COMPARATIVE STUDY OF HUB AIRPORTS IN EUROPE: TICKET PRICES, TRAVEL TIME AND RESCHEDULING COSTS

FRANK BRUINSMA, PIET RIETVELD & MARTIJN BRONS

Free University, Department of Spatial Economics, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands. E-mail: fbruinsma@econ.vu.nl

Received: September 1999; revised January 2000

ABSTRACT

This paper investigates the strategic position of four European airports in the aviation network by means of a generalised cost function. We compare the performance of the hub airports London, Paris, Frankfurt, and Amsterdam. Our analysis entails flights from smaller European airports via these hubs to intercontinental destinations and vice versa. The comparative positions of the cities in the airport network is determined by a generalised cost function in which travel cost, travel time and rescheduling time (as a function of the frequency of the service) are included.

An important feature of the comparative study is that various market segments are identified (business, tourists). We find that the positions of the hub airports for the business class passengers differ from those for economy class passengers. Using high-speed rail as an alternative for the European part of the trip is only attractive for a rather restricted segment of the market.

Key words: Hub airports, generalised costs, high-speed rail

INTRODUCTION

The aviation sector is one of the most dynamic transport sectors. Large ongoing investments in airports are required in order to accommodate the rise in demand of air passengers. Airport operations are characterised by indivisibilities (an additional runway creates a discrete increase in capacity). Therefore, once the capacity is available, airports can benefit greatly from a growth in demand with relatively low costs. A related phenomenon is the presence of economies of scope for airports. As an airport attracts more passengers, thus conveying the notion that it has more destinations and flights, its attractiveness as a node for additional carriers increases. Given these features of the airport business (Doganis 1992), it is not surprising that many airports are urgently looking for opportunities to increase the number of their customers.

Airports basically operate on two markets: the regional (or 'home') market and the transfer market. Strong competition may take place in both markets. The first involves passengers and freight that have the region around the airport as an origin or a destination. In many large metropolitan areas residents can choose between more than one airport and so competition between airports in the region can occur in various ways. Passengers will, for example, pay attention to:

1. the services offered by the airlines using the airport: fares, frequencies, number of destinations, convenient departure times, etc.;
2. the accessibility of the airport in terms of travel time, infrastructure quality for various transport modes such as car, metro, etc.;
3. local aspects of accessibility at the airport: parking regime, parking prices, car rentals, location of public transport terminal;

Tijdschrift voor Economische en Sociale Geografie – 2000, Vol. 91, No. 3, pp. 278–292.

Published by Blackwell Publishers, 108 Cowley Road, Oxford OX4 1JF, UK and 350 Main Street, Malden MA 02148, USA

4. additional services of the airports: such as tax-free shopping, restaurants, casino, etc.

This list of quality aspects underlines the variety of actors involved in the production of aviation services and the complementarity of their activities. For aspects 1–4 we note inputs from, among other things, airlines, public and private infrastructure providers, public transport companies, airports, firms renting space at airports, etc. To achieve an attractive aggregate level of services, co-ordination of the activities of these actors is essential.

The above situation, in which an area is served by more than one airport, may take place not only within a metropolitan area with multiple airports, but also in a non-metropolitan context. Spatial market area analysis (see, for example, Paelinck & Nijkamp 1975; Greenhut *et al.* 1987) may be used to identify the orientation of regions without an airport towards neighbouring regions which do have one.

The second market on which airports operate is the transfer market. The competition concerns passengers or freight from distant places to be transported to other places further away that may use the airport as a transit point. The markets of origin and destination can obviously be numerous in this case. Competition takes place with other hub airports. Here, local accessibility is of no importance, thus implying that aspects 2 and 3 are no longer relevant. These are replaced by criteria associated with the quality of the connection between the incoming and outgoing flights. This quality depends on among other things the timetables and reliability of the airlines as well as the airport facilities. For example, an airport based on a one-terminal principle will realise shorter minimal connecting times than will multi-terminal airports.

