Journal of Transport Geography 26 (2013) 108–116

Contents lists available at SciVerse ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Estimating potential long-haul air passenger traffic in national networks containing two or more dominant cities

Athina Sismanidou [a,b,*], Joan Tarradellas [a,b], Germà Bel [c], Xavier Fageda [c]

[a] Department of Business Administration, Universitat Politècnica de Catalunya, Av. Diagonal 647, 7th Floor, 08028 Barcelona, Spain
[b] EADA Business School, c/Aragó 204, 08011 Barcelona, Spain
[c] Department of Economic Policy, UB, Universitat de Barcelona, Av. Diagonal 690, 08034 Barcelona, Spain

ARTICLE INFO

Keywords:
Airport choice
Secondary hubs
Hub-and-spoke networks
MIDT
Airport competition
Route optimization

ABSTRACT

In this paper, we build an analytical framework to estimate potential passenger traffic for new long-haul routes originating in secondary airports within national airport systems where a main hub concentrates most of the transcontinental traffic. The results are particularly important in the context of air space liberalization, which is generating opportunities for new city-pair traffic. If airport and airline managers can correctly value route alternatives, they can make better decisions concerning alliances, expansion plans, or the development of their hub-and-spoke networks.

1. Introduction

In recent years, the air transport industry has experienced changes that have entirely re-shaped its structure. Among the processes that have most affected airlines and airports are deregulation, privatization, the emergence of low cost carriers, and the opening of new airports (Malighetti et al., 2011).

Air space liberalization, where established, created opportunities for network reconfiguration and the establishment of new routes (Berechman and de Wit, 1996; Graham, 1998; Thompson, 2002). In the US, deregulation of the domestic flights resulted in a reorganization from point-to-point networks to hub-and-spoke networks (Reynolds-Feighan, 2000). In Europe, at least at a national level, de facto hub-and-spoke systems pre-existed as many national carriers concentrated their flights through their countries' major airports. Nevertheless, the EU–US multilateral Open Skies agreement is expected to contribute to more flexibility with respect to the airport points served today (de Wit and Burghouwt, 2008), and it offers new potential for transatlantic routes from secondary airports (Bel and Fageda, 2010a). Similar liberalization processes are under way for other geographical areas (e.g., Asia and Asia-Pacific) and are also expected to create new opportunities for network or airport development.

Network airlines may exploit density economies by focusing traffic in their hub airports.[1] Density economies imply a decrease in average costs from increasing traffic at the route level. The savings come partly from using bigger airplanes (which are more cost efficient) at higher load factors. Another cost advantage of concentrating operations in the hubs is saving on fixed costs. Furthermore, by concentrating traffic in hub airports, network airlines may increase the number of frequencies (thus increasing utilization of the planes and the crew) and the number of destinations (hence increasing the airport's attractiveness for passengers).

However, airlines may also have incentives to disperse traffic among several airports. Economic growth and globalization have stimulated demand for long-haul, point-to-point services from non-hub airports (Weber and Williams, 2001). The largest airports may be congested; environmental and urban pressures may limit capacity; and, at least in Europe, the threat of foreign airlines entering neglected national airports may push former flag carriers to follow a pre-emption strategy and disperse their network structure. The multi-hub strategy may be used when the secondary large airport is able to generate a high amount of traffic.

Choosing between a one-hub versus a two- (or multiple-) hub strategy involves calculating the potential traffic demand for the alternative network, as passenger traffic is the major profitability parameter for both airlines and airports. Our paper describes an analytical framework that can be used to estimate passenger demand for new long-haul routes from secondary hubs.

Our analysis is based on the hypothesis that a significant proportion of national airport systems are composed of one primary hub through which one flag carrier concentrates most of its intercontinental traffic, assisted by one or more secondary airports with objective demand and connectivity potential that may be underexploited as international air gateways. Thus, our definition of secondary hub airports coincides with that employed by Fuhr and

---

* Corresponding author. Tel.: +34 616 94 06 53; fax: +34 934 01 60 54.
E-mail addresses: athina.sismanidou@upc.edu, atids@yahoo.com (A. Sismanidou).

[1] Note that low-cost airlines tend to focus their flights in short-haul, point-to-point routes (Francis et al., 2007).

0966-6923/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jtrangeo.2012.07.010

Beckers (2006): i.e., airports that display a moderate-to-high frequency of passenger and airline traffic, that are located in large catchment areas, and that provide a large portion of the hub-and-spoke network feeder traffic and attract point-to-point transport. Examples of such secondary hubs in Europe would be Geneva, Barcelona, Birmingham, or Milan. In other regions, examples of secondary airports with potential unexploited opportunities for redistribution of traffic would be Rio in Brazil and various cities in China and India.

The potential establishment of new routes creates opportunities for new airline–airport vertical agreements and alliances, as airlines and airports are invited to take positions and exploit such opportunities to the maximum. International route development, in particular, would play a key role in the niche strategies foreseen for many secondary hubs and their specialization in certain geographic destinations.

Evaluating unexploited route opportunities from secondary airports is further important in the context of the privatization of previously public airports, as it results in the quest for growth as well as improved efficiency in airport management (Oum et al., 2008; Pels et al., 2003).

Our paper is organized as follows: after presenting our research context and describing in-depth our analytical framework, in order to assess the merits of our proposal, we apply our model to the Madrid–Miami and Barcelona–Miami city pairs. At the end of the paper, we present and discuss our results and conclusions.

2. Research context

In this work, we aim at a general study of airport competition and an analysis of air transport networks, focusing on the more specific aspect of passenger demand forecasting.

Several studies on airport competition exist (Currier, 2008; Chou, 1993; Fu et al., 2006; Starkie, 1998; Yang and Zhang, 2011), with recent literature focusing on liberalization (Alberts et al., 2009; Basso, 2008; Bowen, 2002; Li et al., 2010), privatization (Bel and Fageda, 2010b; Malighetti et al., 2007; Oum et al., 2008), and vertical agreements between airlines and airports (Barbot, 2009; Forbes and Lederman, 2010; Fuhr and Beckers, 2006; Kuchinke and Sickmann, 2007; Oum and Fu, 2008). Redondi et al. (2012) document several de-hubbing patterns in airports all over the world from 1990 to 2009, including US airports like Cincinnati, Pittsburgh, or St. Louis, or European airports like Milan–Malpensa, Brussels, or London Gatwick.

Various researchers have studied airport competition from the perspective of passenger choice and demand, and have developed nested logit models to investigate air travel choices in multi-airport markets, identifying in their studies as key parameters of passenger choice: air fare, surface-access costs, and frequency (Ishii et al., 2009; Pels et al., 2000, 2003; Wei and Hansen, 2006). Other recent studies (Blackstone et al., 2006; Suzuki, 2007) also identify the frequency of flight service, airfare, access time, and passenger charges as variables determining passengers' airport choice. The previous literature has also shown that hubs are more likely to be attractive to passengers when flight frequency is high and the disadvantages of longer travel and connecting times are low (Berechman and Shy, 1996; Brueckner and Zhang, 2001; Harvey, 1987). Along the same line of results, Veldhuis (1997) incorporates passenger choice parameters into a model aimed at evaluating the "connectivity" attractiveness of an airport.

A different strand of the air competition literature focuses on network composition and on analyzing the two most common air transport network configurations—i.e., hub-and-spoke and point-to-point (Button, 2002). Defendants of the hub-and-spoke system agree that hub-centered strategies provide cost and demand-side benefits, as well as market entry barriers (Dennis, 1994; Oum and Zhang, 1995). On the other hand, Adler and Berechman (2001) claim that for a large enough network to be balanced, a second hub should also be considered and point out that an airline may add direct connections to its hub-and-spoke network when the decision is justified by demand.

