Airline Schedule and Network Competitiveness: a consumer-centric approach for business travel

Nenum, S., Graham, A. and Dennis, N.

AIRLINE SCHEDULE AND NETWORK COMPETITIVENESS:
A CONSUMER-CENTRIC APPROACH FOR BUSINESS TRAVEL

ABSTRACT

The aim of this paper is to undertake a comparative analysis of the competitiveness of airline schedules and networks from a business traveller perspective with a particular focus on Europe and travel to and from this continent. A unique and innovative customer-centric model is developed using a passenger survey and airline schedule data to overcome the shortcomings of traditional models that lack the passenger viewpoint. The results show that Austrian Airlines/Vienna airport and Swiss/Zurich airport have the highest quality connections, whilst the top five competing European hubs are served by the Lufthansa group. The findings provide a significant opportunity to airlines to grow their knowledge and understanding of their competitive position and their ability to offer scheduling convenience to passengers.

Keywords: Airlines; schedules; networks; hubs; business travellers

1. INTRODUCTION

Traveller choice of air services is a complex issue. It is affected by numerous factors including fare, scheduling convenience and other influences such as airline reputation, reliability, safety, in-flight services, seat availability, airline competition and frequent flyer programmes. Business passengers, being generally more journey time sensitive and less price sensitive than leisure passengers, are usually assumed to be particularly influenced by schedule factors and the design of airline networks. Therefore this paper focuses on this important aspect of air service choice for business travellers, namely scheduling convenience, whilst acknowledging that a number of the other factors undoubtedly also play a role. As a consequence, it is not the purpose of the research to produce an econometrically driven all-inclusive choice model for air passengers.

Traditionally to understand and model the attractiveness of the scheduling or 'quality' aspects of the airline product, airlines have applied the so-called Quality of Service Index (QSI) which uses parameters such as weekly frequency, seat capacity, aircraft type and total journey time to estimate individual airline market share. Academic research in this area has also tended to focus on these parameters. However such an approach is primarily a mathematical computation process that lacks the passenger perspective. This paper overcomes this shortcoming by adding in passenger views as regards scheduling convenience that have been obtained from an extensive passenger survey. Hence it has been possible to develop an innovative consumer-centric approach with new index measures to demonstrate passenger preferences which has been called the realistic market share estimation (REMSET) model. The overall specific aim here in using the REMSET model is to undertake a comparative analysis of the competitiveness of airline schedules and networks from a business traveller perspective with a particular focus on Europe and travel to and from this continent.

2. LITERATURE REVIEW

Analysing and modelling passenger choice of air services and airports is an area that has received considerable attention in the literature (e.g. Adler et al., 2005; Başar and Bhat, 2004; Coldren and Koppelman, 2005; Gao and Koo, 2014; Hess et al., 2007; Moreno, 2006; Oyewole, 2007; Pels et al., 2001), especially by using multivariate probit or discrete choice logit models With the latter, there are mutually exclusive alternatives to be considered, each with an associated utility or attractiveness (Garrow, 2010). This general methodology has also been used within the wider tourism industry for other purposes such as tourism expenditure (e.g. Wu et al. 2013; Rashidi and Koo, 2016). For air travel, the choice factors investigated typically include price, schedule features (e.g. flight time, direct or connecting flight, frequency, routing, aircraft type) and many others such as access time/cost, on-time performance, frequent flyer programmes, seat availability, in-flight service, airline/airport reputation, airline competition, security and safety (Abdelghany and Abdelghany, 2009). For example Coldren and Koppelman (2005) used level-of-service, connection quality, carrier attributes, aircraft type, and departure time in their discrete choice model for markets in the United States and Canada.

Meanwhile industry sources, such as the global passenger survey undertaken by the International Air Transport Association (IATA), have found that the top three factors influencing ticket purchase with a particular airline are price (43%), schedule and convenient flight time (21%) and frequent flyer programme (13%) (IATA, 2015). Similar findings have been recorded elsewhere, for example in the UK, where it was observed that the top three influences were price, flight times and location of departure/destination airports (Mintel, 2013). This shows how important flight times, which are the focus of this research, are to passengers.

The passenger's choice is also influenced by their specific characteristics such as socio-economic profiles (Castillo-Manzano and Marchena-Gómez, 2010; Milioti et al., 2015) and income (Gallet and Doucouliagos, 2014). Moreover trip purpose is very important. At the broadest level, even just differentiating between business and leisure passengers can be insightful as these two groups have different travel preferences and required experiences (Unger et al., 2016) - so separate choice models can be developed (e.g. see Wu and So, 2018). As an example in the UK, the Civil Aviation Authority (CAA) found that the 'flight time or route was a particular consideration for business flyers' (CAA, 2015: 37), whilst Mason (2001) found that for UK business travellers the most significant factors were punctuality and frequency, with price/ticket flexibility only being the third most important. As regards fares, in an analysis of 21 different research papers, Gillen et al. (2002) observed median price elasticity values of -0.26 for long-haul international business travel and -0.73 for short to medium-haul business, whilst the values for leisure demonstrated a more price sensitive demand (-0.99 for long-haul international leisure and - 1.52 short to medium-haul leisure). InterVISTAS (2007) in their comparative study of 23 papers also confirmed that business travellers were less sensitive to fare changes than leisure travellers. Moreover Seetaram et al. (2018) confirmed that passengers using business class are less price sensitive when it comes to paying passenger taxes. In addition with their discrete logit model Proussaloglou and Koppelman (1999) found a higher price sensitivity of leisure travellers, with greater importance of convenient schedules being given to business models. Milioti et al. (2015) with their multivariate probit model concluded that people who travel for business purposes are less price sensitive and more likely to consider the flight schedule (and frequent flyer program) as being important choice factors.

As a consequence this means that for business travel schedule convenience attributes can be very significant hence the focus of this research on business travel. This is the case for both direct flights, and also connecting flights where there may well be many options on offer. This has led to growing research in this area and particularly in the development of airport connectivity models (Burghouwt and Redondi, 2013). Different approaches have been adopted, especially when assessing hub airports, that not only take into account the number of connections, but also the perceived 'quality' in terms of transfer and in-flight times (Doganis and Dennis, 1989; Veldhuis 1997; Burghouwt and De Wit, 2005; Burghout and Veldhius, 2006). The so-called Netscan model, which has been developed in some of this research, is also used by the industry organisation ACI-Europe (2017). Meanwhile Allroggen et al. (2015) have established a Global Connectivity Index that includes a destination quality variable as well. In addition more detailed hub performance of certain individual airlines has been examined. For example Li et al. (2012) analysed All Nippon Airways' dual-hub strategy at Toyko's Haneda and Narita airports, while Logotheris and Miyoshi (2018) used what they defined as a Hub Connectivity Performance Analyser (HCPA) to evaluate the hub connectivity of Turkish Airlines at Istanbul airport and Emirates Airline at Dubai airport. Within this literature on connectivity models, various approaches to determining key connectivity variables such as the minimum and maximum connection times, and maximum detour distances for connections, are frequently discussed and have been used to inform the development of the REMSET model.

