Characterisation of Airline Networks: a North American and European Comparison

Aisling Reynolds-Feighan[1]
School of Economics, University College Dublin,
Belfield, Dublin 4, Ireland
Email: aisling.reynolds@ucd.ie

Abstract

This paper compares and contrasts the North American and European air transport markets using the extensive OAG Databases. The pattern of network development in the two continental regions is examined using data for the period 1996- 2008. The top 10 carriers in both regions are analysed closely in terms of network structures and the basic geographical characteristics of these networks are highlighted. In addition, different measures of air transport activity such as seating capacity, number of movements and number of routes are compared. Visualisations of carrier networks are presented to highlight the different network strategies operated by low cost carriers and full service carriers. It is shown that European carrier networks display many significant differences to North American carrier networks. European carriers generally organise their networks around one or two key nodes within the member state in which they are registered and generally do not operate interactive, continental-wide, multiple hub-and-spoke networks as do North American carriers. European and North American low cost carriers operate much more interconnected networks than full services carriers. Southwest Airlines stands out as operating a highly interconnected network compared to all other carriers.

[1] Funding for this research was provided by the Irish Research Council for the Humanities and Social Sciences (IRCHSS). Thanks to David Pitfield and Kieran Feighan for very helpful and insightful comments on earlier versions of this paper.

Key words: airline networks; hub-and-spoke network; network visualisations; low cost carriers; full service carriers.

Introduction

This paper focuses on characterising airline networks using data derived from the comprehensive OAG Historical Max Plus databases over the period 1996 to 2008. In the paper, descriptive statistics and summary measures of activity for the North American and European air transport markets are presented in order to compare the two markets at a macro-level as well as at the firm–level, using individual airline traffic information. The focus on carrier network structure attempts to capture aspects of carrier production plans and traffic flow organisation and thus represent measures of airline technology. Deregulation or liberalisation of air transport services has resulted in significant changes in the manner in which airlines operate and organise traffic flows through their networks. As the process of liberalisation continues apace in all continental regions of the world, it is important to examine the ways in which carrier networks are evolving and adapting to the new market environments.

The pattern of network development in the two continental regions will be examined using data for the period 1996- 2008. The top 10 carriers in both regions will be examined closely in terms of network structures and the basic geographical characteristics of these networks will be highlighted. In addition, different measures of air transport activity such as seating capacity, number of movements and number of routes will be compared. Some conclusions on the differences and similarities between European and North American airline network structures will be outlined in the conclusions.

1. Approaches to characterising network structure & organisation

Network structure is a critical aspect of firm behaviour for transportation service providers. The network represents the carrier's production plan and also the carrier's product offerings. The unit of supply for the carrier is a single airline movement. The unit of demand is smaller and heterogeneous. Passengers, or travel agents on their behalf, may purchase origin-destination flight services by joining together non-stop air transport movements offered by one or more carriers. Thus passengers on a given flight may be consuming that service in isolation, or as a complementary or substitutable service to other flights within the same or another carrier's network. Passengers can connect between flights and the costs of such indirect services may be spread between the passenger, the airport and the airline in varying degrees depending on the strategies, preferences and costs to these three actors in the market[2].

In the US shortly after deregulation in the late 1970s for example, carriers organised their networks with high levels of passenger connections at so-called 'hub' airports. This enabled carriers to greatly expand their product offerings (in terms of the origin-destinations pairs served) with relatively modest increases in the number of flight segments offered. The surviving US carriers of 2008 have expanded greatly in size in the last three decades, with a small number of very large carriers now carrying the dominant share of domestic and US-originating international traffic. Carriers have

[2] Keeping track of how passengers might travel between an origin-destination pair can be quite involved. For example, in the US Department of Transportation T-100 databases, the following types of scheduled air services are distinguished: (i) Non-stop service where the aircraft takes off from the passenger's origin point and lands at the passenger's destination point (ii) Connecting service, where the passenger changes aircraft between the origin and destination (iii) Offline Connection where the passenger changes aircraft and airline (iv) Online connection where the passenger changes aircraft but not airline (v) Direct service may be a 0, 1 or multiple stop service, but the passenger does not change aircraft (vi) Change of gauge, where the passenger changes aircraft but since the flight number does not change, it is not considered a connecting service. An excellent guide to US DOT airline data terminology may be found in the DataBase Products O&D Training Manual (2008) at www.airlinedata.com.

increased their total capacity through increasing frequency of service and expanding the number of non-stop flight segments offered. The greatly expanded volume of traffic has lead to increasing congestion at many large and medium airports. New entrant competitors, particularly the low-cost carriers (LCCs) offer direct or multistop services in competition with incumbent carriers direct and indirect service offerings. The LCCs in many instances have focused their network expansion on secondary airports in many of the larger urban areas.

Outside North America, liberalisation of air transport has been taking place at varying temporal and geographical scales. International agreements liberalising air transport movements between major continental air transport systems have been negotiated with increasing pace in the last decade.

Several studies have analysed European network structures using similar approaches and assumptions relating to the structure and motivations of European carriers (see for example Brueckner and Pels (2004), Berechman and deWit (1996) and Burghouwt et al (2003)). In these studies, European flag carrier networks are presented as broadly similar to US carrier networks in terms of the concentration in space and time of traffic flows in hub-and-spoke networks. However detailed comparative analyses of the structure and organization of traffic flow in European and North American airline networks have not been undertaken to date to validate the implicit assumptions that there are broad similarities between the two continental air transport systems and their carriers. Reynolds-Feighan (2008) presented a preliminary analysis of US and European Union Carriers and highlighted several key differences between the two

groups of carriers. In this paper, analysis is broadened to compare North American[3] and European[4] carriers and air transport systems using a variety of traffic measures. Seating capacity, aircraft movements and route structures at carrier airports are compared and contrasted. The geographical orientation of carrier networks are also focused and compared.

2. Comparison of North American and European Air Transport Systems

The Official Airline Guide 'OAG Max Historical Plus databases' contain daily airline schedules for every airline in every country. The database facilitates the generation of annual traffic distributions by carrier and airport for any given year. In this study, the annual traffic flows were generated for the North American market (NA) (traffic by NA and non-NA carriers originating from all airports within NA, whether or not the destinations were NA based) and the European market (as defined earlier). Scheduled and non-scheduled movements and seats available on market segments with two or less stops, serviced by all categories of jet aircraft (including regional jets) are included. Airports and carriers with at least 1,000 seats in a one year period are counted.

The datasets are very large and are available in January each year for the proceeding year's actual schedules. Annual data series were generated from the daily schedules

[3] North America consists of Canada, USA, Greenland and Saint Pierre and Miquelon.

[4] Europe is broadly defined and includes Austria, Belgium, Denmark, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, Cyprus, Turkey, Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Belarus, Croatia, Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Macedonia (Former Yugoslav Republic), Moldova Republic of, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovenia, Slovakia, Ukraine. This categorization of Europe is based on IATA definitions of the region.

for all air transport services transporting passengers on jet equipment for all airports and carriers worldwide. A traffic matrix detailing every carrier and airport for each continental region was constructed for each of the years 1996 to 2008. Using the results of the annual data series allows construction of route adjacency matrices for each airline operating in the NA and European market in a given calendar year. The use of annual series removes errors or bias associated with monthly or seasonal variations in flight services. The inclusion of all jet services, including regional jets gives a comprehensive view of the industry particularly in North America where increasing proportions of services are provided using these aircraft. The OAG Max Historical Plus databases allow for direct comparison of NA and European air transport sectors because these data are drawn from a single comprehensive census of flight schedules.

Table 1 shows the number of carriers and airports and total air traffic activity for Europe and North America in 1996, 2000, 2004 and 2008, derived from the OAG databases. The North American market is considerably larger than the European market though the difference in size has narrowed significantly in the last 12 years. The North American market had 86% more movements than the European market in 2008, and 44% more seating capacity. This difference is explained by the increasing use of regional jets by North American carriers in the five years.

The steady increase in the number of airports receiving jet air services in Europe from 1996 onwards is noted. There were 81 more airports in Europe receiving jet air services in 2008 than were receiving such services in 1996. The process of European air transport liberalisation reached a critical phase in April 1997 with the full

liberalisation of domestic (cabotage) and cross-border air services within the single European market. Seating capacity increased by a very substantial 4% per annum over the period 1996 to 2008 in the larger European area considered in this study. The increase in movements was slightly higher, giving rise to a decline in the number of seats per movement in the period 1996 – 2004, with average seats increasing again in the 2004-08 period. The number of carriers grew rapidly also in the 1996-2004 period, but has sharply declined in the last four years. The total number of carriers in Europe is still substantially greater than the number operating in North America.