More recently, Düdden (2006) has evaluated demand considerations that can lead to rejecting the single-hub as the most profitable network approach. On the one hand, Düdden observes that in the US market, carrier consolidation brought a greater concentration to a smaller number of larger hubs and claims that mergers of European carriers could also result in similar solutions. On the other hand, he points out that airlines like Lufthansa follow a multi-hub strategy as a competitive advantage and as a part of its positive differentiation criterion.

Another strand of literature related to our paper focuses on the patterns of concentration or dispersal of air traffic in a global context and for large markets like the US or Europe (O'Connor, 2003). Overall, results from this literature are not conclusive, although the more recent studies tend to find a general tendency towards de-concentration of air traffic. Some authors (Burghouwt and Hakfoort, 2001; Goetz and Sutton, 1997; O'Connor and Scott, 1992; O'Connor, 1995; Reynolds-Feighan, 2000, 2001) observe a trend toward concentration of total air traffic in the US and in Europe, in a small number of airports. However, other studies suggest a decreasing role for very large global cities and major hubs in favor of a group of next largest cities (Bel and Fageda, 2010a; Maertens, 2010; Suau-Sanchez and Burghouwt, 2011; Suau-Sanchez et al., 2011).

The attractiveness and competitiveness of airport hubs has also attracted attention from transport geography researchers, who vigorously use airline data as an indicator in their urban network studies (Derudder et al., 2010; Derudder and Witlox, 2009; Devriendt et al., 2010; Hess and Polak, 2005; O'Connor and Fuellhart, 2012; Keeling, 1995; Shin and Timberlake, 2000). Derudder and Witlox (2009) employ a non-directional dominance index (DIT) for groups of European airports in order to measure hierarchical differentiation in national urban systems, and reveal that some of cities with similar DIT values show distinct airline connectivity levels, demonstrating that actual air connectivity is not aligned with the importance of these cities as air traffic originators. This would be the case with the Madrid/Barcelona, Rome/Milan, or Geneva/Zurich cities.

In our opinion, the results of Derudder and Witlox (2009), consistent with Devriendt et al. (2010), indicate the existence of underexploited routes for major airports that are not fully developed as hubs. We draw from this result to propose, for the first time, an analytical framework to estimate potential demand for new direct long-haul flights from a secondary airport in a national system. We base our methodology on true origin and destination data (TOD) from Marketing Information Data Tapes (MIDT), a powerful data source introduced by Derudder and Witlox (2005). In addition, we employ the quality index proposed by Veldhuis (1997) in order to measure the relative quality of the "new" connections in a theoretical new hub-and-spoke system.

3. Methodology and data

3.1. MIDT data

Most air transport statistics report traffic between separate city-pairs rather than providing details of a trip as a whole. If the initial airport origin or final destination information of the passengers flown is omitted, it is not possible to assess the real air transport relationships between cities and the potential for direct air connectivity between them.

Many different researchers have observed the lack of adequate air traffic statistics and especially the lack of TOD information (Derudder and Witlox, 2005; Taylor, 1999; Veldhuis, 1997). Derudder and Witlox (p. 232) observe that "data on flows between cities are conspicuous by their absence" and that "most data collection agencies focus upon attribute data because they are easier to collect." As a result, when estimating passenger demand, most researchers collect the input data for their models from surveys and indirect statistics and their conclusions on potential flows rather than from actual passenger traffic.

While most air transport statistics (from ICAO, IATA, BTS, OAG, etc.) do not provide data on the actual routes flown by passengers, MIDT data contain all known fields at the time of the booking, including the true departure airports, stopovers, and arrival cities. In this study, our model assumes the use of MIDT data when assessing TOD flows.

MIDT information is collected by Global Distribution Systems (GDSs) when a flight is booked through their system, and is a very complete database as practically all travel agency and online bookings for most scheduled airlines and many low cost carriers are made through a GDS (Sismanidou et al., 2009). Reservations made through certain airlines' direct distribution channels that do not use a GDS booking engine are not included in MIDT. However, many scheduled airlines—like British Airways, SAS, or Iberia—also use a GDS booking platform for their own offices and websites; therefore, all their bookings (direct and indirect) are included in MIDT.

The use of MIDT data has previously been supported by Derudder and Witlox (2005, 2008), followed more recently by Devriendt et al. (2009), who were the first ones to introduce MIDT as a data source in their calculations.

3.2. Model foundation

We measure the potential demand for a new long-haul route from a secondary hub within a national urban system containing two dominant cities. Therefore, we analyze and compare the data for two city pairs, (a) main hub-intercontinental destination and (b) secondary hub-intercontinental destination, on the key assumption that if a new route were established between the secondary hub and the intercontinental destination, the demand for such routes would stem primarily from the existing traffic between the main hub and the intercontinental destination.

For simplification, we verbally express the route as if the flights only depart from the main hub or the secondary hub and end at the intercontinental destination. However, the model's logic works for return flights as well, and the volumes of passengers calculated by the model include both departing and arriving passengers.

3.3. Connection Quality Index

In addition to the demand from passengers with their true origin at the secondary hub airport, the model allows for incorporating the desired spokes that will be feeding the new route. For this purpose, the Connection Quality Indexes of the two airports (main and secondary hubs) are being used to distribute proportionally the existing connecting traffic that originated at other spoke airports. If the indexes for the two alternative hubs are equal, the potential distribution of traffic is assumed to be 50% for each hub. If one of the two airports has a higher Connection Quality Index, the assumption is that passengers will be distributed between the two airports with the same proportion as the relative Quality Indexes between the two airports.

The model proposed in this study is based on the assumption that passengers have no *a priori* preferences for any connecting airport (Suzuki, 2007). Travelers base their choices on combinations of airports and airlines jointly, trying to maximize their direct utility (Ishii et al., 2009; Pels et al., 2009). In the case of connecting flights, for which passengers have multiple choices of connecting airports with different airlines, some authors, such as Veldhuis (1997) or Burghouwt and de Wit (2005), have tried to measure connectivity indicators to determine the relative attractiveness of alternative connecting airports.

We have incorporated into our model the Connection Quality Index perceived by Veldhuis (1997), which measures the loss of attractiveness of an airport due to the extra perceived travel time of the connection.

After discarding secondary attractiveness factors, such as airport preference or mile redemption programs, Veldhuis (1997) determines that given a similar faring policy and equal frequencies among different potential connecting airports for a particular destination n, the attractiveness or Connection Quality Index δn of an indirect connection via hub D, versus the Connection Quality Index θn of an alternative connecting hub Z, depends primarily on several factors: the waiting time—or transfer time—at each hub, the detour factor stemming from the geographical locations of the departing airport, the connecting airport and the destination airport, and, ultimately, the perceived total travel time compared to the ideal direct, non-stop flying time from any spoke airport.