As already discussed, within the airline industry passenger choice factors are commonly taken into account by using the Quality of Service Index (QSI). This was initially used pre-airline deregulation by the US government to predict traffic changes due to changes in airline service. It has evolved to take into account factors such as aircraft types, number of stops and direct versus indirect services (Belobaba et al., 2016). A coefficient is applied to each of these factors which can have a relative value (e.g. non-stop flight = 1, single connection = 0.25) or absolute value (e.g. number of frequencies). By imputing data related to the airport pair market size and airline schedules, the index can then calculate market share. It has thus become more sophisticated but has still been subject to much criticism (Jacob et. al., 2012; Transportation Research Board, 2002), particularly due to its simplistic methodology, and being based on data from airline schedules which cannot take into account the passenger perspective.

In essence, there are currently two main methods to assess the competitiveness of airline schedules and networks. One is a ‘top-down’ approach to developing a network connectivity index by considering current airline schedules simultaneously and making assumptions about key connectivity variables such as the minimum and maximum connection times, and detour distances. The other ‘bottom-up’ approach involves devising a scoring system with the QSI index for individual routes, taking into account factors such as aircraft type, frequency and connections, which can be used to determine market share on each individual route.

However, both these approaches do not effectively take into account the passenger viewpoint. This is primarily due to two reasons. Firstly, the assumptions that are made are rarely built around actual up-to-date evidence about passenger preferences obtained directly from passengers. Secondly they ignore other important factors that affect passenger attitudes, for example, in relation to operating or code-share flights, scheduling preferences for connecting flights and ideal time allocations at airports and between sectors of multi-leg itineraries. The methodology adopted here and described in the next section aims to overcome these significant shortcomings by adopting a more passenger-centric approach. Moreover this method brings greater flexibility, as it can be used just as effectively on a route-by-route, country-by-country or region-by-region basis, with a focus on either comparative airline or airport performance.

3. METHODOLOGY

3.1 Data Sources

The methodology for this research involved combining information obtained directly from the schedules of airlines and a passenger survey to inform the schedule convenience measures. For the schedule data, IATA’s Schedule Reference Service (SRS) database, which is designed to fulfil the data requirements of airlines, global distribution systems (GDSs) and airports, was used. This contains information of passenger and cargo schedules of more than 900 airlines worldwide, representing more than 99.9% of the air segments flown every day. This specific analysis is based on 115,711 flights (52,867 operating flights and 62,844 codeshare flights) for a final week in June 2016 as detailed in SRS.

The passenger survey was undertaken in 2015 at nine global airports (New York, Delhi, London, Istanbul, Dubai, Geneva, Frankfurt, Hong Kong and Johannesburg) with a total sample size of 962. The number of respondents was evenly split between the nine airports with the smallest sample of 98 at Delhi airport and the highest sample size of 114 at Hong Kong airport. The survey was undertaken in the departure areas of the airports, with a paper self-completion questionnaire, at different time intervals and different days of the week over the January-March period to encourage diversity within the respondent set.

Following on from the literature review, the basic attributes of a business trip itinerary with regards to schedule convenience were identified and grouped into three categories, namely core, time- and product- related factors. The core attributes involved gathering basic schedule information obtained directly from SRS such as direct or connecting flights, and operating or codeshare flights. However, in order to determine the quantitative relationship concerning preferences between a direct and connecting flight as well as an operating and codeshare flight, questions regarding the passenger's willingness to pay different levels of fare for each option were asked in the passenger survey. As expected, this found that travellers were willing to pay more for direct flights than for connecting services, with their willingness to take a codeshare flight was lower than for an operating service. The time-related measures, which were also directly obtained from airline schedules, were journey time, flight time and connecting time (t_{total}, t_{flight}, t_{conn}), with the journey time being equal to the sum of the other two measures.

The product-related factors were mostly measured with the survey of passenger preferences. In order for the responses to be included into the accepted respondent set, two criteria were tested: (i) The respondents had to have flown within the past 12 months and (ii) they had to report at least some interest in schedule convenience (e.g. listing this as a factor that influenced their choice of flight). Overall within the sample there was a broad spread of return trip frequency in the last 12 months (1=19%; 2=23%; 3-5=36%; 6-9=15%; 10 or more=7%) with an average trip number of 4.06.

However, data for a few product-related factors were obtained directly from the SRS database. This included each airport's minimum connection time (MCT), which is the minimum time required for a passenger to leave the aircraft of the incoming flight at the connecting airport, complete the formalities and catch the next flight. Another measure, taken directly from the schedule data was the detour factor. This is the ratio between the direct and indirect connecting flights in terms of distance. The detour factor has a minimum value of 1 and as the detour ratio rises, the inconvenience of the flight increases compared to a direct flight alternative. Any flights above a detour factor of 1.75 were excluded from the analysis to avoid using remote connections. Data related to the ratio between the flight time of the two connecting flights were also gathered.

The first of the product-related attributes obtained directly from the passenger survey were the departure and arrival time quality measures (q_{dep}, q_{arr}), when passengers were asked about the attractiveness of departure time and arrival time (in terms of worst, poor, good, best) for two hour time periods in a 24 hour day/night. For example for departing flights, the best periods were 08:00 – 09:59, 18:00 – 19:59 and 20:00 – 21:59, whereas the worst were 02:00 – 03:59 and 04:00 – 05:59. Then there was the Maximum Connection Time (MaxCT). This was needed because not all connections meeting the MCT criterion are attractive for passengers and there was a need to eliminate the unattractive very long connections. The survey asked about the maximum tolerance to wait for the next flight and the average value was 290 minutes.

The survey also asked for preferences about the Time Split Ratio (q_{split}). For instance, for two competing connecting itineraries having the same flight time of 9 hours, passengers may have a preference for having 8 hours for the first leg and 1 hour for the second leg, compared to the alternative which could be an equal 4.5 hours of flight time for both legs. Flights split either at the very early or at the very late phases of the journey appeared to be the most popular. This could be more convenient as it can provide, for example, more uninterrupted sleep and in-flight-entertainment time.