In North America, new entrants provided service to the industry in the 1996-2000 period, but due to consolidations and financial failures, the total number of jet operators has fallen again to 37 in 2008. The number of North American airports receiving jet services increased in the 2004-2008 period, with the average aircraft size (number of seats per movement) falling rapidly in the same period. This reflects the growing emphasis on regional jet service by the larger carriers. While the total volume of air transport movements increases particularly in the 2000-2004 period, the overall seating capacity fell by 10% between 2000 and 2008.

3. Comparison of North American and European Top 10 Carriers, 1996-2008

The top 10 carriers in Europe and North America were selected for each of the years 1996, 2000, 2004 and 2008 in order to compare individual carrier changes in the two continental systems. The airline codes used in the figures and tables are set out in the appendix at the end of the paper. Figures 1 and 2 summarise the activity of the 20 carriers in 2008. In Figure 1, the total departure seating capacity of carriers in 1996

and 2008 are shown. Figure 2 shows aircraft movements as well as the number of airports served for each of the top 10 carriers in 2008. North American carriers are significantly larger than European carriers in 1996 and 2008; there are many smaller carriers with much smaller capacity operating in Europe as was seen in Table 1. Since deregulation in the US in the late 1970s, there has been considerable consolidation in the industry despite several waves of new entrants to the market in the 1980s and early and late 1990s. The seating data and movements data present very similar trends.

The network size of North American carriers is also generally larger than European carriers, though the North American LCCs, Southwest (WN) and AirTran (FL) have a smaller network of airports than all of the European carriers. Three of the top 10 carriers in Europe in 2008 were LCCs, namely Ryanair (FR), Easyjet (U2) and Air Berlin (AB). In Figure 1 in 1996, there were 4 European carriers (Alitalia (AZ), Aeroflot (SU), Air Inter (IT) and Swiss Air (SR)) in the top 10 that have since been surpassed in terms of traffic by the LCCs, no longer operate or have been taken over by other carriers. Alitalia experienced a significant fall in seating capacity between 1996 and 2008, placing it outside the top 10 in 2008. Three of the larger European FSCs, Lufthansa (LH), Air France (AF), and SAS (SK) increased their seating capacity during the same period. For the North American carriers, Continental (CO) and Delta (DL) recorded a significant fall in their seating capacity between 1996 and 2008. Southwest stands out clearly as the only carrier in the North American top 10 to substantially increase its capacity in this time period.

Figure 3 shows the proportion of traffic at the busiest airport in each carrier's network in 2008, and between 1996 and 2008. Generally, the European carriers have a higher proportion of their total seating capacity departing from their top hub or operational base. Despite liberalisation in Europe, most of the former flag carriers still have single hub networks focused around their national capital or largest city airports. The exceptions are the European LCCs, where between 10 and 15% of total seating capacity is operated from the top ranked airport in the carrier's system.

Between 1996 and 2008, the share of total traffic at the top airport increased for North American FSCs. For four of the European flag carriers, KLM, Turkish Airline, Iberia and BA, the share of traffic at the top airport also increased. The LCCs in both regions experienced significant change with a substantial fall in the traffic share of the top airport in the networks of AirTran, Ryanair and Easyjet and Southwest Airlines. Southwest Airlines stands out as following a different trend with by far the lowest proportion of total traffic at the carrier's top airport and a decline in that proportion between 1996 and 2008. TWA (TW) and AmericaWest (HP) were among the top 10 carriers in North America in 1996, with TWA having the highest proportion of total traffic at its St Louis (STL) hub in that year. TWA was taken over by American Airlines in 2001 and much of the TWA transfer traffic was rerouted through American's secondary hub at O'Hare Airport in Chicago (ORD).

The LCCs in Europe and North America were much smaller in 1996. For AirTran (FL), Easyjet (U2) and Ryanair (FR), these carriers had a considerably higher share of their total traffic departing from their top airport in 1996 than for 2008. As these

carriers have grown and expanded their networks, they have tended to spread their capacity and routes more evenly across other airports in their networks.

Figure 4 shows the average number of seats available per passenger aircraft movement among the top 10 carriers in 1996 and 2008. As was seen in the aggregate data in Table 1, European carriers generally have a higher number of passengers per movement than North American carriers. There was a fall in the average seats per movement between 1996 and 2008. In North America, there is smaller variation among the top 10 carriers in the average number of seats per movement, with Southwest (WN) and AirTran (FL) having the highest and third highest levels in 2008 respectively. The growing emphasis on regional jets to increase service frequency among North American carriers can be observed clearly for carriers like Delta (DL), Northwest (NW), Continental (CO) and American Airlines (AA).

4. Carrier network structures – a comparative analysis

In order to explore differences in network structure between the European and North American carriers, the top airports in each carrier's network were identified and the intervening physical distances were recorded. Figure 5 summarises this information for the top two airports for North American and European carriers, while Tables 2 and 3 report on the top five airports for each of the carriers. Table 2 gives information on the location, percentage of total departure seating capacity and number of routes from each European carrier's top five airports in 1996 and in 2008. Table 3 gives the same details for North American carriers.

In order to highlight spatial aspects of network structure and organisation, Figures 6 and 7 map the top five airports in selected European and North American carriers' networks in 2008. The European carriers generally tend to focus their networks around two airports within the member state in which they are registered. For Air France and BA for example, the top 2 airports are located in the capital cities of Paris (CDG and ORY) and London (LHR and LGW). Indeed for Air France, the top 9 airports in its system are French mainland airports, while for BA, 6 of the top 8 are located in the UK. There is some specialisation in the types of services operated from the top two airports, but both carriers operate a mix of short haul and long haul international services from their top two airports.

Easyjet as a relatively new European LCC follows the same pattern, with its top 2 airports located in London at Gatwick (LGW) and Luton (LTN), and its top 5 airports located in the UK (see Figure 6). For BA, Air France (AF) and Easyjet (U2), there are no flights between the top two airports in their networks. Air Berlin (AB) is the second of three LCCs in the European top 10 and this carrier too has four of its five top airports in Germany, where it is registered. Air Berlin's top airport is Palma Mallorca (PMI) and just less than 8% of total airline seating capacity is allocated to the Palma (PMI) – Dusseldorf (DUS) route.

As can be seen in Figure 6, Lufthansa (LH), Turkish Airlines (TK) and Iberia (IB) have most of their top airports within their home state. For the selected European carriers, the clustering of top airports within the national territory is very clear. The relatively short distance between top airports in Europe contrasts sharply with the continental wide spread of top airports in North American carrier networks in Figure

7. For SAS (SK), because this airline was established as the jointly owned airline for the three Scandinavian countries, Norway, Sweden and Denmark, the top five airports are located in three different states. Traffic and routes are distributed evenly across the top three airports – one in each of the Scandinavian countries. Geographically however, the top three airports are still very close to each other.

KLM (KL) is a relatively large carrier from a relatively small European state and its single national hub is the focus for its route and traffic network. Amsterdam accounts for 48% of all of KLM's departure seating capacity, with the airline's second ranked airport (in terms of seating capacity), London Heathrow (LHR), having just one route to Amsterdam.

Ryanair (FR) is the only top 10 European carrier to have its top airports spread across multiple states. The distribution of capacity across the top five airports is more even than for most other European carriers.

In general then, the European carriers operate regional networks focused on their home state markets and link the state capitals or largest cities to domestic, European and long haul international destinations. Two of the three LCCs operate a similar strategy to the former European flag carriers.

The North American carriers have much greater distances between their top two airports and for most FSCs, this reflects the fact that traffic is organised around regional hubs, with high volumes of traffic between hubs in the network. The surviving North American FSCs of 2008 have become very large airlines, with most

of the top 10 carriers having undergone mergers or takeovers in the last 10 years. The data in Tables 1 and 2 relate to the calendar year of 2008: In Late October 2008, Delta Airlines merged with Northwest Airlines and will complete reorganisation, integration and rebranding under the Delta banner by 2010. United Airlines had been in merger talks with US Airways and later Continental Airlines during 2008. To date (June 2009), no merger has been agreed.