When comparing the airport competition in both markets, the transfer market is usually more competitive than the regional market since people living in a particular region often have fewer opportunities to take direct flights (there is only one airport nearby), whereas for indirect flights they may use several competing hub airports. It is important to remember that the two markets are not independent. A large 'home market' of an airport implies that it easily achieves high frequencies, thus making the airport stronger as a base of operations as a hub airport.

In this paper we focus on competition between airports on the transfer market. We address the quality of hub airport services from a generalised cost perspective by considering fares, travel times and the rescheduling costs of travellers. Other determinants of airport quality, which are more difficult to evaluate monetarily, are not included in the analysis. The generalised cost approach applied in our analysis is consumer oriented. For a study on the competitiveness of hub airports in Europe, with an emphasis on the functioning of transportation systems (airport flight scheduling), including catchment areas, markets served, and airport facilities, we refer to Dennis (1998).

Our paper is structured as follows: the following section describes the specific airports of this analysis. The methods used in the research will be explained and justified in the next section. The results of the research are presented in the fourth section. This section also examines by means of a sensitivity analysis how the position of Schiphol airport (Amsterdam) will be influenced by changes in ticket pricing or the frequency of service. The consequences of the completion of the high-speed rail network in Europe as an important entrance or exit mode of European hubs for intercontinental flights will be analysed in the section following. The last section concludes.

EXPLORING THE AIRPORTS

The quality of the included European hub airports is first quantitatively compared in this section.[1] Second, competition between airlines and airports is given prominence. Liberalisation in intra-European aviation, which has been implemented by the European Commission, will possibly induce concentration and mergers resulting in only a few dominant airlines (Burghouwt 1999; Hakfoort 1999). This may further stimulate the development of hub-and-spoke systems on a limited number of large hub airports. If we consider these developments, it becomes intriguing to investigate the position of the current large hub airports in Western Europe: Charles de Gaulle, Heathrow, Frankfurt and Schiphol.

International comparison of the airports – In the next section the position of the four hub airports is determined by means of a generalised cost function. Ticket prices, travel time, frequencies and rescheduling times are included in this function. Other important factors of airport competition are local market potential, capacity of the runways, quality of the handling of passengers and goods, the number of destinations, and facilities and tariffs of the airport. This section offers an overview of a number of these factors for the four airports in our empirical analysis.

Table 1 shows that the potential market area with regard to population size is about equal, while the size of the city and the national population are quite varied. The hinterlands of the four airports scarcely overlap. When we consider the competition among the four hub airports and other regional airports such as Brussels and Düsseldorf, good accessibility to the airport by car and train is important. In this respect, Heathrow performs badly. The other airports are linked to the international road and rail network. These airports will probably be included in the European high-speed rail network.

The level of service is given by the supply of direct line services in the first seven days of the month of October 1998 from all airports in our focal urban areas (Paris: Charles de Gaulle and Orly; London: Heathrow, Gatwick, Stanstead, Luton and City). Transfer connections, irregular flights and charters are excluded from our consideration. Insofar as the number of countries and destinations are concerned, London, Paris and Frankfurt perform equally. However, with respect to the frequencies of service, London performs best and Paris is second. Amsterdam clearly lags behind the competition with respect to the number of countries and destinations, but the average frequency of connections is higher than in Frankfurt and almost the same as in Paris.

In Table 2 the flights during the first week of October 1998 are presented for the four cities. London has the most average distribution of flights. In Paris domestic air traffic and services on (former) French colonies are overrepresented. Orly concentrates completely on these national links and connections with the former colonies, whereas Charles de Gaulle serves European and intercontinental destinations. The position of Frankfurt within the German air traffic is not as dominant as the position of the other three cities in their respective countries. Given the small home market, the number and share of flights of Amsterdam to domestic destinations is low: Schiphol needs to attract passengers from the larger European market for increased numbers of intercontinental flights.