Another measure is the Stress Time Factor (t_{stress}) which was computed with reference to the MCT. This is needed because this minimum time is not always favoured by passengers, as any delays with the incoming flight or any complication or inconvenience experienced at the connecting airport can increase the risk of missing the second flight. For this reason, it was assumed that passengers prefer a buffer time (t_{buffer}) (on top of the MCT at the connecting airport). This assumption was tested by the passenger survey and an average buffer value of 29.2 minutes was obtained. If the connecting time of the journey was less than the MCT plus the buffer time preferred by the passengers it was deemed stressful. The Stress Time Factor was calculated to be the difference between the connecting time and the sum of the MCT and buffer. It will be zero for direct flights (as the passenger does not use a connecting airport) and when the connecting time is greater than the MCT plus buffer time. There was also the Wasted Time Factor (t_{waste}) which, like the Stress Time Factor, was calculated with reference to the MCT and was tested through the passenger survey. Any connecting time, which is more than the MCT plus buffer time, is deemed to be wasted, but this has a value of zero if the connecting time is less, or if it is a direct flight. Therefore these definitions imply that if the connecting time at the connecting airport is not equal to the sum of the MCT and buffer time demanded by passengers, then there is either a wasted or stress time for the passengers, called the inconvenient time ($\%_{inconvenient\_time}$). If the stress time of a journey is greater than zero, the wasted time is equal to zero. Conversely, when a journey includes wasted time, then it lacks stress time.

Table 1 summarises the details about all the attributes considered in the REMSET model, the survey main findings (when appropriate) and the data sources used.

Table 1: REMSET Measures and Data Sources

Attribute (scale/unit)	Detail and results of survey (when appropriate)	Source
	Core Attributes	
Direct or connecting flight (dichotomous scale - no unit)	Direct flight from the origin to destination or connecting flight where passengers change aircraft at an intermediary airport.	Schedule data
Operating or codeshare flight (dichotomous scale - no unit)	Flight is provided by the operating airline or on behalf of another marketing carrier (i.e. a codeshare flight).	Schedule data
Value of direct vs connecting	Passenger preferences (measured by willingness to pay) Survey findings (varies by schedule	Survey

and operating vs codeshare flight (numerical continuous scale – no unit)	inconvenience/convenience): • Direct and operating service (u_{do}): 1.230 – 1.333 • Direct and codeshare service (u_{dc}): 0.864 – 0.990 • Connecting and operating service (u_{co}): 1.000 – 1.131 • Connecting and codeshare service (u_{cc}): 0.796 – 0.854	
Time - Related Attributes		
Flight time (t_{flight}) (mins)	Time spent on the flight excluding any connecting time.	Schedule data
Connecting time (t_{conn}) (mins)	Time spent at the connecting airport (zero for direct flights).	Schedule data
Journey time (t_{total}) (mins)	Total travel time between the departure from the origin airport and landing to the destination airport (flight time + connecting time).	Schedule data
Product - Related Attributes		
Minimum connection time (MCT) (mins)	Minimum time required to leave the aircraft of the incoming flight at the connecting airport, complete the formalities and catch the next flight.	Schedule data
Maximum connect time (MaxCT) (mins)	Passenger view of maximum acceptable connection time. Survey findings: Average value of 290 minutes	Survey
Detour factor (numerical continuous scale)	Ratio between the direct and connecting flight in terms of distance (minimum value is 1 for direct flights and maximum value is set at 1.75).	Schedule data
Flight time split ratio (f_{split}) (numerical continuous scale)	Ratio between the flight time of the two connecting flights	Schedule data
Departure time quality (q_{dep}) (ordinal scale with four time periods)	Passenger view of attractiveness of departure time for each time interval of the 24 hour day/night. Survey findings: 1 (Worst) → 02:00 – 03:59, 04:00 – 05:59 2 (Poor) → 00:00 – 01:59, 12:00 – 13:59, 14:00 – 15:59 3 (Good) → 06:00 – 07:59, 10:00 – 11:59, 16:00 – 17:59, 22:00 – 23:59 4 (Best) → 08:00 – 09:59, 18:00 – 19:59, 20:00 – 21:59	Survey

Arrival time quality (q_{arr}) (ordinal scale depending on four time periods)	Passenger view of attractiveness of arrival time for each time interval of the 24 hour day/night. Survey findings: 1 (Worst) → 00:00 – 01:59, 02:00 – 03:59, 04:00 – 05:59 2 (Poor) → 06:00 – 07:59, 20:00 – 21:59, 22:00 – 23:59 3 (Good) → 10:00 – 11:59, 14:00 – 15:59, 18:00 – 19:59 4 (Best) → 08:00 – 09:59, 12:00 – 13:59, 16:00 – 17:59	Survey
Time split ratio quality (q_{split}) (numerical discrete scale with five options)	Passenger preferred time split ratio between the two connecting flights of one journey. Survey findings: Passengers preferred their journey to be interrupted by the connection either at the very early or late stages of the flight - (For nine hours flying time 41% preferred first leg=8 hour/second leg = 1 hour and 35% preferred first=1 hour/second leg = 8 hours)	Survey
Buffer time (t_{buffer}) (mins)	Passenger preferred additional connecting time to the MCT. Survey findings: Average value of 29.2 minutes	Survey
Stress time factor (t_{stress}) (mins)	For connecting flights, the stress time factor is the difference between (MCT + t_{buffer}) and t_{conn}: $\text{Stress Time} = \begin{cases} 0, \text{ if } t_{conn} \geq (\text{MCT} + t_{buf} \\ \text{MCT} + t_{buffer} - t_{conn}, \text{ if } t_{conn} < (\text{M} \end{cases}$ For direct flights, the stress time factor is zero.	Calculated from other measures
Wasted time factor (t_{waste}) (mins)	For connecting flights, the wasted time factor is the difference between t_{conn} and (MCT + t_{buffer}): $\text{Wasted Time} = \begin{cases} 0, \text{ if } t_{conn} \leq (\text{MCT} + t \\ t_{conn} - (\text{MCT} + t_{buffer}), \text{ if } t_{conn} > \end{cases}$ For direct flights, the wasted time factor is zero.	Calculated from other measures
$\%_{inconvenient\_time}$ (%)	For connecting flights, the share of inconvenience time (i.e. stress or waste) within the total journey time	Calculated from other measures

3.2 Building the REMSET Model

This section now describes how the REMSET model was built, using the information from Table 1. Firstly combining the values of q_{dep}, q_{arr} and q_{split} can produce an overall schedule time convenience score for a given itinerary:

$$q_{convenience} = q_{dep} + q_{arr} + q_{split}$$

The minimum possible value of $q_{convenience}$ defines the worst possible time convenience, whereas at the other extreme, the highest value refers to the best timing. As shown in Table 1, for q_{dep} and q_{arr} the values were defined to be between 1 and 4, where 1 implies the least preferred option, whilst q_{split} has a minimum value set at zero. Therefore, the minimum value of $q_{convenience}$ can be 2 (1 for $q_{dep,}$ 1 for q_{arr} and 0 for q_{split}), while the maximum can be 8 + q_{split} (4 for $q_{dep,}$ 4 for q_{arr}).