The Connection Quality Indexes, δn and θn, for non-direct connections at two alternative connecting airports, D and Z, in the case of a non-direct flight to a particular destination from an origin n, are as follows:

$$MAXT_n = (3 - [0.075 \times NST_n]) \times NST_n \tag{1}$$

$$PTT_n = FLY_n + (3 \times TRF_n) \tag{2}$$

$$\delta n = 1 - \frac{(PTT_n - NST_n)}{(MAXT_n - NST_n)} \tag{3}$$

$$\theta n = 1 - \frac{(PTT_n - NST_n)}{(MAXT_n - NST_n)} \tag{4}$$

where $MAXT_n$ is the maximum perceived travel time to the final destination from the airport corresponding to spoke n, expressed in hours, NST_n the non-stop (theoretical) travel time to the final destination from the airport corresponding to spoke n, expressed in hours, PTT_n the perceived travel time via the connecting hub, expressed in hours, FLY_n the flying time to the final destination, which equals total time from the airport corresponding to spoke n, expressed in hours (including all the segments along the connection and excluding transfer times) and TRF_n is the transfer time at the hub when travel originates at spoke n, expressed in hours.

With regard to the PTT_n calculation, passengers normally perceive transfer time as more problematic than in-vehicle time (Hensher and Truong, 1985; Madan and Groenhout, 1987). Based on actual travel selections at the Schiphol, Amsterdam, airport, Veldhuis (1997) estimates that transfer time must be multiplied by three in order to determine the total perceived travel time correctly.

Furthermore, Veldhuis (1997) determines in his model the transfer time limits which, depending on the distance to the final destination, make a connection unattractive to travelers. According to his study, for a theoretical NST of 1 h, the maximum transfer time travelers are willing to spend is 2.93 h, whereas for a theoretical NST of 12 h, the maximum transfer time assumed by travelers is 25.2 h.

In order to determine the Connection Quality Indexes, we must first calculate the maximum perceived travel time for the route MAXT. The maximum travel time is a function of the non-stop travel time, NST, that makes the Connection Quality Index equal to one in the case of a direct flight and zero beyond a limit that goes

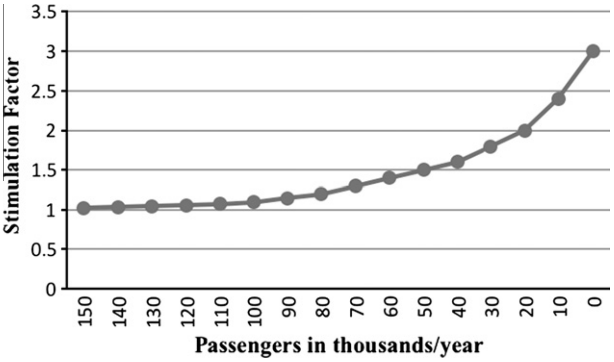

Fig. 1. IATA stimulation effect for new direct, point-to-point routes. Source IATA.

from 2.93 h for a 1-h, non-stop flight and as high as 25.2 h for a 12-h, non-stop flight.

3.4. Fare effect on non-stop versus connecting traffic for the same route

A significant percentage of passengers flying to a destination with the true origin at a main hub with an ample supply of direct, non-stop services choose to take indirect connections instead, mainly due to fare differences. Generally, fares for direct connections are higher than for indirect connections (Veldhuis, 1997). Those indirect connecting passenger volumes do not appear in the OAG data or other segment-based data, but they are clearly identified in MIDT-TOD figures.

In our model, we assume that consumers within the same national system behave similarly with regard to price elasticity when flying from the main and secondary hub cities. Thus, we calculate the percentage of hub–origin passengers that fly non-direct from the main hub and use it as a reference to estimate the percentage of current passengers with true origin in the secondary hub who will take a non-direct flight to the final destination.

3.5. Stimulation effect

In our model, we have also assumed that the creation of new frequencies of direct flights to the intercontinental destination will generate a stimulation effect. Based on real passenger volumes at many airports just before and after the establishment of a new direct route, IATA has developed a stimulation effect curve as shown in Fig. 1. The stimulation effect is measured with a multiplication factor to recalculate the new demand for the route, depending on the existing number of passengers that currently take indirect flights to a particular destination. To illustrate the use of the figure, if a new direct route were established from three different airports to a destination with a current indirect demand for that destination of 6000, 14,000 and 54,000 passengers per year per airport, the stimulation factor would be 2.70; 2.30; and 1.45 respectively. The stimulation effect tends to be exponentially larger for smaller volumes of passengers in that particular airport for that potential direct route.

4. Model formulation

The model is based on a redistribution of current traffic as it appears in the TOD data. We have formulated a model to determine the potential passenger demand for a new direct route from the secondary hub. The potential traffic for the direct route to destination i at the secondary airport, or secondary hub potential demand is designated in the model as *SHPDi*.

The total traffic transiting through a main hub airport to a destination can be divided into three groups:

(1) Local traffic originating at the main hub that takes a direct, point-to-point flight, which in the model appears as a function of the current secondary hub, non-direct demand, *SHNDi*, multiplied by the estimated proportion of passengers that take direct routes if a direct flight is available, γ_i, times the estimated stimulation effect, σ_i.

(2) Local traffic originating at the main hub that, despite the availability of direct connections, takes a non-direct alternative involving a transfer at another international hub j. We call this group main hub non-direct (*MHNDj*) traffic, and the total traffic flying through the secondary hub versus the alternative international connections will depend on the relative attractiveness of the connections, with the total volume for that second block expressed as $\sum_j MHND_j \times \frac{\delta^*}{\theta j+\delta^*}$.

(3) Connecting passengers with origin at one spoke airport n—either national or international—who, after a stop at the main hub, fly to the final destination, either directly or even making a second transfer; we define this as group spoke (*SPKDn*) passenger volume in our model. The actual volume that will take the secondary hub as the connecting choice is assumed to be a function of the relative attractiveness of the connections at the main hub and the secondary hub for all the n spokes incorporated into the system, expressed as $\sum_n SPKDn \times \frac{\delta n}{\theta n+\delta n}$.

In summary, for any new potential direct route i, for any spoke combination with n possible spoke connections, and for any potential traffic from other main international hubs j channeling non-direct traffic from the main hub, the total potential demand for a direct long-haul flight departing from a secondary hub can be expressed as follows:

$$SHPDi = SHNDi \times \sigma_i \times \gamma_i + \left[\sum_n SPKDn \times \frac{\delta n}{\theta n + \delta n} + \sum_j MHNDj \times \frac{\delta^*}{\theta j + \delta^*}\right]_i \tag{5}$$

where *SHPDi* is the secondary hub potential demand for route i, i the route where the destination is the airport currently served by direct, long-haul flights from the main hub but not from the secondary hub, n the index to indicate the spokes currently feeding the main hub's long-haul, direct flight, n being the index corresponding to each originating airport from where passengers fly to the hub (main or secondary) to transfer to the long-haul flight, j the index to indicate the spoke connections from the main hub to the final destination, involving a non-direct flight which connects through other international hubs outside the national network system, j being the index corresponding to each alternative international hub used for the connection, *SHNDi* the secondary hub potential non-direct demand (passengers per year) for route i, *SPKDn* the current true-origin demand, in passenger volume, from spoke n for route i, σ_i the estimated "stimulation effect" for route i when establishing a new direct long-haul service, γ_i the estimated proportion of passengers with true origin at the secondary hub, who despite willingness to fly to destination i, choose non-direct flights even if a direct service would be available, *MHNDj* the current demand for the i route from the secondary hub, currently transiting through airport j instead of flying direct, δn the Quality Index of the connection from spoke n connecting through the main hub, θn the Quality Index of the connection from spoke n connecting through the secondary hub, δ^* the Quality Index of the connection from the main hub connecting through the secondary hub and θj is the Quality Index of the connection from the main hub connecting to another international hub *j*.