In 2002, following the takeover of TWA by American Airlines (AA), the carrier's third ranked airport was Lambert Field, St Louis (STL), the former TWA hub. This airport's traffic was reorganised in the following two years, so that by 2004, St Louis ranked 8th busiest airport in American Airline's system. In Table 3, it is noted that American Airline's top 5 airports are the same in 1996 and 2008: hiding the absorption and re-organisation of traffic flows in the intervening years following the 2001 TWA merger. Air Canada took over Canadian Airlines in 2001 and the new entity grew traffic at the top five airports listed in Table 2. Canadian Airlines had focused its network around four of these five airports. The number of routes operated from Air Canada's top airport has increased from 63 in 1996 to 105 in 2008.

Between 1996 and 2008, all but two of the top 10 carriers in North America increased the proportion of total seating capacity at their top airport. The exceptions were AirTran (FL) and Southwest Airlines (WN). Traffic at AirTran's top five airports accounted for 29% of seating capacity in 1996, with this value dropping to 25.6% in 2008. For Southwest Airlines, three of the top five airports changed over this period and the number of routes operated from the top five in 2008 were the same (62) for four of the five airports. Baltimore, the fifth airport, had 60 routes in 2008. In Europe

also, the LCCs, Ryanair and Easyjet recorded a decline in the proportion of traffic at their top 5 airports, as both carriers rapidly and extensively expanded their networks in the 1996-2008 period.

Reynolds-Feighan (2007) noted that deregulation in the US in the late 1970s had resulted in a sustained contraction in the network of airports receiving jet services. In the European Union, liberalisation resulted in a substantial expansion in the number of airports receiving jet services. The European national or flag carriers had focused on developing single or dual national hubs that connected the home country with European and worldwide destinations. The North American carriers by contrast focused on developing domestic networks, serving regional and intercontinental markets using regional hubs. During the 1990s and more recently, the North American carriers have focused on linking their substantial domestic networks to increasing numbers of international destinations, while reducing domestic capacity by using smaller aircraft with the same or higher frequencies of service. The North American carriers operate multiple hub-and-spoke networks. There are generally 4 or 5 key airports in the network around which connections are focused. Southwest operates a different strategy, with high levels of direct connections between all of the airports in its network.

To illustrate differences in the network strategy, the pattern of route connections was drawn using the NetDraw software. Figure 8 illustrates the networks of 6 of the top 10 European carriers of 2008. The Air France (AF) and BA (BA) networks have 2 distinct hubs with a relatively small share of overlapping destinations. However, it was shown in Figure 5 that the distance between the top two airports for these carriers

was less than 50km. Thus the BA and Air France networks are more similar to the star (single hub) KLM (KL) and Turkish Airlines (TK) networks illustrated in Figure 8. Where KLM and Turkish have one dominant hub, BA and Air France have one dominant city, with traffic split between two airports. Ryanair (FR) and Easyjet (U2) have more interconnected networks, although the dominance of the top airports is still clearly evident in the illustration. The networks for these two LCCs are quite different to the other European carriers because of the relatively high level of interconnectedness. The visualisations presented in Figure 8 have no geographic properties and purely illustrate the set of connections for both of the carriers. Thus for example, London Heathrow (LHR) is located east of Amsterdam (AMS) which has been placed at the centre of the KLM illustration.

Figure 9 presents visualisations for 6 of the top 10 North American carriers. American Airlines (AA), United Airlines (UA) and Continental Airlines (CO) are considerably larger networks than any of the European carriers. The illustrations identify the top five airports for each carrier described in Tables 2 and 3 (i.e. based on departing seating capacity). The networks of American, United and Continental Airlines consist of a series of interactive hub-and-spoke subsystems, or interacting wheels centred on a small number of hubs. The Air Canada (AC) network shows one dominant hub, with a series of small hubs and overlaps between these hub-and-spoke subsystems and is more similar to the European flag carrier networks. The AirTran (FL) network shows a different pattern as does the Southwest illustration. AirTran shows a relatively high degree of overlap among all nodes in the network with the top 5 airports being very much less visible compared with the FSCs. The AirTran networks looks similar to Ryanair's network.

Southwest has a high degree of overlap among all of the nodes in the network. The set of routes is very dense because of the high proportion of direct routes between the 62 nodes in this carrier's network. This pattern is very different to all of the other North American and European carriers illustrated.

5. Summary and conclusions

There are clear differences between the European and North American air transport markets from the proceeding analysis. The size and scale of North American carrier operations is far greater than that of European carriers. There are also clear differences in network structure and traffic organisation. The examination of basic geographical aspects of carrier networks and review of descriptive statistics for the airports in each carrier's network is a critical part of the analysis of the two continental markets. European carriers were shown to operate networks focused on airports within the member state in which the carrier is located, and linking that member state to a large number of other domestic, European and international destinations. European carriers do not operate the interactive hub-and-spoke networks that became popular among FSCs in the US following deregulation in 1978. Despite over 10 years since full liberalisation of the European Union's single air transport market, European FSC's networks are still focused around key national capitals or largest cities. It is expected that there will be consolidation in the European industry over the next decade, as Europe has a large number of relatively small carriers. The analysis presented in this paper can be updated to identify changes in network organisation in Europe as this consolidation takes place.

This paper has set out clear illustrations of key geographical aspects of carrier networks that are distinctive and different when compared for European and North American carriers. Further research is needed to links the characteristics identified in this paper with those captured in summary measures of network activity. The visualisations of carrier networks help to highlight key differences between LCC and FSC networks, and also between European and North American FSCs. The visualisations illustrate the extent of interconnectedness among routes within a carrier's network. This tool in conjunction with the mapping of the top airports highlighted important geographical and spatial aspects of carrier network structures.

Appendix

Carrier Codes and Country of Registration

Europe:

Carrier Code	Carrier Name	Carrier Country of Registration
AB	Air Berlin	Germany
AF	Air France	France
BA	British Airways	United Kingdom
FR	Ryanair	Ireland, Republic of
IB	Iberia	Spain
IT	Air Inter Europe	France
KL	KLM-Royal Dutch Airlines	Netherlands
LH	Lufthansa German Airlines	Germany
SK	SAS Scandinavian Airlines	Sweden
SR	Swissair	Switzerland
SU	Aeroflot Russian International Airlines	Russian Federation
TK	Turkish Airlines	Turkey
U2	Easyjet	United Kingdom

North America:

Carrier Code	Carrier Name	Carrier Country of Registration
AA	American Airlines	USA
AC	Air Canada	Canada
AS	Alaska Airlines	USA
CO	Continental Airlines	USA

DL	Delta Air Lines	USA
FL	Airtran Airways	USA
HP	America West Airlines	USA
NW	Northwest Airlines	USA
TW	Trans World Airlines	USA
UA	United Airlines	USA
US	US Airways	USA
WN	Southwest Airlines	USA

References

Alderighi, Cento, Nijkamp & Rietveld (2007) "Assessment of new hub-and-spoke and point-to-point airline network configurations**",** *Transport Reviews* 27 (5), pp. 529-549

Brueckner, J. (2002) "Airport Congestion When Carriers Have Market Power" *American Economic Review* 92, 1357-1375 (December 2002).

Brueckner, J. & E. Pels (2005), "European airline mergers, alliance consolidation, and consumer welfare", *Journal of Air Transport Management*, 11(1), pp. 27-41.

Burghouwt, G. & J. de Wit (2005), "Temporal configurations of European airline networks ",*Journal of Air Transport Management* 11 (3), pp. 185-198.

Burghouwt, G., J. Hakfoot & J.R. VanEck (2003), "The spatial configuration of airline networks in Europe", *Journal of Air Transport Management*, 9(5), pp. 309-323 .

FAA (1999) "*Airport Activity Statistics of Certificated Air Carriers*", United States Federal Aviation Administration, Washington D.C.

Guimerà**,** R., S. Mossa, A. Turtschi & L.A.N. Amaral, (2005), "The worldwide air transportation network: anomalous centrality, community structure, and cities' global roles", *Proceedings of the National Academy of Sciences* 102, 7794-7799.