After identifying the routing and the flight type (operating vs codeshare) of an itinerary, an index score q_{index} can be obtained. For example (as can be seen from Table 1) with a direct and operating flight, the q_{index} value will range from 1.230 to 1.333 depending on the time convenience factor, $q_{convenience}$. If the itinerary has the lowest $q_{convenience}$ score of 2, the quality value of the product would be 1.230. On the other hand, in the reverse case, if the $q_{convenience}$ is reported to be the highest, which is 8 for a direct service, then the quality value for the product would be 1.333. For itineraries with $q_{convenience}$ scores in between the lower and upper bound, the q_{index} value would result in a value more than 1.230 and less than 1.333. These values were obtained from the willingness to pay part of the passenger survey which looked at the perceived passenger value of connecting vs direct flights, and operating vs codeshare flights. The willingness to pay was indexed to 1 for an inconvenient time on an operating connecting flight.

In essence q_{index} is a function of an itinerary's routing, type and $q_{convenience}$ scores. However the q_{index} score is not a leg based metric assessing the standalone quality index of the individual segments within a journey. Instead it refers to a factor that measures the quality value of the entire directional itinerary as a whole. This implies that for connecting journeys, q_{index} does not reflect the impact of an inconvenient time period within the total journey time due to stress or wasted time. So q_{index} needs to be discounted by $\%_{inconvenient}$. The factor that is obtained after the discounting is called $q_{index\_normalised}$

Finally although $q_{index\_normalised}$ is a parameter measuring an itinerary's schedule related quality, it does not take into account the relative performance in total journey time. t_{total} is a definite factor of choice for travellers, as they do not appreciate longer journey times. Therefore, the relative advantage or disadvantage of the itinerary's t_{total} needs to be incorporated into the final schedule convenience score, which is performed by adjusting the $q_{index\_normalised}$. In order to include this t_{total} into the final quality score calculation, firstly if an airline offers more than one combination of connections, total journey times of each combination are weighted with reference to the corresponding seat supply. Then the normalised quality indexes ($q_{index\_normalised}$) are discounted with reference to the shortest available product per service type to find the $q_{a\_index\_normalised}$. For each service type, the best performing airline gets $q_{a\_index\_normalised}$ equal to $q_{index\_normalised}$, where the remaining $q_{index\_normalised}$ scores are discounted with reference to $t_{total,}$ by the percentage deviation from that minimum. Through this discounting mechanism, shorter t_{total}s are rewarded. While the deviation from the minimum t_{total} increases, the adjusted normalised quality score decrease as the appreciation of the product descends in comparison to the competitors available in the market. This produces the final adjusted normalised quality score ($q_{a\_index\_normalised}$) which is a key measure of the REMSET model.

For the research in this paper, the REMSET model was used to compare the hub performance of hub airlines and their codeshare partners by using their schedule convenience scores (i.e. $q_{a\_index\_normalised}$) and frequency shares ($\%_f$) for connecting itineraries at a region-to-region level. The $q_{a\_index\_normalised}$ score of the airport can be regarded as the hub's connection quality score as it indicates the average quality score of the itineraries using the airport as a transfer point. $\%_f$ in the general REMSET model is the frequency shares connecting itineraries. It is based on all possible flights, calculated from scratch from the SRS database, which can be used for connections that fall between the MCT and MaxCT and have a detour factor of less or equal to 1.75. For this specific analysis the $\%_f$ is calculated by rebasing these general percentages with reference to the sum of connecting frequencies available at only the selected hub airports in the paper at a region to region level. $\%_f$ and $q_{a\_index\_normalised}$ include both the operating and codeshare itineraries and all flights were considered, including multiple stop ones. Since these factors are examined to assess the connectivity efficiency of the competing airline hub airports only connecting flights are included in the analysis, eliminating direct services. The connectivity index (CI), which is the capacity blended hub quality performance of the competing hub airports is calculated as follows:

$$CI = \%_f \times q_{a\_index\_normalised}$$

So CI is a numerical index that gives an overall connectivity score for airports by taking into account both the schedule convenience scores, based on passenger preferences, and the frequency shares. For this analysis, regional origin and destination (O&D) pairs associated just with Europe (Europe/Middle East, Europe/America, Europe/Africa, Europe/South Asia, the Far East and the Commonwealth of Independent States, Europe/Europe) reported in the 2016 schedules (both directions) are considered for selected hubs, as a global coverage would be too extensive for this paper. As Europe/Australia is only served one-stop in a limited manner, the Australasian continent is not included. In terms of total O&D and connecting revenue passenger kilometres (RPKs), in 2017 these five regional flows accounted for around a third of global RPKs. The Europe/Europe traffic was the largest market (37% of RPKs) followed by Europe/America (26%) and Asia/CIS (19%). The share for Europe/Middle East was 11% and Europe/Africa 7%. (Boeing, 2018) The airlines, their hubs and country location that were used for the analysis are shown in the Appendix. While determining the selected airports, major hubs in the Gulf region were chosen. Likewise, historically larger European hubs (i.e. Amsterdam, London Heathrow, Frankfurt, Munich and Paris Charles De Gaulle) served by the major three global alliances and emerging transfer points (i.e. Istanbul Ataturk and Sabiha Gokcen) were included in the sample.

4. RESULTS

4.1 Europe/Middle East

The frequency share, quality and CI (equal to frequency share x quality) scores of the competing airline hubs are reported in Table 2 for the Europe/Middle East market. The best schedule convenience score for the connecting itineraries are achieved at VIE by Austrian

Airline flights followed by ZRH which is used as the hub airport by Swiss. The central location in Europe of these airports, their compact layout giving short MCTs, and the scheduling strategy of the two airlines, helps explain why the airports achieve the highest $q_{a\_index\_normalised}$ scores. However, the frequency share is relatively disadvantaged in comparison to rival hubs in the region.