As an application example, suppose that an airline—the flag carrier operating at the main hub or any other competing airline—plans to establish a new long-haul route for a destination *i* at a secondary hub, plans also to incorporate five spoke connections to that new long-haul route, and knows that a certain number of passengers currently departing flights from the main hub choose non-direct alternatives via three other international hubs. For a direct route *i*, the model to be applied in order to estimate potential demand would look like the following:

$$\begin{aligned} SHPDi = SHNDi \times \sigma_i \times \gamma_i + \Bigg[\Bigg\{ \left(SPKD_1 \times \frac{\delta_1}{\theta_1 + \delta_1} \right) + \left(SPKD_2 \times \frac{\delta_2}{\theta_2 + \delta_2} \right) \\ + \left(SPKD_3 \times \frac{\delta_3}{\theta_3 + \delta_3} \right) + \left(SPKD_4 \times \frac{\delta_4}{\theta_4 + \delta_4} \right) + \left(SPKD_5 \times \frac{\delta_5}{\theta_5 + \delta_5} \right) \Bigg\} \\ + \Bigg\{ \left(MHND_1 \times \frac{\delta^*}{\delta_1 + \delta^*} \right) + \left(MHND_2 \times \frac{\delta^*}{\delta_2 + \delta^*} \right) \\ + \left(MHND_3 \times \frac{\delta^*}{\delta_3 + \delta^*} \right) \Bigg\} \Bigg]_i \end{aligned} \quad (6)$$

5. Model application

We have applied the proposed model to the Spanish market, and have estimated the demand for intercontinental flights from Barcelona to Miami (secondary hub), rather than from Madrid (main hub). The main source of data is true origin and destination (TOD) data for the period January–December 2004, as recorded in the MIDT database, to which we had partial access through the assistance of an airline and some government agencies. The database contains information on a total of 635,083 passengers for the city pairs MAD–MIA and BCN–MIA for this period. We have made use of other data blocks for alternate city pairs to check the consistency of our findings with some of the main spokes (Malaga, Rome, Düsseldorf, Seville, Frankfurt, Tel Aviv, etc.).

In order to calculate the Connection Quality Indexes, we have extracted real connection times from www.amadeus.net. When a real connection is currently made with different transfer times because of multiple frequencies, we have taken the shortest one for simplification. We assume that for all the potential spokes, the connecting times are 20% higher at BCN than at MAD. We then perform a sensitivity analysis to check the impact of different connecting times.

Flying distances and flying times have been calculated using the geographic distances between airports and allowing some time for departure and landing. Finally, see Fig. 1 for the possible stimulation effect stemming from the new route. For the volume of passengers in our sample, the stimulation effect has been calculated to be 1.30.

Table 1
Excerpt of the MIDT database for the city pairs MAD and BCN to MIA. Passengers for each origin and destination in 2004.

City pair MAD–MIA/ MIA–MAD.	Total = 565,494	City pair BCN–MIA/MIA–BCN.	Total = 69,589
MAD–MIA	111,301	BCN–MIA	33,313
MAD–SJO	23,785	BCN–SJO	9987
BCN–MIA	20,296	BCN–GUA	3458
CUN–MAD	16,590	BCN–CUN	2986
GUA–MAD	14,624	BCN–MGA	2116
FCO–MIA	12,520	BCN–SAL	1712
MAD–PTY	9120	BCN–PTY	1444
BCN–SJO	8590	BCN–SAP	1281
MAD–MGA	7411	MIA–TLV	1078
FRA–MIA	6832	BCN–MCO	889
MIA–MUC	6639	CAI–MIA	506
MAD–SAL	6502	BCN–LIM	441
CUN–FCO	6457	ATH–MIA	402
LIS–MIA	5379	BCN–TGU	385
MIA–VCE	5243	MIA–ORY	376

Table 2
Detailed examination of the traffic from/through MAD to MIA.

Trip airline	Passengers	Share	Origin	Aln1	Stop1	Aln2	Stop2
IB	33,386	57.66	MAD	IB	MIA		
AA	15,895	27.45	MAD	AA	MIA		
US	1500	2.59	MAD	US	PHL	US	MIA
AF	1381	2.38	MAD	AF	CDG	AF	MIA
BA	1138	2.00	MAD	BA	LHR	BA	MIA
DL	1108	1.91	MAD	DL	ATL	DL	MIA
CO	720	1.24	MAD	CO	EWR	CO	MIA
LH	399	0.69	MAD	LH	FRA	LH	MIA
KL	341	0.59	MAD	KL	AMS	KL	MIA
VS	277	0.48	MAD	IB	LHR	VS	MIA
AA	205	0.35	MAD	AA	SJU	AA	MIA
AZ	202	0.35	MAD	AZ	MXP	AZ	MIA
LX	177	0.31	MAD	LX	ZRH	LX	MIA
AA	172	0.30	MAD	AA	JFK	AA	MIA
MP	162	0.28	MAD	KL	AMS	MP	MIA
LH	112	0.19	MAD	LH	MUC	LH	MIA
AA	46	0.08	MAD	AA	ORD	AA	MIA
IB	46	0.08	MAD	IB	JFK	AA	MIA
AA	42	0.07	MAD	IB	LHR	AA	MIA

Table 1 shows the volumes of passengers originating or transiting, both ways, through the city pairs MAD–MIA (left-hand block) or BCN–MIA (right-hand block). The total number of passengers transiting via Madrid in 2004 was 565,494. The total number of passengers transiting via Barcelona in 2004 was 69,589.

Table 2 is an excerpt of the MIDT database examining the 111,301 block of MAD–MIA passengers in more detail.

The main body of the table corresponds to the 57,906 passengers (52.03% of 111,301 passengers) from MAD to MIA and details

Table 3
Summary for the TOD passenger flow MAD–MIA/MIA–MAD.

Spoke Cities to/from MAD			Passengers with True origin/ destination at MAD airport		
Barcelona El Prat	BCN	45,113	Flying direct MAD/MIA		96,886
Frankfurt	FRA	14,714	Flying MAD/MIA via another International Hub		14,415
Paris Orly	ORY	14,439	Detail indirect:		
Munich F.J. Strauss	MUC	13,390	London Heathrow	LHR	2914
Milan Malpensa	MXP	12,291	Paris Charles de Gaulle	CDG	2762
Venice Marco Polo	VCE	10,556	Amsterdam Shiphol	AMS	1006
Lisbon Portela	LIS	9687	Frankfurt	FRA	798
Malaga P.R. Picasso	AGP	8359	Zurich	ZRH	354
Dusseldorf	DUS	8524	Other		6581
Valencia Manises	VLC	8571			
Zurich	ZRH	7470			
London Heathrow	LHR	7328			
Geneva	GVA	6715			
Tel Aviv Ben Gurion	TLV	6264			
Bilbao	BIO	5539			
Berlin Tegel	TXL	5184			
Alicante	ALC	5158			
Amsterdam Schiphol	AMS	4880			
Seville San Pablo	SVQ	4539			
Tenerife Los Rodeos	TFN	3031			
Copenhaven Kastrup	CPH	2944			
Santiago C Lavacolla	SCQ	2719			
Athens E. Venizelos	ATH	2657			

the airline and airports (if any) for the main corresponding stops. In total, direct flights accounted for 85.1% of the total passengers. In other words, even though there was an ample supply of direct flights, approximately 14.9% of passengers with their true origin in MAD decided to take connecting alternatives in Europe, mainly London Heathrow (LHR), Paris Charles de Gaulle (CDG), and Frankfurt (FRA).

Table 3 summarizes all the information for the passengers flying to MIA from MAD or via MAD into a scheme of passenger flows for the two city pairs. Only the most important airports in terms of passenger volume are shown.