Martín, J.C., Voltes-Dorta, A. (2008), "Theoretical evidence of existing pitfalls in measuring hubbing practices in airline networks", *Networks and Spatial Economics*, 8 (2-3), pp. 161-181

Martins, J.C. & A. Voltes-Dorta, (2009) "A note on how to measure hubbing practices in airline networks" *Transportation Research Part E: Logistics and Transportation Review*, 45(1), pp. 250-254.

Reynolds-Feighan, A.J. (2007), "Competing networks, spatial and industrial concentration in the US airline industry", *Spatial Economic Analysis* 2 (3), pp. 237-257.

Table 1: Basic Descriptive Statistics Comparing European and North American Air Transport

Europe									
Year	Number of European Registered Carriers	Number of Airports	% Change in Number of Airports (4 year intervals)	Seating Capacity (‘000)	% Change in Seating Capacity (4 year intervals)	Movements	% Change in Movements	Average number of Seats per Movement	% Change in Average Number of Seats per Movement
							(4 year intervals)		
1996	158	441		566,796		3,865,115		147	
2000	200	473	7.3	670,759	18.3	4,813,249	24.5	139	-5.0
2004	234	511	8.0	746,261	11.3	5,420,112	12.6	138	-1.2
2008	160	522	2.2	851,660	14.1	5,841,334	7.8	146	5.9
North America									
Year	Number of North American Registered Carriers	Number of Airports	% Change in Number of Airports (4 year intervals)	Seating Capacity (‘000)	% Change in Seating Capacity (4 year intervals)	Movements	% Change in Movements	Average number of Seats per Movement	% Change in Average Number of Seats per Movement
							(4 year intervals)		
1996	34	328		1,304,991		9,522,389		137	
2000	45	301	-8.2	1,382,111	5.9	10,440,023	9.6	132	-3.4
2004	43	340	13.0	1,286,502	-6.9	11,261,272	7.9	114	-13.7
2008	37	348	2.4	1,233,735	-4.1	10,905,987	-3.2	113	-1.0

Source: Authors calculations based on OAG Max Historical Plus databases

Table 2: Top Five Airports for 2008 European Top 10 Carriers, 1996 and 2008

Carrier	Airport	Airport Code	Airport Location	Percentage of Total Seating Capacity		Number of Routes	Average distance (km) between Top 5 Airports	Airport Code	Number of Routes	Percentage of Total Seating Capacity	
		2008						**1996**			
AB	Palma Mallorca	PMI	Spain	12.5		42					
	Dusseldorf International	DUS	Germany	11.6		60	848 km				
	Berlin Tegel	TXL	Germany	11.4	49.7	53					
	Munich International	MUC	Germany	8.1		46					
	Hamburg	HAM	Germany	6.1		31					
AF	Paris Charles de Gaulle	CDG	France	30.5		160		CDG	158.0	40.0	
	Paris Orly	ORY	France	11.3		36	450 km	ORY	25.0	3.3	
	Lyon Saint Exupery	LYS	France	3.9	51.6	37		LHR	8.0	2.0	48.8
	Toulouse Blagnac	TLS	France	3.1		16		NCE	8.0	1.9	
	Nice	NCE	France	2.7		16		LIN	2.0	1.6	
BA	London Heathrow	LHR	United Kingdom	35.2		109		LHR	128.0	28.7	
	London Gatwick	LGW	United Kingdom	9.4		78	5799 km /383 km - Europe only	LGW	93.0	9.9	
	Johannesburg O.r. Tambo International	JNB	South Africa	2.5	50.6	10		CDG	10.0	2.8	46.8
	Edinburgh	EDI	United Kingdom	1.9		3		BHX	22.0	2.8	
	New York J F Kennedy International	JFK	USA	1.6		3		MAN	20.0	2.5	
FR	London Stansted	STN	United Kingdom	13.8		112		DUB	10.0	40.6	
	Dublin	DUB	Ireland Republic of	9.5		89	915 km	STN	5.0	21.1	
	Gerona	GRO	Spain	4.6	35.4	61		PIK	4.0	9.7	81.7
	Milan Orio al Serio	BGY	Italy	3.9		48		MAN	3.0	5.4	
	Frankfurt Hahn	HHN	Germany	3.6		53		BHX	1.0	5.0	
IB	Madrid Barajas	MAD	Spain	38.4		114		MAD	80.0	27.1	
	Barcelona	BCN	Spain	8.2		57	594 km	BCN	63.0	14.3	
	Valencia (ES)	VLC	Spain	2.4	53.4	22		SVQ	15.0	3.6	51.5
	Paris Orly	ORY	France	2.3		11		VLC	13.0	3.4	
	Bilbao	BIO	Spain	2.0		13		SCQ	15.0	3.2	

KL	Amsterdam	AMS	Netherlands	48.2		126		AMS	132.0	44.6	
	London Heathrow	LHR	United Kingdom	1.3		1	3460 km/370 km - Europe only	LHR	1.0	2.1	
	Guayaquil	GYE	Ecuador	1.2	52.7	3		SIN	5.0	1.8	51.0
	Paris Charles de Gaulle	CDG	France	1.0		1		CUR	5.0	1.3	
	Bonaire	BON	Netherlands Antilles	1.0		4		LIN	1.0	1.2	
LH	Frankfurt International	FRA	Germany	27.6		171		FRA	163.0	27.0	
	Munich International	MUC	Germany	14.8		114	395 km	MUC	69.0	9.3	
	Dusseldorf International	DUS	Germany	4.6	54.2	57		DUS	45.0	5.8	52.1
	Hamburg	HAM	Germany	4.0		36		HAM	38.0	5.0	
	Berlin Tegel	TXL	Germany	3.3		19		TXL	24.0	5.0	
SK	Copenhagen	CPH	Denmark	17.6		64		ARN	60.0	19.1	
	Oslo	OSL	Norway	17.1		61	541 km	CPH	66.0	18.6	
	Stockholm Arlanda	ARN	Sweden	12.7	57.2	60		FBU	34.0	13.5	57.4
	Trondheim Vaernes	TRD	Norway	5.0		8		GOT	7.0	3.2	
	Bergen	BGO	Norway	4.9		9		BGO	5.0	2.9	
TK	Istanbul Ataturk	IST	Turkey	40.8		146		IST	76.0	37.1	
	Ankara Esenboga	ESB	Turkey	9.2		43	472 km	ESB	42.0	15.6	
	Izmir Adnan Menderes	ADB	Turkey	3.8	58.9	8		ADB	17.0	6.1	64.8
	Antalya	AYT	Turkey	2.9		4		ADA	13.0	3.3	
	Adana	ADA	Turkey	2.2		11		AYT	9.0	2.6	
U2	London Gatwick	LGW	United Kingdom	10.6		73		LTN	7.0	50.0	
	London Luton	LTN	United Kingdom	7.1		34	313 km	EDI	1.0	12.0	
	London Stansted	STN	United Kingdom	5.8	32.4	26		AMS	1.0	11.3	89.7
	Belfast International	BFS	United Kingdom	4.4		23		GLA	1.0	10.2	
	Bristol	BRS	United Kingdom	4.4		39		NCE	1.0	6.1	

Table 3: Top Five Airports for 2008 North American Top 10 Carriers, 1996 and 2008