Table 2: Europe/Middle East Connectivity Scores

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
IST	30.3%	0.7685	23.29
FRA	11.9%	0.8128	9.67
DXB	8.5%	0.7354	6.25
CAI	6.9%	0.7223	4.98
VIE	4.9%	0.9093	4.46
MUC	5.2%	0.7945	4.13
CDG	6.1%	0.6747	4.12
SAW	6.2%	0.6549	4.06
AMS	4.6%	0.7786	3.58
DOH	4.5%	0.7867	3.54
ZRH	3.6%	0.8709	3.14
AUH	2.8%	0.6079	1.70
BRU	1.6%	0.8023	1.28
LHR	1.8%	0.6471	1.16
MAD	0.8%	0.6102	0.49
LIS	0.3%	0.5873	0.18

The $q_{a\_index\_normalised}$ is lowest at AUH with the geographical location of Abu Dhabi being relatively unattractive in comparison to other hubs located in Central or Eastern Europe for the itineraries in the Europe/Middle East region. Likewise, LHR, LIS and MAD are also disadvantaged with this market as their locations are not ideal for connections between Central (or Eastern) Europe and the Middle East. Moreover, the network structure and scheduling of BA together with high MCTs at LHR, results in this carrier being ranked at the bottom of the table with all three measures, together with Iberia and TAP.

The frequency share and the CI score are highest at IST, as Turkish Airlines has a significant share of the Middle East/Europe connections. Furthermore, SAW (the other airport of Istanbul and a base of the low cost carrier Pegasus) reports a considerable CI score, despite its poor $q_{a\_index\_normalised}$ score due to its high frequency score. This confirms that the geographical location of Istanbul which is located in between the two continents can be regarded as a crucial factor of connectivity within the Europe/Middle East axis. Comparing the CI scores at IST (23.29) and FRA (9.67) implies that almost 2.5 times more passengers would transfer via IST than FRA on the hub airlines and their code share partners if only flight frequency and passenger scheduling preferences are taken into account when determining flight choice.

4.2 Europe/America

The North America/Europe and South America/Europe markets are reported separately in Tables 3 and 4. Regarding the adjusted index normalised quality scores, VIE again has the best performance for North America followed by ZRH (no connections were identified for VIE for South America). LHR, MAD and CDG are found to have the best $q_{a\_index\_normalised}$ scores in the Europe/South America market.

Table 3: Europe/North America Connectivity Scores

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
LHR	19.0%	0.8002	15.20
FRA	15.6%	0.8318	12.98
AMS	16.1%	0.7174	11.55
CDG	16.0%	0.7055	11.29
MUC	7.3%	0.8444	6.16
ZRH	6.9%	0.8548	5.90
MAD	6.4%	0.7512	4.81
VIE	4.5%	0.9421	4.24
BRU	3.8%	0.8401	3.19
IST	1.9%	0.7259	1.38
LIS	1.7%	0.7144	1.21
DOH	0.8%	0.6179	0.49
DXB	0.0%	0	0
AUH	0.0%	0	0
CAI	0.0%	0	0
SAW	0.0%	0	0

Table 4: Europe/South America Connectivity Scores

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
LHR	19.9%	0.8152	16.22
MAD	17.3%	0.8005	13.85
AMS	16.2%	0.7922	12.83
CDG	14.5%	0.8012	11.62
LIS	9.4%	0.7775	7.31
FRA	7.6%	0.7421	5.64

ZRH	4.8%	0.7232	3.47
IST	2.9%	0.6883	2.00
AUH	3.0%	0.5982	1.79
DOH	2.4%	0.6223	1.49
DXB	2.0%	0.6122	1.22
MUC	0.0%	0	0
VIE	0.0%	0	0
BRU	0.0%	0	0
CAI	0.0%	0	0
SAW	0.0%	0	0

Between Europe and America (North and South), the CI score of LHR ranks the highest. The hubs in the Gulf region namely, DXB, DOH and AUH, are relatively disadvantaged in the Europe/America market due to their geographical location. It would be inconvenient for passengers to travel to the Middle East for a connection from Europe to America and vice versa. Furthermore, unlike its performance in the Europe/Middle East market, IST does not have a competitive connectivity pattern - also due to its location. Moreover, the supply advantage of British Airways, Lufthansa and Air France/KLM assist LHR, FRA, AMS, MUC and CDG in achieving higher CI scores. British Airways BA via LHR offers the highest number of connecting frequencies in the North America and, thanks to its partnership with Iberia, BA via LHR also reports the highest frequency share to/from South America. The location of London between the edge of Europe and America is a significant advantage for LHR when considering connectivity. MAD and LIS have relatively high scores, primarily explained by their location and the strong historic and cultural links with Spain and Portugal and the South American continent.

4.3 Europe/Africa

The results for the Europe/North Africa and Europe/Sub Saharan Africa markets are shown separately in the Tables 5 and 6. Lufthansa via its hubs FRA and MUC offers the largest number of connecting frequencies from/to North Africa while Air France via CDG has the highest connecting frequency share from/to Sub Saharan Africa followed by its partner KLM via AMS. Concerning the adjusted index normalised quality scores, ZRH (the hub of Swiss) has the best performance despite its lower frequency share in the entire Europe/Africa market. BRU’s $q_{a\_index\_normalised}$ ranks second following ZRH in both North and Sub Saharan Africa. This finding is in line with the business strategy of SN Brussels which involves a strong presence in the African continent.