We observe that the majority of MAD–MIA traffic originates at Spanish and European spokes. This observation can be explained by the vertical integration between the Barajas airport and Iberia (see also Fageda, 2009).

6. Results

The first block of traffic that, according to the model, will be captured by the new non-stop route corresponds to passengers with their true origin in Barcelona. In the model this equals = $SHNDi \times \sigma_i \times \gamma_i$ where *SHNDi* corresponds to the secondary hub non-direct traffic currently flying both ways to route *i* (MIA); σ_i is the stimulation effect for that route *i*; and γ_i is the estimated proportion of current indirect flyers who will take the direct service. According to our sample data, *SHND* stands at 62,645 passengers. The stimulation effect, according to this volume of passengers and the IATA curve σ_i, equals 1.30. Finally, according to the MIDT TOD data for MAD–MIA as a reference, we obtain that $\gamma_i = 85.1\%$. Thus, the total result for that first block of traffic is 69,304 passengers.

The second block of traffic originates at the hubs and equals = $\sum_n SPKDn \times \frac{\delta n}{\theta n + \delta n}$. For our application, we have simulated a strategy that, as a first step, establishes a new daily route from BCN to MIA with some differences in frequencies and capacity from the current direct flights from MAD. Second, the strategy also incorporates connections from the top 25 spokes in terms of current traffic volumes fed to the MAD–MIA connection, both Spanish and international. Thirdly, the transfer times for all these hub–spoke connections at the BCN airport are 20% higher than the corresponding actual connection times in MAD.

Table 4 shows the proportion of traffic that, according to the model, would potentially be derived from the current main spokes. The first and second columns indicate the cities and airport codes for the spokes. The third column is the current passenger volume connecting through the main hub for route *i*. The selected spokes have been ranked according to their importance in terms of current volume through the main hub. The next five columns incorporate the data employed to calculate the Connection Quality Index. TRF is the transfer time for each connection, in hours; FLY is the total flying time without including the transfer time in hours. PTT is a function of the TRF and FLY, and indicates the perceived travel time, according to our model, in hours. NST is the theoretical non-stop flying time, in hours from the spoke airport to the final destination. MAXT, which is a function of all other parameters, indicates the maximum travel time for route *i* from that spoke that would make the Connection Quality Index equal to zero.

In the case of Malaga, for example, the theoretical NST would be 7.43 h, resulting in a MAXT of 18.16 h. Finally, as a function of the previous parameters, we obtain the Connection Quality Index for each spoke for route *i*. In the following columns a similar procedure is followed with the same spokes for the same MIA destination with origin at BCN. The final column provides the diverted traffic that will be captured by the secondary hub according to the relative Connection Quality Index. According to the MIDT data, less than 2.8% of the spoke passengers fly to Madrid to take another connection instead of the direct flight. For simplicity, we have assumed that this percentage is maintained in our model if the spoke passengers flew to MIA via BCN. Hence, the total result for the second block of traffic is 79,125 passengers.

The third block of traffic corresponds to passengers from MAD who are flying to MIA and currently transiting through other hubs on one-stop services. This corresponds to traffic = $\sum_j MHNDj \times \frac{\delta^*}{\theta j + \delta^*}$.

Table 5 shows the proportion of traffic that could be captured by the secondary hub. The table follows the same structure as Table 4 except for the Connection Quality factor between Madrid and

Table 4
Main parameters of the model and spoke traffic potentially redistributed from the main to the secondary hub.

City	Main hub (MAD–MIA)								Secondary hub (BCN–MIA)						Pax redistributed $SPKD^* \delta n/(\theta n + \delta n)$
	Spoke	SPKD	TRF	FLY	PTT	NST	MAXT	θn	TRF	FLY	PTT	NST	MAXT	δn	
Rome Fiumicino	FCO	25,972	1.17	10.95	14.45	10.33	20.99	0.55	1.40	11.00	15.20	9.04	20.99	0.48	12,200
Frankfurt	FRA	14,714	1.75	11.07	16.32	9.75	19.50	0.28	2.10	11.08	17.38	8.17	19.50	0.19	5882
Paris Orly	ORY	14,439	2.00	10.60	16.60	9.13	22.80	0.49	2.40	10.98	18.18	10.20	22.80	0.37	6164
Munich F.J. Strauss	MUC	13,390	2.00	11.12	17.12	9.92	21.53	0.36	2.40	11.03	18.23	9.37	21.53	0.27	5727
Milan Malpensa	MXP	12,291	2.33	10.80	17.79	9.93	21.81	0.33	2.80	10.87	19.25	9.55	21.81	0.21	4779
Venice Marco Polo	VCE	10,556	1.17	11.09	14.60	10.12	19.99	0.47	1.40	11.18	15.40	8.45	19.99	0.40	4856
Lisbon Portela	LIS	9687	2.00	10.14	16.14	8.33	21.65	0.45	2.40	11.15	18.35	9.45	21.65	0.27	3628
Valencia Manises	VLC	8571	1.17	9.79	13.29	9.20	21.70	0.69	1.40	10.18	14.38	9.48	21.70	0.60	3987
Dusseldorf	DUS	8524	2.17	11.07	17.57	9.62	21.12	0.30	2.60	11.15	18.95	9.12	21.12	0.18	3234
Malaga P.R. Picasso	AGP	8359	1.58	9.99	14.74	9.07	21.12	0.53	1.90	10.87	16.57	9.12	21.12	0.38	3480
Zurich	ZRH	7470	2.83	10.82	19.31	9.75	25.86	0.49	3.40	11.03	21.22	12.57	25.86	0.35	3097
London Heathrow	LHR	7328	2.17	10.82	17.33	8.78	25.74	0.63	2.60	11.12	18.93	12.46	25.74	0.51	3279
Geneva	GVA	6715	1.58	10.69	15.43	9.62	22.20	0.55	1.90	10.82	16.50	9.80	22.20	0.46	3067
Tel Aviv Ben Gurion	TLV	6264	2.00	13.60	19.60	12.95	21.83	0.18	2.40	13.43	20.63	9.56	21.83	0.10	2187
Bilbao	BIO	5539	1.58	9.82	14.56	8.80	22.60	0.64	1.90	10.57	16.25	10.07	22.60	0.51	2443
Berlin Tegel	TXL	5184	1.17	11.57	15.07	9.80	19.56	0.40	1.40	11.57	15.77	8.20	19.56	0.33	2374
Alicante	ALC	5158	1.58	9.89	14.64	9.20	21.65	0.57	1.90	10.35	16.05	9.45	21.65	0.46	2290
Amsterdam Schiphol	AMS	4880	2.17	11.00	17.51	9.20	20.03	0.22	2.60	11.22	19.03	8.47	20.03	0.09	1389
Seville San Pablo	SVQ	4539	2.00	9.95	15.95	8.75	21.53	0.46	2.40	10.97	18.17	9.37	21.53	0.28	1707
Tenerife Los Rodeos	TFN	3031	1.58	11.52	16.26	7.93	20.05	0.33	1.90	12.35	18.04	8.48	20.05	0.17	1051
Copenhaven Kastrup	CPH	2944	2.33	11.74	18.73	9.62	21.12	0.20	2.80	11.78	20.17	9.12	21.12	0.08	836
Santiago C Lavacolla	SCQ	2719	2.33	10.09	17.09	8.28	18.39	0.12	2.80	11.08	19.48	7.56	18.39	0.00	0
Athens E. Venizelos	ATH	2657	2.73	12.09	20.28	11.50	21.53	0.10	3.28	11.95	21.78	9.37	21.53	0.00	0
Las Palmas	LPA	2385	2.17	11.51	18.02	8.05	24.32	0.48	2.60	12.37	20.18	11.30	24.32	0.32	946
Cairo	CAI	1043	6.25	13.35	32.10	12.77	19.25	0.00	7.50	13.22	35.72	8.03	19.25	0.00	522

Table 5
Main parameters of the model and non-direct, via international hubs, traffic potentially redistributed from the main to the secondary hub.