Carrier	Airport	Airport Code	Airport Location	Percentage of Total Seating Capacity		Number of Routes	Average distance (km) between Top 5 Airports	Airport Code	Number of Routes	Percentage of Total Seating Capacity	
		2008						**1996**			
AA	Dallas/Fort Worth Intl	DFW	USA	18.3		178		DFW	125.0	17.2	
	Chicago O'Hare Int'l	ORD	USA	9.9		132	2271 km	ORD	92.0	11.1	
	Miami Int'l	MIA	USA	8.9	44.0	107		MIA	94.0	8.4	43.1
	Los Angeles Int'l	LAX	USA	3.7		51		LAX	46.0	3.3	
	New York J F Kennedy Int'l	JFK	USA	3.3		60		JFK	34.0	3.2	
AC	Toronto Lester B Pearson Intl	YYZ	Canada	28.1		105		YYZ	63.0	25.3	
	Vancouver Int'l	YVR	Canada	11.0		41	2085 km	YVR	35.0	9.6	
	Montreal Pierre Elliott Trudeau Int	YUL	Canada	9.4	60.0	51		YUL	26.0	8.9	57.1
	Calgary	YYC	Canada	7.1		36		YYC	23.0	7.6	
	Ottawa Mcdonald Cartier Intl	YOW	Canada	4.5		26		YOW	21.0	5.8	
AS	Seattle/Tacoma Int'l	SEA	USA	27.2		61		SEA	47.0	25.2	
	Anchorage Int'l	ANC	USA	9.5		38	1741 km	PDX	23.0	9.3	
	Portland (US) OR	PDX	USA	8.5	55.0	29		ANC	44.0	9.3	53.9
	Los Angeles Int'l	LAX	USA	6.3		21		LAX	16.0	6.2	
	San Francisco Int'l	SFO	USA	3.5		16		OAK	8.0	3.9	
CO	Houston George Bush Intercontinental Ap	IAH	USA	25.7		192		IAH	104.0	14.8	
	Newark Liberty Int'l	EWR	USA	18.1		173	2198 km	EWR	107.0	13.3	
	Cleveland Hopkins Int'l	CLE	USA	5.6	52.6	91		PHX	42.0	5.6	41.2
	Los Angeles Int'l	LAX	USA	1.6		10		CLE	54.0	4.3	
	Orlando Int'l	MCO	USA	1.5		10		LAX	41.0	3.2	
DL	Atlanta Hartsfield-jackson Intl	ATL	USA	26.3		273		ATL	145.0	18.8	
	Salt Lake City	SLC	USA	5.9		131	2193 km	CVG	119.0	7.2	
	Cincinnati Northern Kentucky Intl	CVG	USA	5.3	44.5	137		SLC	76.0	5.9	39.6
	New York J F Kennedy Int'l	JFK	USA	4.6		126		DFW	70.0	4.6	
	Los Angeles Int'l	LAX	USA	2.4		77		LAX	55.0	3.1	

FL	Atlanta Hartsfield-jackson Intl	ATL	USA	31.1		58		MCO	25.0	50.0		
	Orlando Int'l	MCO	USA	8.0		41	1010 km	SWF	1.0	2.7		
	Baltimore Washington Int'l	BWI	USA	5.8	51.4	24		TYS	1.0	2.6		
										60.5		
	Boston Logan Int'l	BOS	USA	3.2		23		GSP	1.0	2.6		
	New York La Guardia	LGA	USA	3.2		20		DAY	1.0	2.6		
NW	Detroit Wayne County	DTW	USA	16.4		156		DTW	112.0	15.2		
	Minneapolis Int'l	MSP	USA	16.3		162	4418 km / 1865 km - NA only	MSP	127.0	14.3		
	Memphis Int'l	MEM	USA	5.5	42.3	104		MEM	83.0	4.4		39.1
	Tokyo Narita	NRT	Japan	2.5		20		NRT	26.0	2.8		
	Los Angeles Int'l	LAX	USA	1.6		24		LAX	29.0	2.3		
UA	Chicago O'Hare Int'l	ORD	USA	17.7		165		ORD	119.0	16.4		
	Denver Intl	DEN	USA	11.9		128	2149 km	DEN	93.0	11.2		
	Washington Dulles Int'l	IAD	USA	8.4	51.0	107		SFO	69.0	6.5		43.0
	San Francisco Int'l	SFO	USA	7.6		83		LAX	66.0	5.6		
	Los Angeles Int'l	LAX	USA	5.4		75		IAD	47.0	3.3		
US	Charlotte	CLT	USA	15.3		140		CLT	92.0	11.0		
	Philadelphia Int'l	PHL	USA	10.1		126	2113 km	PIT	102.0	10.3		
	Phoenix Sky Harbor Intl	PHX	USA	9.4	43.3	91		PHL	73.0	9.5		39.9
	Washington Ronald Reagan National	DCA	USA	4.7		88		BOS	68.0	5.0		
	Las Vegas McCarran Int'l	LAS	USA	3.8		66		LGA	61.0	4.2		
WN	Chicago Midway	MDW	USA	5.8		62		PHX	41.0	7.2		
	Las Vegas McCarran Int'l	LAS	USA	5.6		62	1912 km	HOU	42.0	6.7		
	Phoenix Sky Harbor Intl	PHX	USA	5.2	25.6	62		LAS	36.0	5.4		29.1
	Baltimore Washington Int'l	BWI	USA	4.6		60		OAK	26.0	4.9		
	Dallas/Fort Worth Love Field	DAL	USA	4.5		62		LAX	30.0	4.8		

Figure 1: Departure Seating Capacity 1996 & 2008, Top 10 European & North American Carriers

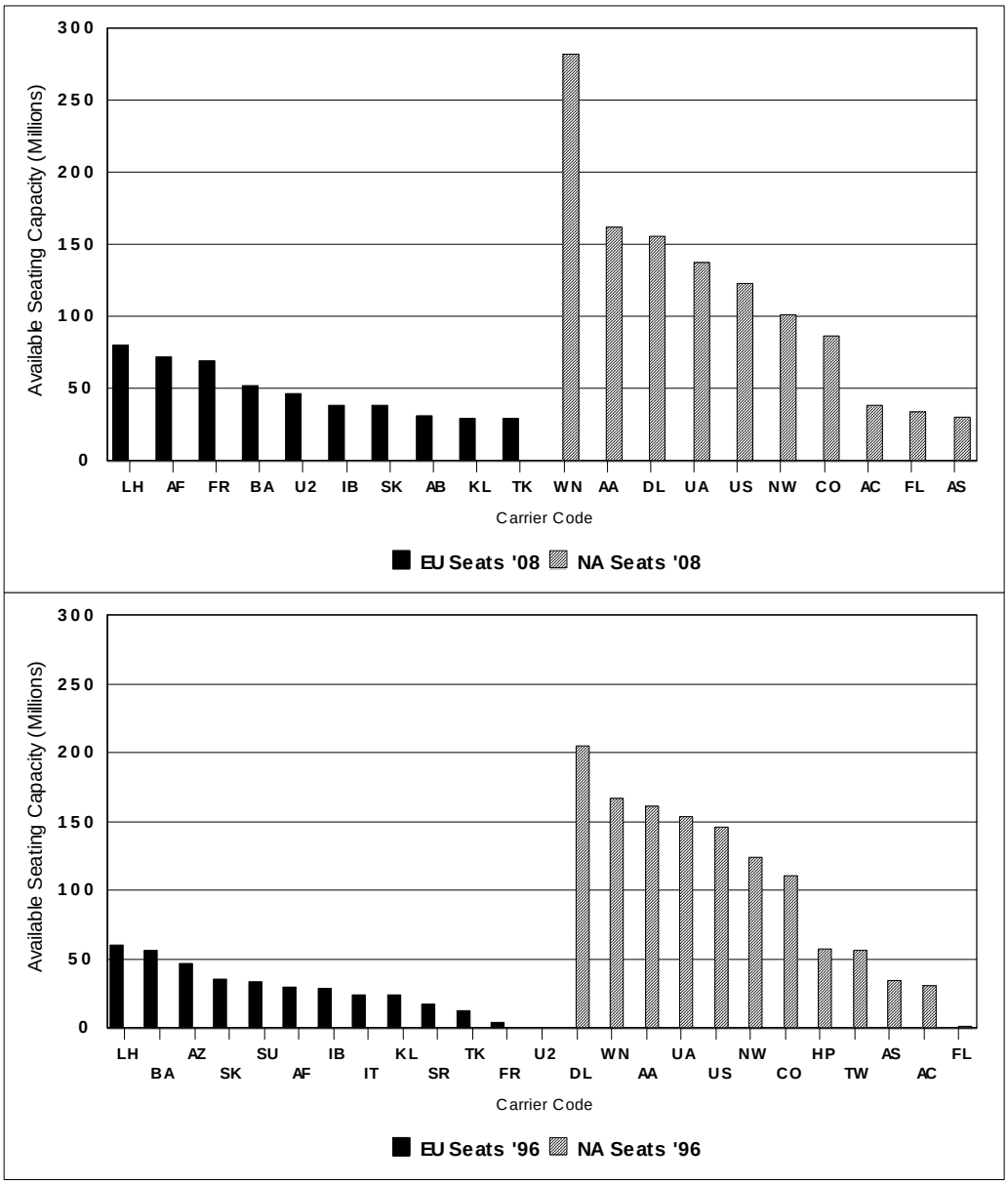
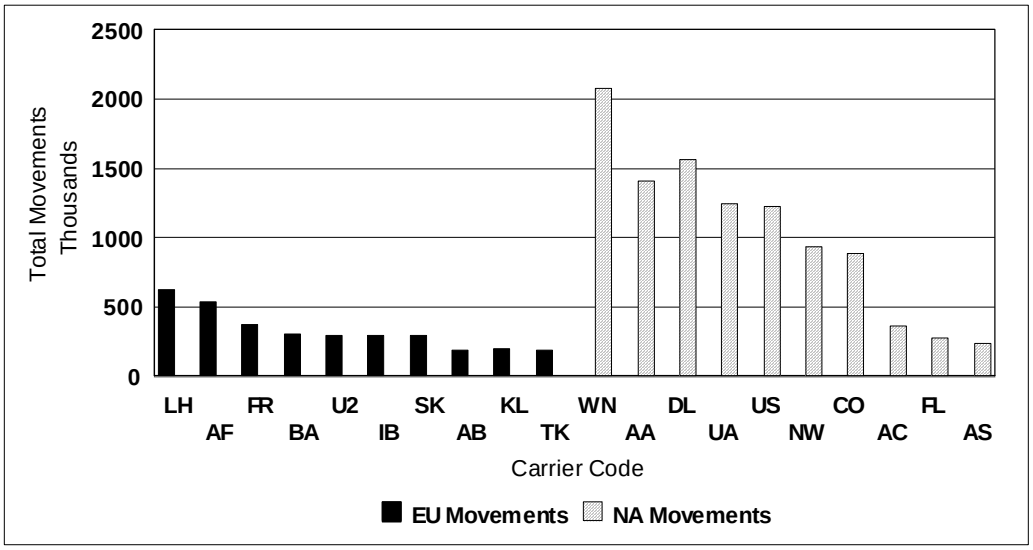