Table 5: Europe/North Africa Connectivity Scores

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
FRA	13.6%	0.8171	11.11

CDG	15.1%	0.6856	10.35
LHR	12.2%	0.7065	8.62
IST	9.1%	0.6688	6.09
CAI	9.5%	0.6212	5.90
AMS	7.7%	0.6144	4.73
ZRH	5.3%	0.8831	4.68
DOH	5.7%	0.5998	3.42
AUH	5.4%	0.5648	3.05
MUC	3.3%	0.8005	2.64
VIE	2.9%	0.8611	2.50
BRU	2.0%	0.8651	1.73
MAD	2.4%	0.6612	1.59
SAW	2.7%	0.5544	1.50
DXB	2.3%	0.5212	1.20
LIS	0.8%	0.6713	0.54

Table 6: Europe/Sub Saharan Africa Connectivity Scores

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
CDG	20.4%	0.6968	14.21
AMS	21.3%	0.6504	13.85
BRU	12.2%	0.7402	9.03
IST	11.3%	0.6159	6.96
FRA	7.6%	0.7095	5.39
LHR	5.0%	0.6903	3.45
CAI	4.6%	0.6829	3.14
DOH	5.2%	0.5984	3.11
AUH	4.1%	0.6146	2.52
MUC	2.8%	0.6922	1.94
DXB	2.4%	0.5407	1.30
ZRH	1.4%	0.7499	1.05
MAD	1.1%	0.5894	0.65
VIE	0.4%	0.5225	0.21
LIS	0.2%	0.5357	0.11
SAW	0.0%	0	0

The superiority of Turkish Airlines over Emirates in transfer opportunities is verified in Tables 5 and 6 as IST's $\%_f$ scores are greater than those of DXB. Additionally, in the Europe/Sub Saharan Africa market, DXB's $q_{a\_index\_normalised}$ score is inferior to the connectivity index of AUH although both airports are located in the same country and are only 123 kilometres away from each other. Therefore, although the $q_{a\_index\_normalised}$ is influenced by the geography of the airports, it is clearly not the sole parameter that shapes the connection quality of the hub airport, which will also be clearly affected by factors such as the layout and design of the terminal, its utilisation, and the scheduling strategies of the airlines.

4.4 Europe/South Asia, the Far East and the Commonwealth of Independent States (CIS)

In the Europe/South Asia and Far East market, Austrian Airlines via VIE has the best $q_{a\_index\_normalised}$ score again, whilst Turkish Airlines via IST has the highest $\%_f$ share and CI score as shown in Table 7. The CI scores of the top-ranking airports are not far from each other, and the dominance of the Gulf hubs (DOH, DXB) and IST in the market is apparent. DOH has a higher score than DXB which could perhaps be due to more optimal scheduling by Qatar Airlines and/or more congested facilities at DXB. ZRH again has a relatively superior $q_{a\_index\_normalised}$ score in comparison to many other European hubs while CDG and BRU do not report a competitive quality score. The quality scores of FRA, MUC and AMS are found to be very similar to each other. Although CAI has an attractive $q_{a\_index\_normalised}$ score like VIE, the airport has a very low CI score due to its inadequate level of traffic in comparison to the rival hubs.

Table 7: Europe/South Asia and Far East Connectivity Scores

Airport	$\%_f$	$q_{a\_index\_normalised}$	CI
IST	13.7%	0.8670	11.88
DOH	12.7%	0.9089	11.54
DXB	13.5%	0.8112	10.95
FRA	12.7%	0.8191	10.40
AMS	12.2%	0.8150	9.94
LHR	10.4%	0.8008	8.33
AUH	8.6%	0.8056	6.93
CDG	7.4%	0.7669	5.68
ZRH	5.0%	0.8583	4.29
MUC	1.8%	0.8022	1.44
MAD	1.1%	0.6204	0.68
BRU	0.9%	0.6500	0.59
VIE	0.6%	0.9666	0.58
CAI	0.5%	0.9128	0.46
LIS	0.2%	0.4974	0.10
SAW	0.0%	0	0.00

The results for the Europe/CIS route are shown in Table 8. Turkish Airlines via IST and Lufthansa via FRA have a significant advantage in the market due to their large frequency share in comparison to rivals. Additionally, IST has the highest $q_{a\_index\_normalised}$ in the market followed by VIE. Primarily due to their relative geographical inconvenience, MAD and LIS and the hubs in the Gulf region do not have competitive connectivity indexes.

Table 8: Europe/CIS Connectivity Scores

Airline	%f	$q_{a\_index\_normalised}$	CI
IST	33.1%	0.9086	30.07
FRA	24.7%	0.8765	21.65
CDG	6.7%	0.8007	5.36
AMS	6.4%	0.7763	4.97
SAW	6.3%	0.7321	4.61
MUC	4.2%	0.7654	3.21
ZRH	3.8%	0.7965	3.03
VIE	2.8%	0.8128	2.28
LHR	3.0%	0.7569	2.27
CAI	2.8%	0.5609	1.57
BRU	1.7%	0.7075	1.20
DXB	1.6%	0.6769	1.08
AUH	1.0%	0.6534	0.65
MAD	0.7%	0.6412	0.45
DOH	0.6%	0.6888	0.41
LIS	0.2%	0.5976	0.12

4.5 Europe/Europe

With the intra-European connections, the results are overwhelmingly influenced by the domestic flights as shown in Table 9. Indeed the connections are dominated by the Lufthansa group due to its relatively larger domestic market. Additionally, the central location of FRA and MUC in the European continent is another advantage for those airports in achieving comparably higher CI scores. As expected, the hubs in the Gulf region cannot report a CI score due to the geographical inconvenience. In terms of the $q_{a\_index\_normalised}$ scores, ZRH ranked top, followed by VIE and MUC.

Table 9: Europe/Europe Connectivity Scores

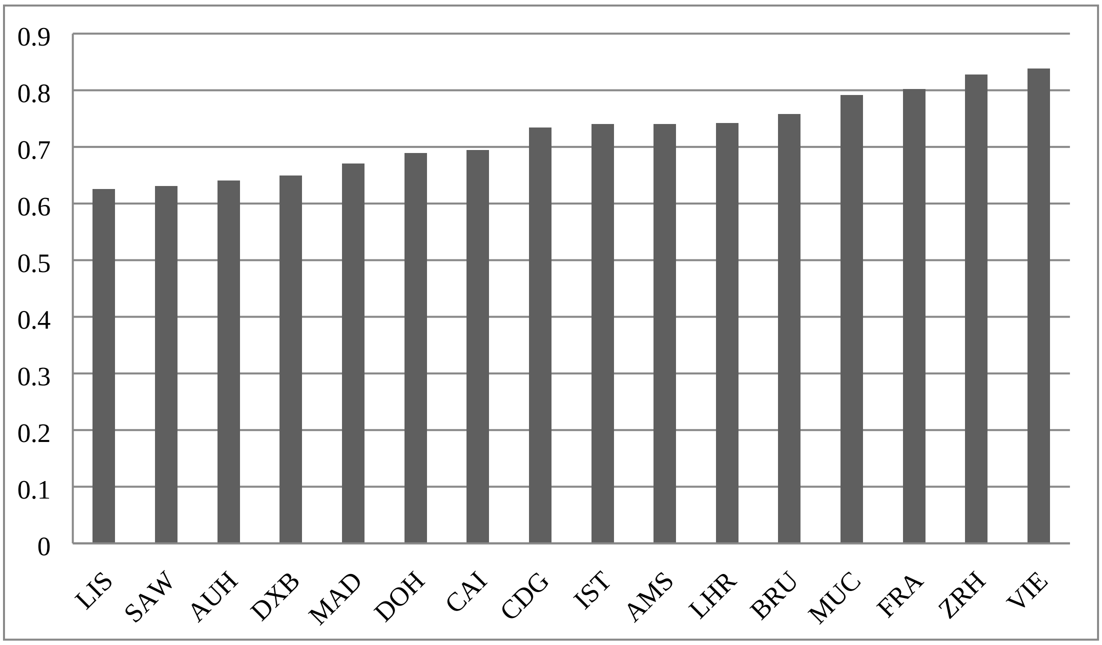
Airline	%f	$q_{a\_index\_normalised}$	CI
FRA	31.2%	0.8043	25.09
MUC	14.0%	0.8432	11.80
CDG	12.3%	0.7421	9.13
ZRH	8.8%	0.8821	7.76
AMS	9.2%	0.7766	7.14