City	Spoke	MAD–Int'l hub							MAD–BCN						Pax redistributed $SPK * \delta^*/(\theta n + \delta^*)$
		SPK	TRF	FLY	PTT	NST	MAXT	θn	TRF	FLY	PTT	NST	MAXT	δ^*	
London Heathrow	LHR	2914	1.17	1.85	5.35	8.97	20.87	1.30	1.40	8.80	13.00	8.97	20.87	0.66	981
Paris Charles de Gaulle	CDG	2762	1.17	1.60	5.10	8.97	20.87	1.32	1.40	8.80	13.00	8.97	20.87	0.66	920
Frankfurt	FRA	798	1.30	2.08	5.98	8.97	20.87	1.25	1.56	8.80	13.48	8.97	20.87	0.62	265
Amsterdam Shiphol	AMS	1006	1.40	2.13	6.33	8.97	20.87	1.22	1.68	8.80	13.84	8.97	20.87	0.59	328

Barcelona for the route MIA, δ^*, which remains constant—because the connection alternative to any international hub j is always the same, MAD–BCN–MIA. In this case, we have included all major international hubs that concentrate the vast majority of the transfers to MIA with true origin in MAD, which in the example are LHR, CDG, FRA, and AMS, ranked according to actual volumes derived from MIDT data. The transit corresponding to this third block amounts to 2493 passengers.

To summarize the results, if the connecting system included the 25 most important spokes, the total potential volume for a direct service from BCN to MIA would amount to 150,922 passengers. The drain of passengers from the direct connection departing from MAD would reduce the current direct flight volumes from the current 415,863 passengers to 264,941 passengers. This reduction includes the diverted traffic from spokes currently feeding the direct flight MAD–MIA, as well as the percentage of volume currently originating in BCN, which would choose the direct connection from BCN to MIA instead of connecting via MAD.

As indicated earlier, when the new direct route is incorporated into the model, the total volume for the new route is theoretically composed of three blocks of passengers. In two cases—i.e., passengers originating from the secondary hub and passengers originating from the primary hub—travelers will use the direct route from their respective hubs regardless of the proactive strategies pursued by the airlines or the airports. This conclusion stems from the assumption that the direct flight between main and secondary hubs is already in place and that fares will be equally competitive between all potential hubs for the trip to the intercontinental destination.

The third block of passengers—passengers from other spoke airports—on the other hand, may be influenced by proactive actions undertaken by the airline because it will provide additional volume for the direct long-haul segment departing from the secondary hub if two conditions are met: first, if there is an available connection between the spoke airport and the secondary hub, and, second, if the transfer time for that spoke at the secondary hub is not too long compared to that at the primary hub. The Connection Quality Indexes incorporated in the model make the volumes of passengers captured from a spoke airport particularly sensitive to transfer times or, more precisely, to the relative transfer times between the main and secondary hubs.

Therefore, although some factors affecting the connection attractiveness for one hub versus another are out of the airlines' or airport authorities' control, such as the geographic location of the airports involved, airlines may influence the volume of passengers captured via the spoke airports either by (a) incorporating more spokes into the potential connection or (b) improving the connecting (transfer) times for the existing spokes at the secondary hub.

One question needing to be addressed is whether the model can provide indications regarding what combination of policies may optimize the passenger volumes diverted to the secondary hub for a particular intercontinental route.

Fig. 2 shows an example of three alternative strategies for the example BCN–MIA. The first strategy consists of incorporating into the connection in BCN the airports of MXP, DUS, and TLV. The first strategy includes the necessary policies—slot management, gate management, terminal management, schedules, etc.—to make transfer times at BCN (the secondary hub) 20% shorter than the corresponding connections at MAD (the main hub). The second alternative strategy shown in Fig. 2 keeps the connecting times equal between the main and secondary hubs (BCN versus MAD) but incorporates a new spoke into the model, in this case AMS (Amsterdam). The third strategy shows the impact of the addition of a fifth spoke, CPH (Copenhagen), but with connecting times 20% longer for all the spokes connecting in BCN versus in MAD. The first

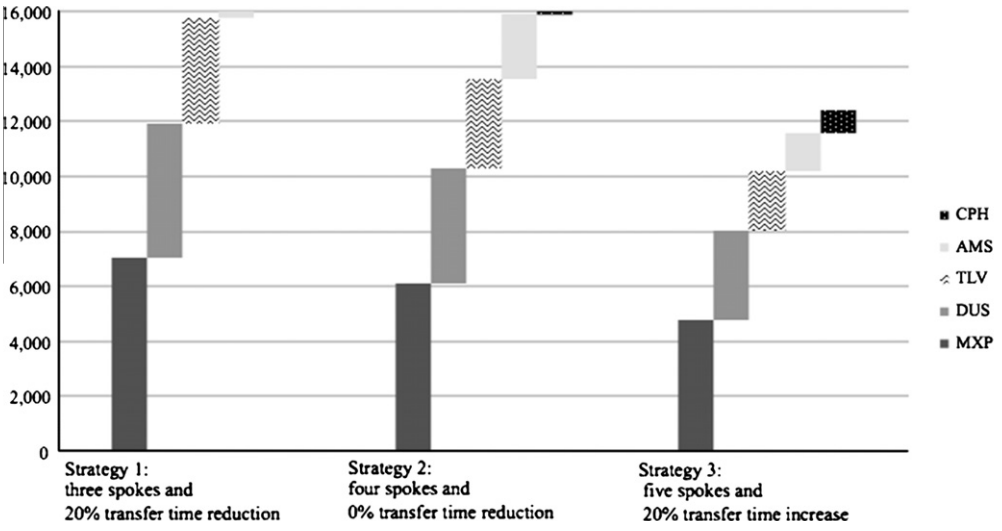

Fig. 2. Passenger volume generated by different combinations of spokes connecting at BCN depending on the relative increase/decrease of transfer time at BCN airport compared to the transfer time at MAD airport for each corresponding connection.

strategy, consisting of only three spokes but with a 20% reduction in connecting times, generates a higher passenger volume than the other two strategies. The second strategy, consisting of four spokes and equal connecting times, also provides higher volumes than the third strategy, consisting of five spokes with 20% longer connecting times.

In the example shown, the spoke passengers from AMS appear to be particularly sensitive to the connecting times because of the longer detour implied in the connection via BCN when compared to the connection via MAD. On the other hand, the spoke passengers from MXP (Milano Malpensa) are less sensitive to longer connecting times than passengers from CPH because the connection via BCN has almost no detour factor when flying from MXP to MIA.

A remarkable result of the analysis shown in Fig. 2 is that, in some cases, the impact of introducing a new spoke into the network may be less effective than a 20% improvement in the connecting times for the already incorporated spokes. In other words, proper management of the connecting times for each individual spoke feeding the transcontinental flight may have a higher impact than the introduction of a new spoke into the system.

7. Conclusions and limitations

This study contributes to methodologies currently used by researchers to calculate air traffic passenger flows. Using TOD data, we are able to estimate demand not only at the hub level but also at the spoke level, by combining the current traffic with the attractiveness of potential alternate connections for passengers currently transiting through different hubs.