Figure 2: Departure Movements and Number of Airports served, Top 10 European & North American Carriers 2008



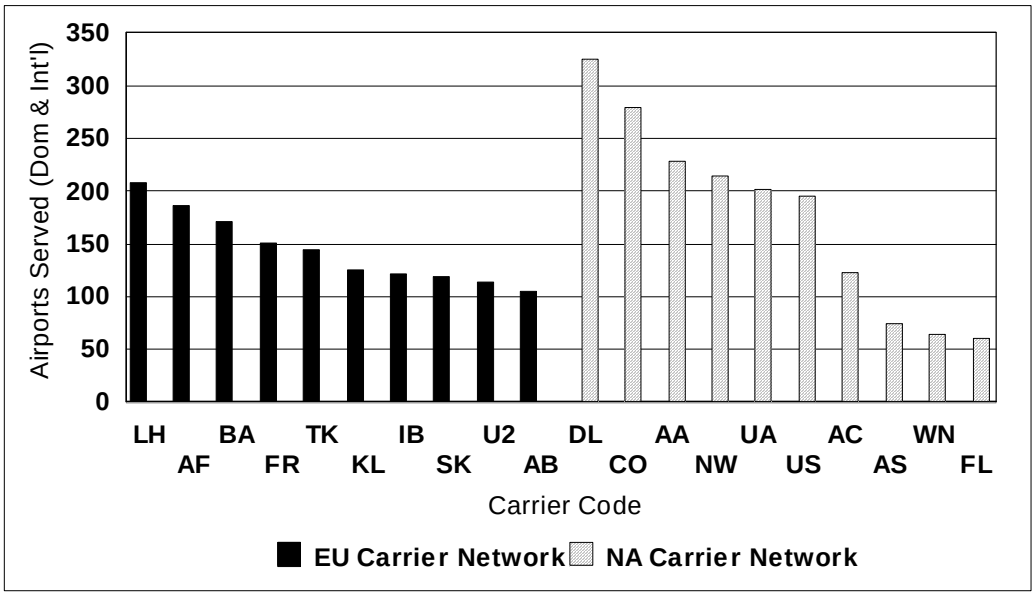
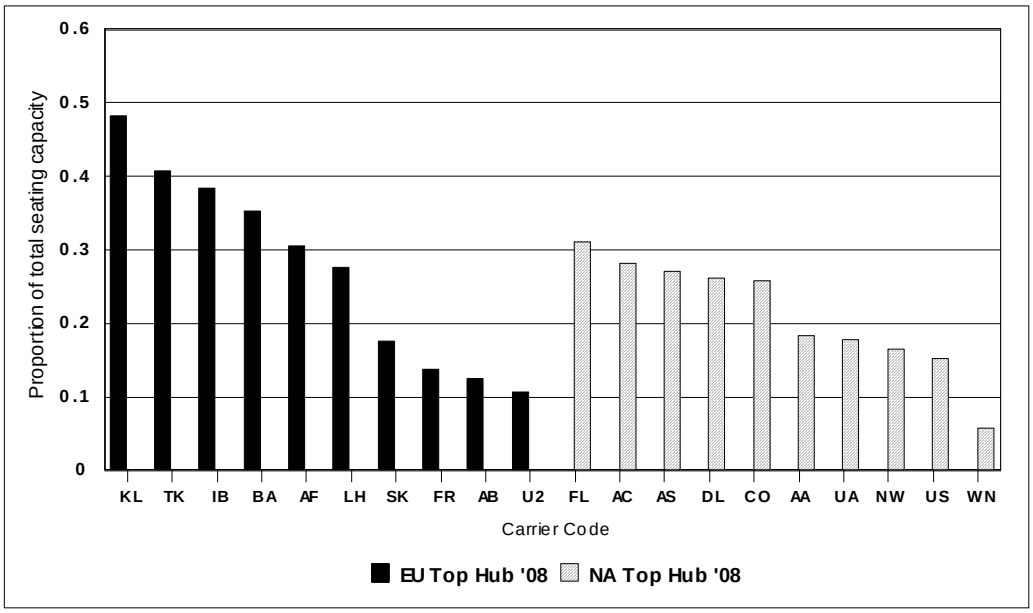


Figure 3: Proportion of Departure Seating Capacity from Carriers Busiest Hub, 1996 & 2008



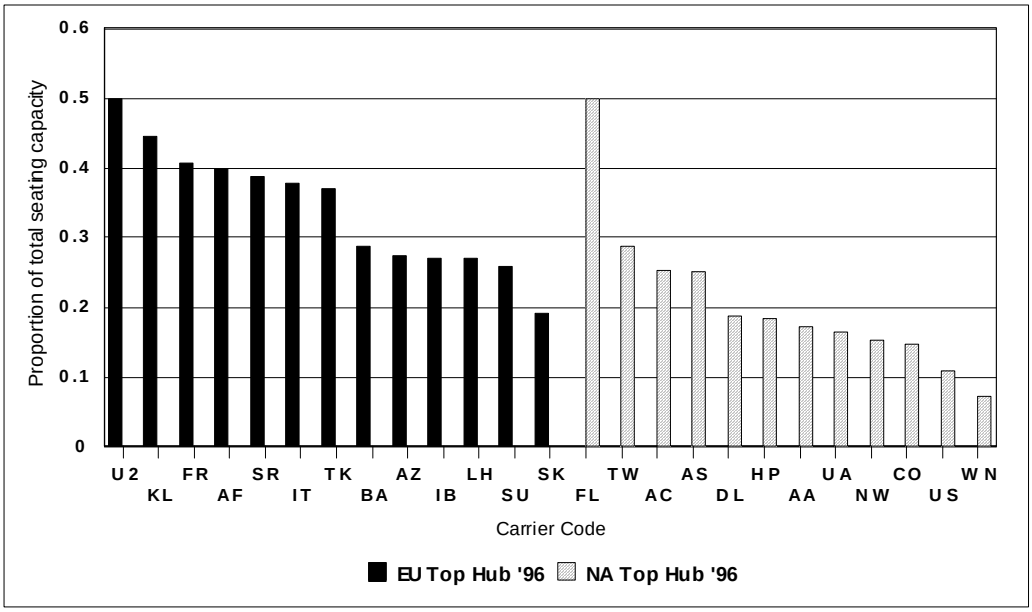
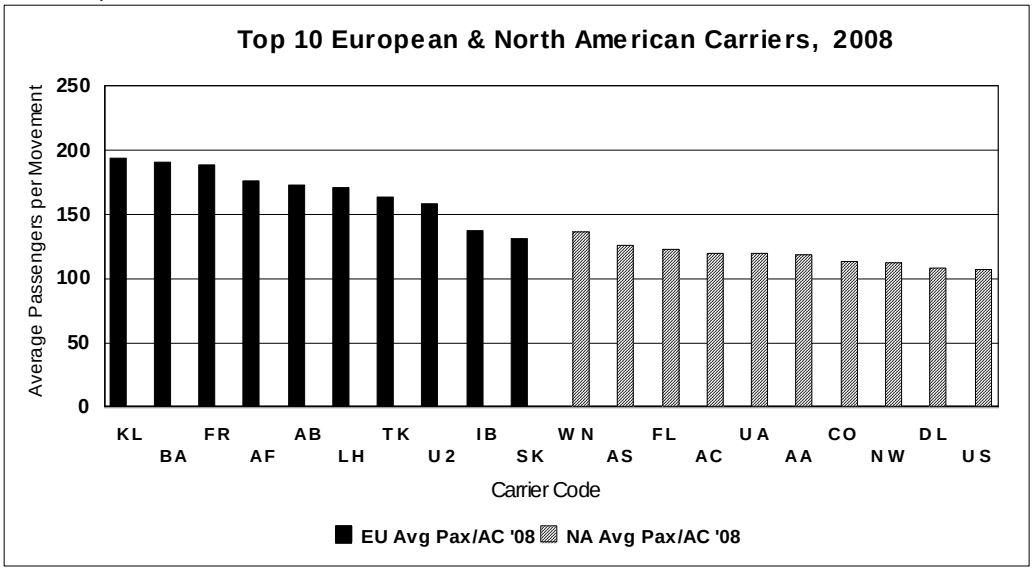