LHR	8.1%	0.7224	5.85
VIE	5.0%	0.8511	4.26
IST	4.6%	0.6761	3.11
MAD	3.1%	0.6912	2.14
BRU	1.7%	0.7021	1.19
LIS	1.1%	0.6222	0.68
SAW	0.5%	0.5831	0.29
CAI	0.4%	0.6652	0.27
DXB	0.0.%	0	0
AUH	0.0%	0	0
DOH	0.0%	0	0

4.6 Europe/Worldwide

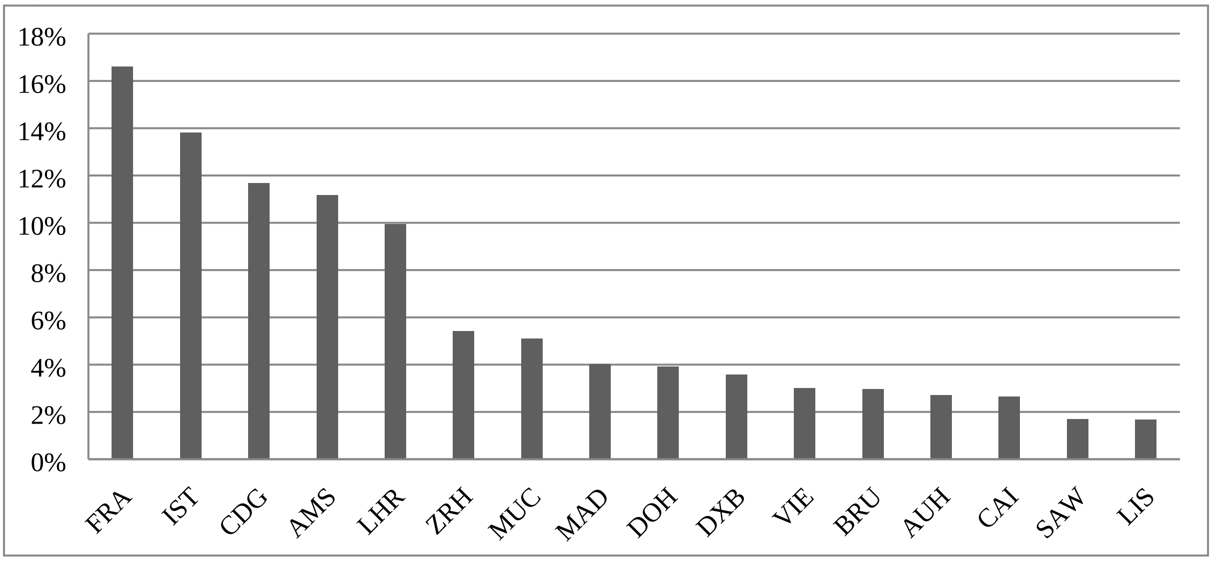
By using the calculated $q_{a\_index\_normalised}$ scores referred in the tables above, it is possible to develop the aggregate Europe/worldwide quality index score of the competing hubs. This has been achieved by simply averaging the quality index (Figure 1). VIE and ZRH have the best average $q_{a\_index\_normalised}$ scores while the hubs of Lufthansa, namely FRA and MUC, rank third and fourth respectively. LHR, AMS, IST and CDG are placed at the middle rankings as the competitiveness of these hubs in $q_{a\_index\_normalised}$ scores vary depending on the specific market. Interestingly, all the five top hubs are served by the Lufthansa group. The Gulf hubs rank lower primarily due to their geographical location. These relatively lower $q_{a\_index\_normalised}$ scores for the Gulf hubs do not necessarily imply that these airports lack good quality connections everywhere. Indeed whilst they are not in an ideal location for connections with Europe/America or Europe/Africa, they can, however, offer better connection quality in other markets. MAD and LIS also have low values, reflecting their relatively weak competitive position with the exception of the American markets. In addition, SAW ranks second to last which demonstrates the difficulty that the predominantly point-to-point low cost carrier Pegasus has in competing for transfer traffic with Turkish Airlines even though they serve the same location.

Figure 1: Worldwide (Europe/World Market) Average $q_{a\_index\_normalised}$ Scores



In order to observe the effect of frequency on connectivity of the hubs in the Europe/World market, it is possible to calculate the percentage CI (denoted as $\%_{CI}$) of each airport. $\%_{CI}$ is calculated by summing each airport's CI values in Tables 2 to 9 and then dividing this with the total sum of all CIs. Therefore, the $\%_{CI}$ of an airport refers to its share of the CI scores in the selected markets and is shown in Figure 2. FRA has the highest share of $\%_{CI}$ followed by IST and CDG. Despite their advantage with the $q_{a\_index\_normalised}$ scores VIE and ZRH cannot report higher $\%_{CI}$ shares as these airports are relatively disadvantaged in terms of their frequency supply. As expected, the Gulf hubs have a lower $\%_{CI}$ below 4%, primarily due to their geographical position.

Figure 2: Worldwide (Europe/World Market) $\%_{CI}$ Scores



5. CONCLUSIONS

The overall aim of this paper has been to undertake a comparative analysis of the competitiveness of airline schedules and networks from a business traveller perspective with a particular focus on Europe and travel to and from this continent. In achieving this aim the analysis has reflected not only on comparative network or hub airport performance, but also on the connection effectiveness of the airlines using these airports as their hub location. These are crucial factors that business travellers take into account when choosing specific air services. Using the REMSET model, the $q_{a\_index\_normalised}$ score of the itineraries has been used as a metric of connectivity quality, while $\%_f$ was used to reflect the volume of traffic in terms of frequency at the hub airport. Together these are used to produce the connectivity index (CI) of the airports which assesses the capacity blended hub quality performance.

