (2017a) *IAG's LEVEL starts four Barcelona routes to Americas; eyes Paris & Rome bases, Asia destinations*.

CAPA (2017b) *IAG Takes Flying to a New Level*.

CAPA (2017c) *LEVEL increases Barcelona-Buenos Aires frequency*.

CAPA (2017d) *Norwegian Air's long-haul launch from Barcelona. Ambitious 70 aircraft plans for Argentina*.

CAPA (2017e) *Norwegian Group to launch three new long-haul routes in Sep-2017*.

Cook, G. N. and Goodwin, J. (2008) 'Airline Networks: A comparison of Hub-and-Spoke and Point-to-Pont Systems', *Journal of Aviation/Aerospace Education & Research*, 1(17).

Copenhagen Airports (2017) *Record growth in 2016*.

Dennis, N. (1994) 'Airline hub operations in Europe', *Journal of Transport Geography*, 2(4), pp. 219–23.

Dublin Airport Authority (2017) *Annual Report 2016*.

EFTA (2017) *The European Free Trade Association*. Available at: www.efta.int (Accessed: 17 July 2017).

FINAVIA (2017) *Passengers 2016*.

FlightGlobal (2017) *ANALYSIS: Alitalia's woes a potential ABS downside?*

Geneve Aeroport (2017) *Traffic Evolution*.

Goedeking, P. (2010) *Networks in Aviation: Strategies and Structures*. Frankfurt: Springer.

Homsombat, W., Lei, Z. and Fu, X. (2011) 'Development Status and Prospects for Aviation Hubs — a Comparative Study of the Major Airports in South-East Asia', *The Singapore Economic Review*, 56(4), pp. 573–591. doi: 10.1142/S0217590811004420.

IATA (2017) *IATA Forecasts Passenger Demand to Double Over 20 Years*.

Italy Magazine (2009) *Rome's Fiumicino to be Alitalia's main hub*. Available at: http://www.italymagazine.com/italy/fiumicino/romes-fiumicino-be-alitalias-main-hub (Accessed: 20 July 2017).

Ivy, R. (1993) 'Variations in hub service in the US domestic air transport network', *Journal of Transport Geography*, 1(4), pp. 211–218.

Janic, M. (1997) 'Liberalisation of Europea Aviation: Analysis and Modelling of the Airline Behaviour', *Journal of Air Transport Management*, 3(4), pp. 167–180.

Malighetti, P., Paleari, S. and Redondi, R. (2008) 'Connectivity of the European network: "Self-help hubbing" and business implications', *Journal of Air Transport Management*, 14, pp. 53–65.

Morrell, P. (2009) 'Can long-haul low-cost airlines be successful?', *Research in Transportation Economics*, 24(1), pp. 61–67. doi: 10.1016/j.retrec.2009.01.003.

Prague Airport (2017) *Traffic Report - 2016*.

Rodríguez-Déniz, H., Suau-Sanchez, P. and Voltes-Dorta, A. (2013) 'Classifying airports according to their hub dimensions: An application to the US domestic network', *Journal of Transport Geography*, 33, pp. 188–195. doi: 10.1016/j.jtrangeo.2013.10.011.

Rodríguez-Déniz, H. and Voltes-Dorta, A. (2014) 'A frontier-based hierarchical clustering for airport efficiency benchmarking', *An international Journal*, 21(4).

Rosenblatt, H., Armengod, H. and Scordamaglia-Tousis, A. (2013) 'Post Danmark: predatory pricing in the European Union', *The European Antitrust Review 2013*, pp. 21–25.

Sarkis, J. and Talluri, S. (2004) 'Performance based clustering for benchmarking of US airports', *Transportation Research A*, 38, pp. 329–346.

SEO economic research (2014) *Airport Industry Connectivity Report*.

SEO economic research (2016) *Airport connectivity and competition*.

Suau-Sanchez, P. and Burghouwt, G. (2012) 'Connectivity levels and the competitive position of Spanish airports and Iberia's network rationalization strategy, 2001-2007', *Journal of Air Transport Management*. Elsevier Ltd, 18(1), pp. 47–53. doi: 10.1016/j.jairtraman.2011.08.004.

Suau-Sanchez, P., Burghouwt, G. and Fageda, X. (2014) 'Reinterpreting EU Air Transport Deregulation: A Disaggregated Analysis of the Spatial Distribution of Traffic in Europe, 1990-2009', *Tijdschrift voor Economische en Sociale Geografie*, 107(1), pp. 48–65. doi: 10.1111/tesg.12133.

Suau-Sanchez, P., Voltes-Dorta, A. and Rodríguez-Déniz, H. (2017) 'An assessment of the potential for self-connectivity at European airports in holiday markets', *Tourism Management*, 62, pp. 54–64. doi: 10.1016/j.tourman.2017.03.022.

Swedish Airport Statistics (2017) *traffic statistics*.

Tembleque-Vilalta, M. and Suau-Sanchez, P. (2016) 'A model to analyse the profitability of long-haul network development involving non-hub airports: The case of the Barcelona-Asian market', *Case Studies on Transport Policy*. World Conference on Transport Research Society, 4(2), pp. 188–197. doi: 10.1016/j.cstp.2014.12.004.

UK Civil Aviation Authority (2017) *Size of Reporting Airports 2016*.

Veldhuis, J. (1997) 'The competitive position of airline networks', *Journal of Air Transport Management*, 3(4), pp. 181–188.

Vienna Airport (2017) *Traffic Results*.

Zaharia, S. E. (2014) *Airport Connectivity, an Essential Element for Economic Performance*. Prague: INAIR.

Zurich Airport (2017) *Annual Report 2016*.