Figure 4: Average Seats Per Aircraft Movement, Top 10 European & North American Carriers, 1996 & 2008



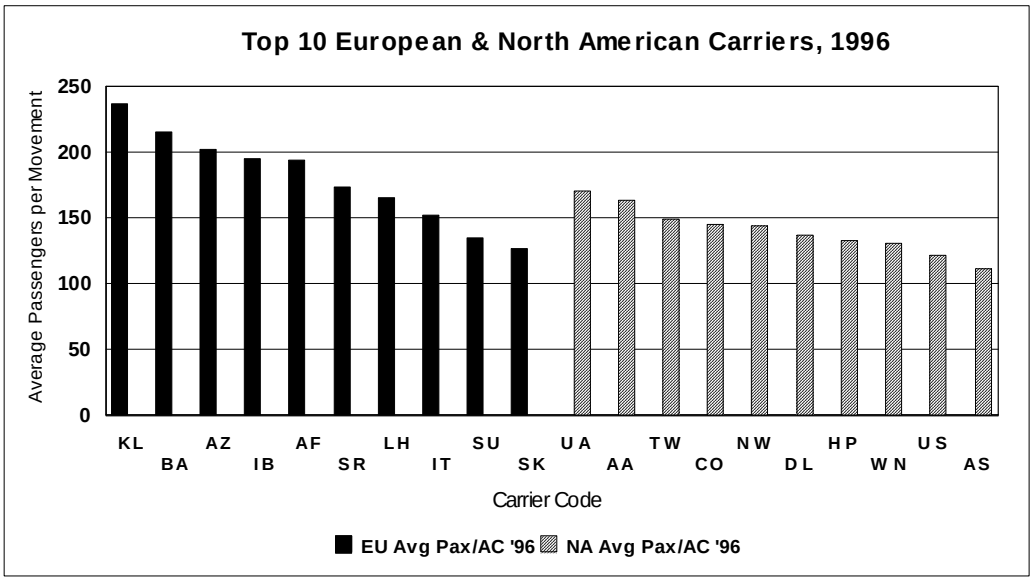
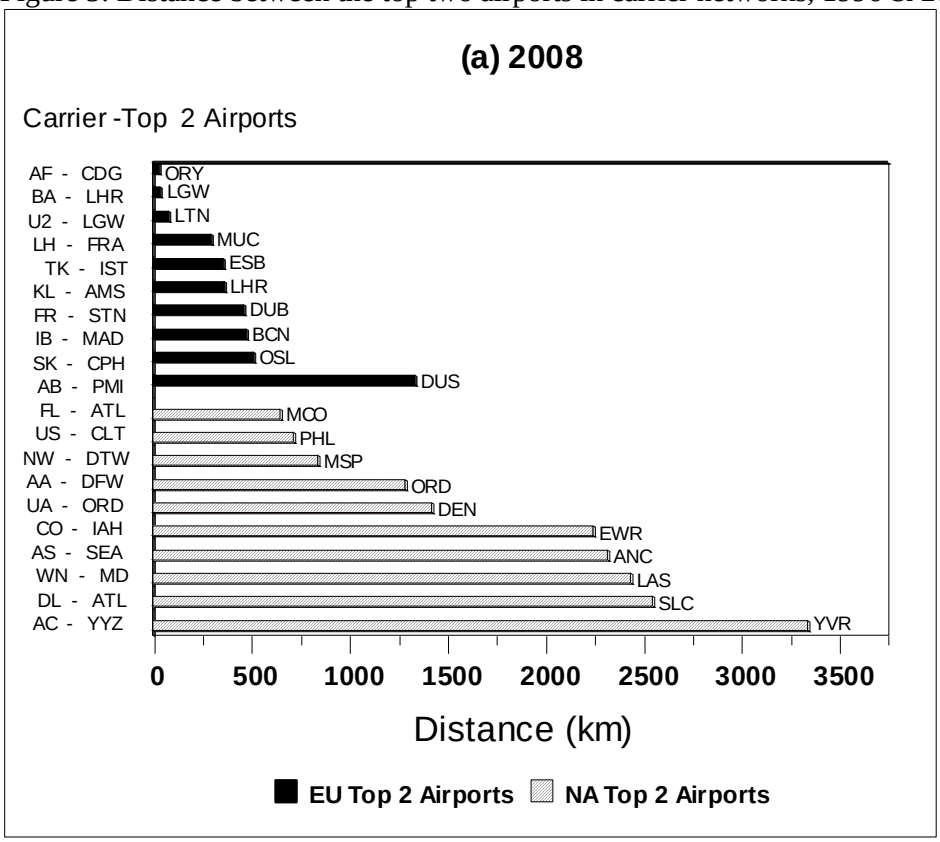