Overall, although VIE and ZRH appear to offer 'high-quality' connections, the carriers using these airports as hubs (Austrian and Swiss respectively) are disadvantaged in their volume of supply which results in their CI scores being relatively small in comparison to their rivals. IST is found to be a competitive hub for Europe/Middle East and Europe/Far East connections whereas the hubs in the Gulf region are found to be attractive for the Europe/South Asia and Far East markets. Furthermore LHR is relatively competitive for both Europe/North America and Europe/South America connections. Moreover, the Air France/KLM group is found to be relatively active in the Sub Saharan Africa market although BRU's performance is notable in this region too. Geographic location of the hubs is an essential component of their $q_{a\_index\_normalised}$ and CI scores. For instance, the hubs in the Gulf region such as DXB, AUH and DOH are relatively disadvantaged in the Europe/America market due to the higher detour ratios, as are LIS and MAD with the regions east of Europe.

Although the methodology used in this paper is different from the Netscan model used by ACI Europe (2018), the overall worldwide CI results are fairly similar. Amongst European/Middle Eastern hubs, the Netscan model ranks Frankurt first followed by AMS, CDG, IST, LHR, MUC, DOH, DXB, SVO (Moscow – not included) MAD, MXP (Milan – not included) and ZRH. The comparative ranking with this research are FRA, IST, CDG, AMS, LHR, ZRH, MUC, MAD, DOH and DXB. Likewise the research here agrees with Logothetis and Miyoshi (2018) who find that Turkish Airlines with their Istanbul hub provide more transfer opportunities between Europe and Africa and America than Emirates. However, by contrast these authors find Emirates/DXB to be superior to Turkish/IST in the Asia-Pacific market whereas with this research IST is ranked top in CI terms (albeit that DXB comes a close third).

These similarities arise primarily because of the frequency share component in the connectivity measure. However what this research shows, which is missing in other research, is the consumer-centric perspective regarding schedule convenience, namely the $q_{a\_index\_normalised}$ factor. This unique measure identifies the connection and schedule quality of an airline for any given route or routes taking into account passenger priorities and preferences. The research has thus conceptualised the comparative and competitive advantages of airline schedule and network design from the passenger viewpoint and made a significant and distinctive contribution to knowledge and theory in this area.

However, a potential limitation with the application of the REMSET model in this specific case is the possibility of any bias within the survey. To minimise any bias the wording of the questions were carefully designed, as was the survey implementation plan at the airports. The sample was considered adequate in terms of size and diversity even though it was not possible for practical reasons to use a totally representative sample with a random selection method. However the issue of any bias within the sample could be addressed with additional surveys, with the value of certain variables revised if necessary. Nevertheless this does not undermine the major significance of this research and its role in developing a new and innovative consumer-centric methodology to assess passenger schedule convenience.

Clearly, the research has considerable practical implications. The results can be used by individual airlines to assess their competitive position in different regions, analyse the efficiency of their network investments, and as an input into future scheduling decisions. In particular, the reasons for the top performance of ZUR (Swiss) and VIE (Austrian Airlines) in terms of schedule convenience could be investigated further and potentially used as an example of best practice. One possible general influencing factor might be the level of competition as it could be argued that if there is less competition (e.g. in terms of a higher frequency/seat share for certain airlines, or less airlines serving the market with connections) then there would be less incentives for the airlines in more limited competitive situations to design or fine tune their network/schedules to produce ‘quality’ connections. However a visual examination of the relationship between $\%_f$ (as a measure of competition) and quality scores shows no obvious link between the two, although this could be investigated further.

The flexibility of the REMSET model means that the findings that have been produced on a region to region basis can be expanded to include more airports or airlines or further investigated at a more disaggregate level, such as country to country basis or airport to airport basis, for example to measure the impacts of additional frequency, changing departure times or code-sharing with partner airlines, albeit that this is beyond the scope of this paper here due to length constraints. In fact the REMSET model can be used to assess schedule preferences for any itinerary as long as the schedule information has been included in the specific schedule database that is being considered. The research also has implications for airport management who can assess their comparative position for connections in different markets which can have consequences, for example, in how they market themselves to airlines and passengers, or plan for connecting flights.

Having a focus on business passenger, this paper has concentrated on schedule convenience which is an important choice factor for such passengers. For pure leisure travellers, the influence of fare is likely to be far more significant and so adopting this approach for these travellers needs to be undertaken with much more caution. Whether dealing with either business or leisure travel, it needs to be recognised that to achieve a total picture concerning choice factors (including other drivers such as fares, load factors, seat availability, airline competition) would be more appropriately dealt with techniques such as passenger choice models, but this was not the purpose of this research. Meanwhile the REMSET model could be suitably developed to provide even further insight into the consumer's view of schedule convenience by considering factors such as airport connecting facilities and airport preferences. It could also be used more extensively by considering different years to assess how the airline networks are evolving and in addition network centrality measures (e.g. degree, closeness, betweenness, eigenvector) could be calculated to provide further insightful connectivity comparisons.

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Appendix: Airports and their Hub Airlines used in the Research

Airline	Airport	Country
Air France	Paris Charles De Gaulle (CDG)	France
KLM	Amsterdam/Schiphol (AMS)	The Netherlands
British Airways	London Heathrow (LHR)	United Kingdom
Lufthansa	Frankfurt International (FRA)	Germany
Lufthansa	Munich International (FRA)	Germany
Swiss	Zurich Kloten (ZRH)	Switzerland
Austrian Airlines	Vienna Schwechat (VIE)	Austria
Iberia	Madrid Barajas (MAD)	Spain
TAP Air Portugal	Lisbon Humberto Delgado (LIS)	Portugal
Turkish Airlines	Istanbul Ataturk (IST)	Turkey
Pegasus Airlines	Istanbul Sabiha Gokcen (SAW)	Turkey
Emirates Airline	Dubai International (DXB)	United Arab Emirates
Etihad Airways	Abu Dhabi International (AUH)	United Arab Emirates
Qatar Airways	Doha Hamed (DOH)	United Arab Emirates
EgyptAir	Cairo International (CAI)	Egypt