Our model could be used to evaluate the feasibility of new intercontinental routes; it may also serve as a strategic planning tool for airlines—or airport systems—to redistribute traffic within the national network in order to optimize capacity utilization. Such redistribution has an immediate impact for the “secondary” hub airport involved as far as capacity and modernization programs or regional accessibility and social development are concerned (Halpern and Brathen, 2011).

It also has an impact on the secondary hub city, as airline hubs and international air gateways are more likely to attract companies’ headquarters, high-tech jobs, and foreign investments. In this regard, Strauss-Kahn and Vives (2009) show that US urban areas with an airport hub (whether large or small) are much more attractive for locating headquarters while Bel and Fageda (2008) find evidence that location choices of multinational firms and knowledge intensive activities (high-order services, headquarters, high-technology industries) are strongly influenced by the availability of direct intercontinental air services in European urban areas.

Finally, the application of our model reveals that potential transcontinental traffic for new routes in secondary airports might equal or eventually surpass that of the main national hub if the conditions for an efficient hub-and-spoke network were put in place. It also highlights the main elements of an optimal traffic redistribution strategy and its impact on the potential traffic. Particularly, while managing frequencies from the spoke cities appears to be critical, the model shows that proper planning of transfer times at the hub level may have an even more significant impact on the potential traffic redistribution between the main and secondary airports. This result is particularly important in airport planning when considering infrastructures that facilitate the reduction of connecting times.

This study is not free of limitations, the most important being the hypothesis that following deregulation carriers are free to choose their networks. The assumption, though reasonable, is subject to slot allocation restrictions in congested airports. The EU airports’ slots for example, are—in theory—negotiated annually, but in reality, historical grandfather rights prevail over present needs (Condorelli, 2007).

Despite such limitations, in the context of route planning and optimization (because of airport congestion or slot allocation policies), airlines can employ our model to give priority to the most important spokes available after the application of non-demand related criteria.

In this paper we have shown the application of our model to the MAD–MIA and BCN–MIA city pairs. However, we have also applied the model to other main routes where BCN had no (or very limited) direct flights whereas MAD had an ample supply of direct services in 2004: Sao Paulo (GRU) and New York (both JFK and EWR). In all cases, we have obtained results consistent with the MIA example. For all the analyzed long-haul destinations, according to the 2012 year to date OAG data, different airlines are currently offering direct services with high capacity records: Delta and American Airlines offer daily services to JFK, Iberia and Singapore Airlines have daily flights to Sao Paulo, and there are also daily frequencies from Barcelona to Miami (by Iberia/American Airlines). As we write this paper, American Airlines is considering the introduction of a second daily frequency from BCN to JFK. These new, successful long-haul services from BCN partially substantiate our model.

The results of our study are useful not only for the established hub carriers, but also for new airlines attempting to establish an intercontinental hub in the secondary airport. Furthermore, the results may be useful not only for long-haul flight, but also for medium and short haul services, as well as when analyzing demand for hubs within a regional system (e.g. Europe). Finally, airport authorities can also take advantage of our model when assessing the potential impact of alternative strategies to manage slots, connecting gates, and airport terminals.

References

Adler, N., Berechman, J., 2001. Evaluating optimal multi-hub networks in a deregulated aviation market with an application to Western Europe. Transportation Research Part A: Policy and Practice 35 (5), 373–390.

Alberts, H.C., Bowen Jr., J.T., Cidell, J.L., 2009. Missed opportunities: the restructuring of Berlin’s airport system and the city’s position in international airline networks. Regional Studies 43 (5), 739–758.

Barbot, C., 2009. Airport and airlines competition: incentives for vertical collusion. Transportation Research Part B: Methodological 43 (10), 952–965.

Basso, L.J., 2008. Airport deregulation: effects on pricing and capacity. International Journal of Industrial Organization 26 (4), 1015–1031.

Bel, G., Fageda, X., 2008. Getting there fast: globalization, intercontinental flights and location of headquarters. Journal of Economic Geography 8 (4), 471–495.

Bel, G., Fageda, X., 2010a. Intercontinental flights from European airports: towards hub concentration or not? International Journal of Transport Economics 37 (2), 133–153.

Bel, G., Fageda, X., 2010b. Privatization, regulation and airport pricing: an empirical analysis for Europe. Journal of Regulatory Economics 37 (2), 142–161.

Berechman, J., Shy, O., 1996. The structure of airline equilibrium networks. In: Van der Bergh, Nijkamp, P., Rietveld, P. (Eds.), Recent Advances in Spatial Equilibrium: Methodologies and Applications. Springer-Verlag, Berlin.

Berechman, J., de Wit, J., 1996. An analysis of the effects of European aviation deregulation on an airlinés network structure and choice of a primary West European hub. Journal of Transport Economics and Policy 30 (3), 251–274.

Blackstone, E.A., Buck, A.J., Hakim, S., 2006. Determinants of airport choice in a multi-airport region. Atlantic Economic Journal 34 (3), 313–326.

Bowen, J., 2002. Network change, deregulation and access in the global airline industry. Journal of Economic Geography 78 (4), 425–439.

Brueckner, J.K., Zhang, Y., 2001. Scheduling decisions in an airline network: a hub-and-spoke system’s effect on tight frequency, fares and welfare. Journal of Transport Economics and Policy 35, 195–222.

Burghouwt, G., Hakfoort, J.R., 2001. The European Aviation Network 1990–1998. Journal of Air Transport Management 7 (5), 311–318.

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

Button, K., 2002. Debunking some common myths about airport hubs. Journal of Air Transport Management 8 (3), 177–188.

Chou, Y.H., 1993. Airline deregulation and nodal accessibility. Journal of Transport Geography 1 (1), 36–46.

Condorelli, D., 2007. Efficient and equitable airport slot allocation. Rivista di Politica Economica 97 (1–2), 81–104.

Currier, K., 2008. Price cap regulation of airports: a new approach. Economics Bulletin 12 (8), 1–7.

de Wit, J., Burghouwt, G., 2008. Slot allocation and use at hub airports, perspectives for secondary trading. European Journal of Transport and Infrastructure Research 8 (2), 147–164.

Dennis, N., 1994. Airline hub operations in Europe. Journal of Transport Geography 2 (4), 219–233.

Derudder, B., Devriendt, L., Witlox, F., 2010. A spatial analysis of multiple airport cities. Journal of Transport Geography 18 (3), 345–353.

Derudder, B., Witlox, F., 2005. An appraisal of the use of airline data in assessing the world city network: a research note on data. Urban Studies 42 (13), 2371–2388.

Derudder, B., Witlox, F., 2008. Mapping global city networks through airline flows: context, relevance, and problems. Journal of Transport Geography 16 (3), 305–312.

Derudder, B., Witlox, F., 2009. The impact of progressive liberalization on the spatiality of airline networks: a measurement framework based on the assessment of hierarchical differentiation. Journal of Transport Geography 17 (4), 276–284.

Devriendt, L., Burghouwt, G., Derudder, B., de Wit, J., Witlox, F., 2009. Calculating load factors for the transatlantic airline market using supply and demand data: a note on the identification of gaps in the available airline statistics. Journal of Air Transport Management 15 (6), 337–343.

Devriendt, L., Derudder, B., Witlox, F., 2010. Conceptualizing digital and physical connectivity: the position of European cities in Internet backbone and air traffic flows. Telecommunications Policy 34 (8), 417–429.

Düdden, J.C., 2006. Multi-hub network configurations – a temporary or permanent outcome of airline consolidation? Review of Network Economics 5, 421–434.