Figure 5: Distance between the top two airports in carrier networks, 1996 & 2008



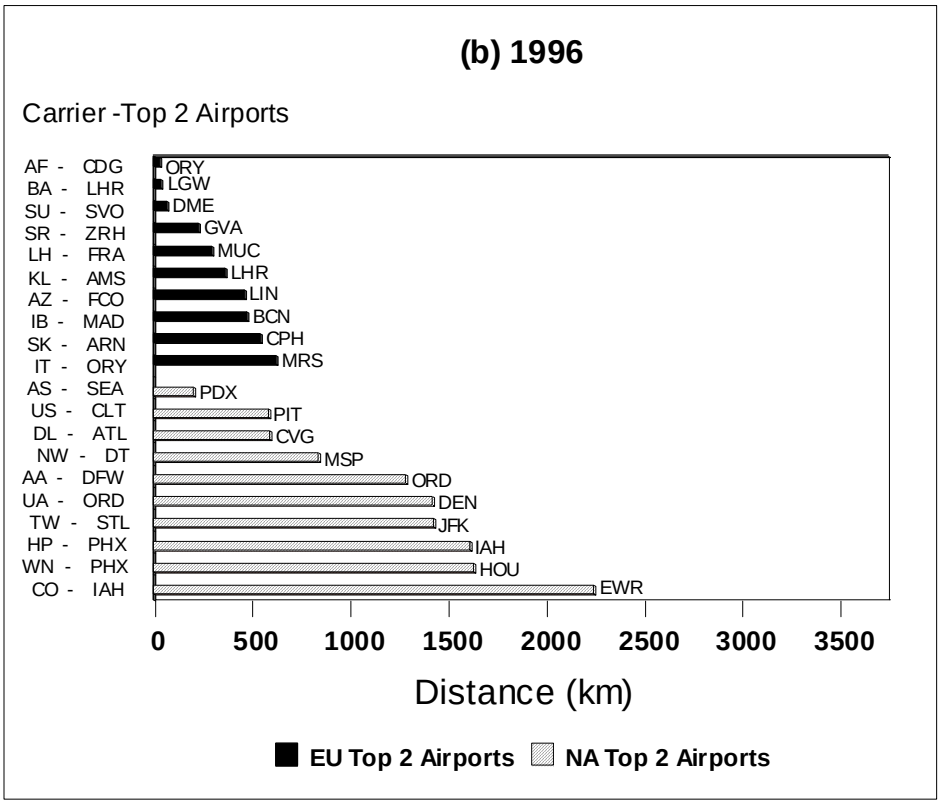


Figure 6: Top 5 airports in selected European carrier networks in 2008

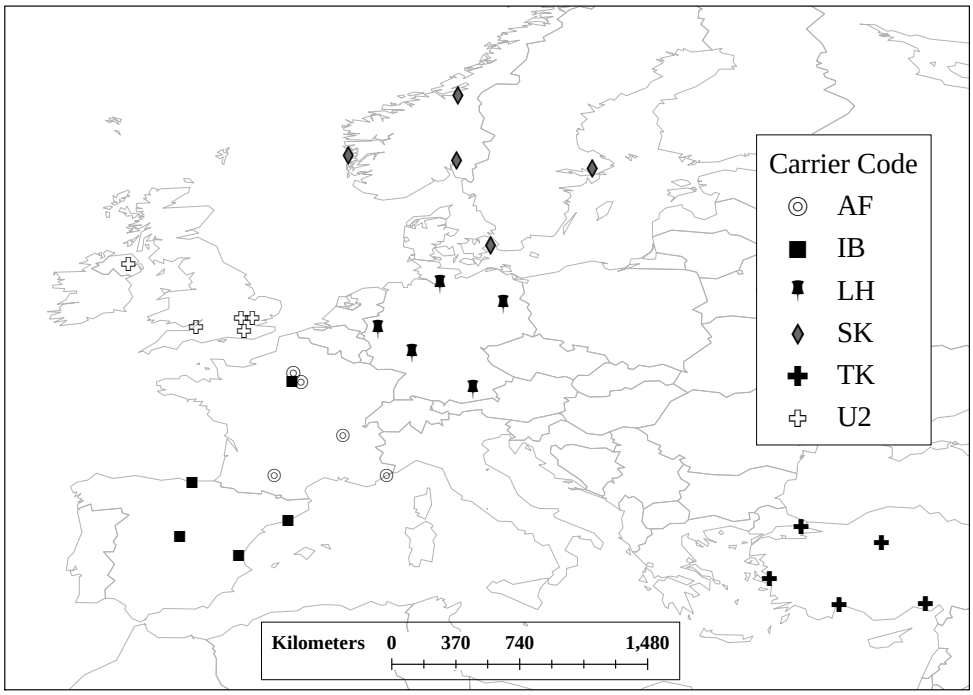


Figure 7: Top 5 airports in selected North American carrier networks in 2008

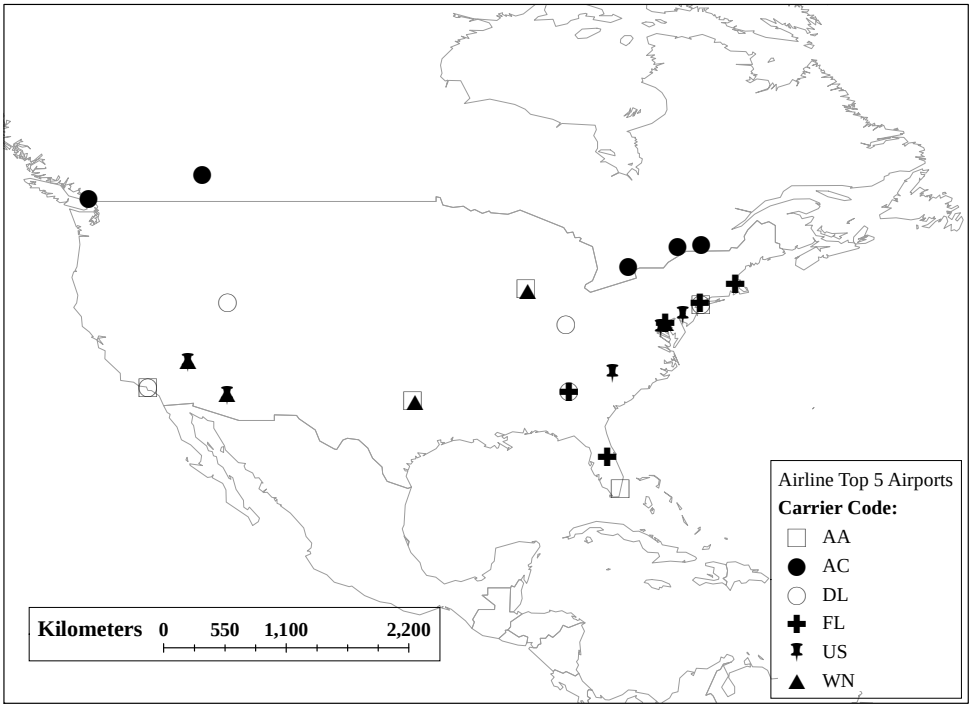


Figure 8: Visualisation of European Airlines Linkage Structure, 2008

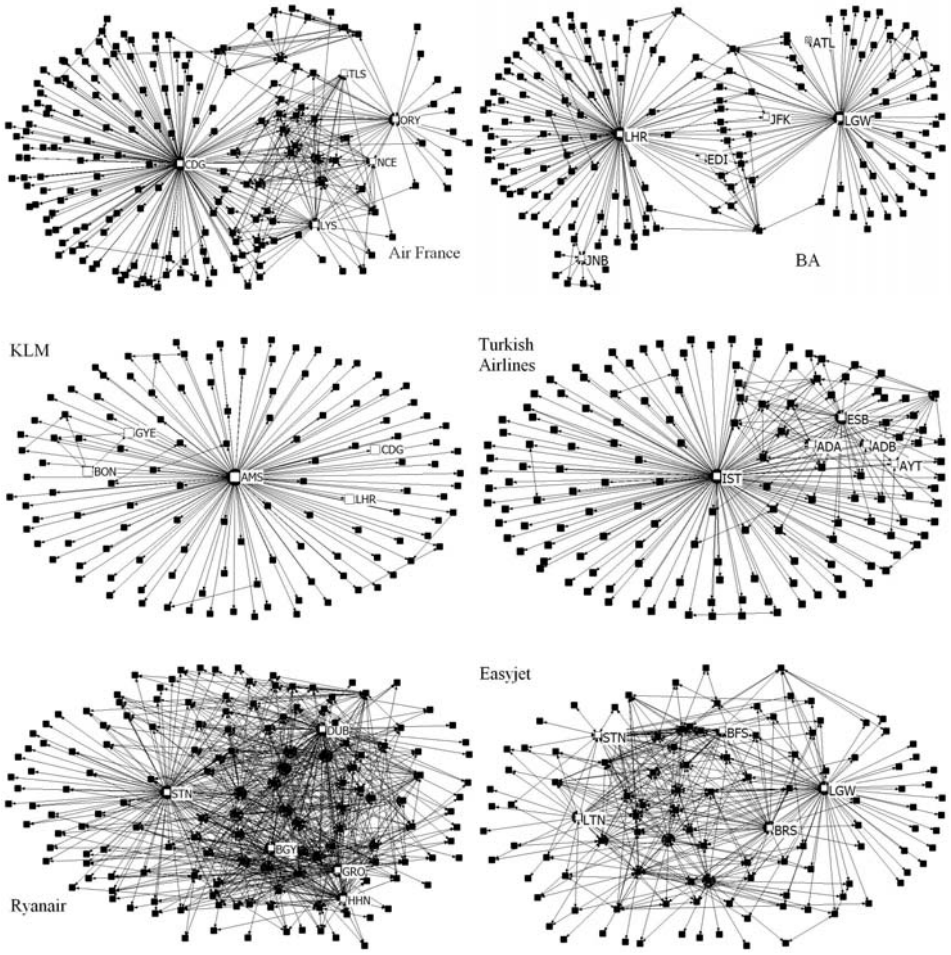


Figure 9: Visualisation of North American Airlines Linkage Structure, 2008