Fageda, X., 2009. Infrastructure dominance in short-haul air transport markets. Revista de Economía Aplicada-Spain 17 (49), 135–156.

Forbes, S.J., Lederman, M., 2010. Does vertical integration affect firm performance? Evidence from the airline industry. Rand Journal of Economics 41 (4), 765–790.

Francis, G., Dennis, N., Ison, S., Humphreys, I., 2007. The transferability of the low-cost model to long-haul airline operations. Tourism Management 28 (2), 391–398.

Fu, X., Lijesen, M., Oum, T.H., 2006. An analysis of airport pricing and regulation in the presence of competition between full service airlines and low cost carriers. Journal of Transport Economics and Policy 40 (3), 425–447.

Fuhr, J., Beckers, T., 2006. Vertical governance between airlines and airports: a transaction cost analysis. Review of Network Economics 5 (4), 386–412.

Goetz, A.R., Sutton, C.J., 1997. The geography of deregulation in the US airline industry. Annals of the Association of American Geographers 87 (2), 238–263.

Graham, B., 1998. Liberalization, regional economic development and the geography of demand for air transport in the European Union. Journal of Transport Geography 6 (2), 87–104.

Halpern, N., Brathen, S., 2011. Impact of airports on regional accessibility and social development. Journal of Transport Geography 19 (6), 1145–1154.

Harvey, G., 1987. Airport choice in a multiple airport region. Transportation Research Part A: Policy and Practice 21 (6), 439–449.

Hensher, D.A., Truong, T.P., 1985. Valuation of travel time savings. Journal of Transport Economics and Policy 19 (3), 237–261.

Hess, S., Polak, J.W., 2005. Mixed logit modelling of airport choice in multi-airport regions. Journal of Air Transport Management 11 (2), 59–68.

Ishii, J., Jun, S., Van Dender, K., 2009. Air travel choices in multi-airport markets. Journal of Urban Economics 65 (2), 216–227.

Keeling, D.J., 1995. Transport and the world city paradigm. In: Knox, P.L., Taylor, P.J. (Eds.), World Cities in a World-System. Cambridge University Press, Cambridge, pp. 115–131.

Kuchinke, B.A., Sickmann, J., 2007. Vertikale integration von fluglinien und flughafen: Eine wettbewerbsokonomische analyse (with English summary). Z Wirtschaftspolitik 56 (1), 84–107.

Li, Z., Lam, W.H.K., Wong, S.C., Fu, X., 2010. Optimal route allocation in a liberalizing airline market. Transportation Research Part B: Methodological 44 (7), 886–902.

Madan, D.B., Groenhout, R., 1987. Modelling travel mode choices for the Sidney work trip. Journal of Transport Economics and Policy 21 (2), 135–149.

Maertens, S., 2010. Drivers of long-haul flight supply at secondary airports in Europe. Journal of Air Transport Management 16 (5), 239–243.

Malighetti, P., Martini, G., Paleari, S., Redondi, R., 2007. An empirical investigation on the efficiency, capacity and ownership of Italian airports. Rivista di Politica Economica 97 (1–2), 157–188.

Malighetti, P., Meoli, M., Paleari, S., Redondi, R., 2011. Value determinants in the aviation industry. Transportation Research Part E: Logistics and Transportation Review 47 (3), 359–370.

O'Connor, K., 1995. Change in the pattern of airline services and city development. In: Brotchie, J., Batty, M., Blakely, E., Hall, P., Newton, P. (Eds.), Cities in Competition. Longmans, Melbourne, pp. 88–104.

O'Connor, K., 2003. Global air travel: toward concentration or dispersal? Journal of Transport Geography 11 (2), 83–92.

O'Connor, K., Fuellhart, K., 2012. Cities and air services: the influence of the airline industry. Journal of Transport Geography 22 (May), 46–52.

O'Connor, K., Scott, A., 1992. Airline services and metropolitan areas in the Asia Pacific region. Review of Urban & Regional Development Studies 4 (2), 240–253.

Oum, T.H., Zhang, A., Zhang, Y., 1995. Airline network rivalry. Canadian Journal of Economics 28, 836–857.

Oum, T.H., Fu, X., 2008. Impacts of Airports on Airline Competition: Focus on Airport Performance and Airport-Airline Vertical Relations. Joint Transport Research Centre, International Transport Forum, OECD. <http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200817.pdf>.

Oum, T.H., Yan, J., Yu, C., 2008. Ownership forms matter for airport efficiency: a stochastic frontier investigation of worldwide airports. Journal of Urban Economics 64 (2), 422–435.

Pels, E., Nijkamp, P., Rietveld, P., 2000. Airport and airline competition for passengers departing from a large metropolitan area. Journal of Urban Economics 48 (1), 29–45.

Pels, E., Nijkamp, P., Rietveld, P., 2003. Inefficiencies and scale economies of European airport operations. Transportation Research Part E: Logistics and Transportation Review 39 (5), 341–361.

Pels, E., Njegovan, N., Behrens, C., 2009. Low-cost airlines and airport competition. Transportation Research Part E: Logistics and Transportation Review 45 (2), 335–344.

Redondi, R., Malighetti, P., Paleari, S., 2012. De-hubbing of airports and their recovery patterns. Journal of Air Transport Management 18 (1), 1–4.

Reynolds-Feighan, A., 2000. The US airport hierarchy and implications for small communities. Urban Studies 37 (3), 557–577.

Reynolds-Feighan, A., 2001. Traffic distribution in low-cost and full-service carrier networks in the US air transportation market. Journal of Air Transport Management 7 (5), 265–275.

Shin, K.H., Timberlake, M., 2000. World cities in Asia: cliques, centrality and connectedness. Urban Studies 37 (12), 2257–2285.

Sismanidou, A., Palacios, M., Tafur, J., 2009. Progress in airline distribution systems: the threat of new entrants to incumbent players. Journal of Industrial Engineering and Management 2 (1), 251–272.

Starkie, D., 1998. Allocating airport slots: a role for the market? Journal of Air Transport Management 4 (2), 111–116.

Strauss-Kahn, V., Vives, X., 2009. Why and where do headquarters move? Regional Science and Urban Economics 39 (2), 168–186.

Suau-Sanchez, P., Burghouwt, G., 2011. The geography of the Spanish airport system: spatial concentration and deconcentration patterns in seat capacity distribution, 2001–2008. Journal of Transport Geography 19 (2), 244–254.

Suau-Sanchez, P., Burghouwt, G., Fageda, X., 2011. Determinants for Seat Capacity Distribution in EU and US, 1990–2009. Working Paper.

Suzuki, Y., 2007. Modeling and testing the 'two-step' decision process of travelers in airport and airline choices. Transportation Research Part E: Logistics and Transportation Review 43 (1), 1–20.

Taylor, P.J., 1999. So called 'world cities': the evidential structure within a literature. Environment and Planning A 31, 1901–1904.

Thompson, I.B., 2002. Air transport liberalisation and the development of third level airports in France. Journal of Transport Geography 10 (4), 273–285.

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

Weber, M., Williams, G., 2001. Drivers of long-haul air transport route development. Journal of Transport Geography 9 (4), 243–254.

Wei, W., Hansen, M., 2006. An aggregate demand model for air passenger traffic in the hub-and-spoke network. Transportation Research Part A: Policy and Practice 40 (10), 841–851.

Yang, H., Zhang, A., 2011. Price-cap regulation of congested airports. Journal of Regulatory Economics 39 (3), 293–312.