An airport's position in intercontinental air traffic is an important factor of its strategic position as a hub airport in Europe. In absolute numbers, London is the main player, Frankfurt and Paris score the same (the supply in frequencies is two-thirds of the supply of the London airports in both cases) and Amsterdam lags behind (London has twice as many intercontinental flights). When we evaluate the share of intercontinental destina-

Table 1. *Main figures for the airports.*

	Amsterdam	Frankfurt	Paris	London
Home market (million inhabitants):	5	7.8	8.7	7.7
Urban region	24	25	24	24
Radius of 200 km				
Supply of international direct lines:*				
Number of countries (first week Oct 1998)	93	114	116	114
Destinations (first week Oct 1998)	225	259	249	269
Frequencies (first week Oct 1998)	3,690	3,122	4,372	6,847

*Paris: Charles de Gaulle & Orly and London: Heathrow, Gatwick, Luton, Stanstead and City.
Sources: Ministry of Transport 1996/adapted from OAG 1998.

Table 2. *Flights to destinations during the first week of October 1998.*

	Amsterdam		Frankfurt		London		Paris	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%
Domestic	124	3.3	708	18.5	1,660	19.5	2,349	35.0
Other European	2,773	72.7	1,793	46.8	4,792	56.3	3,033	45.1
Intercontinental	917	24.0	1,329	34.7	2,055	24.2	1,339	19.9
Total	3,814	100.0	3,830	100.0	8,507	100.0	6,721	100.0

Source: adapted from OAG, 1998

tions, Amsterdam (24%) performs the same as London (24.2%) and better than Paris (19.9%). Take note of the emphasis upon the intercontinental destinations of Frankfurt: almost 35% of all flights have an intercontinental destination.

The influence of worldwide alliances of airlines – A 'hub-and-spoke' system in aviation is a system where continental passengers fly via a hub before they begin an intercontinental flight. The emergence of this system has resulted in two major types of alliances between airlines. The first strategy is to co-operate with partners within the continent (Europe) in order to combine passengers for intercontinental flights and to distribute incoming passengers throughout Europe. The co-operation is usually limited to 'code-sharing', where two companies agree to serve European relations jointly. The second strategy is to co-operate with partners outside the continent in order to create mass on the intercontinental link and offer more destinations on both intra-continental sides. This approach usually leads to strategic alliances between the airlines. Both companies serve their own continents where they can collect and distribute passengers and freight for the partner. Agreements are made for code sharing for the intercontinental connections. For example, the code sharing between KLM and Northwest Airlines made it possible for KLM to serve 177 destinations in the USA (transfer in the USA) and for Northwest Airlines to serve 30 extra destinations in Europe (Ministry of Transport 1996).

The four home carriers of the hub airports studied (British Airways (BA), Air France (AF), Lufthansa (LH), KLM) are increasingly involved in code sharing within Europe during the period 1992–97. Code sharing is not only used to collect passengers for intercontinental destinations, but also to decrease the costs (larger planes or higher occupation rate), or to offer connections with higher frequencies. All home-carriers are involved in an alliance with an American partner.[2] For the European airlines the connection between Europe and the USA is the most important intercontinental route. The destinations where partners from European home-carriers are based are not considered in our empirical study.

The percentage of flights carried out by home-carriers via their own hubs has increased from 77% to 85% during the period 1992–97. This is remarkable since the European Commission is trying to increase competition in the European market with the 'fifth-freedom and cabotage rights'.

OPERATIONALISING THE GENERALISED COST FUNCTION

Selection of airports – We have chosen the four largest airports in Western Europe in order to study their quality as hub airports. A set of airports within Europe and outside Europe has been selected to compare the costs for passengers when they use the hub airports as a transfer point on a flight between these European origins and intercontinental destinations, and vice versa. The following airports outside Europe have been selected:

- North America: New York, Los Angeles.
- Central America: Mexico City.
- South America: Rio de Janeiro, Buenos Aires.

- Africa: Johannesburg.
- Asia: New Delhi, Singapore, Tokyo, Beijing.

For the selection of the European origin airports two criteria are used: first, the airports must be dispersed throughout Europe, and second, the airports have to be located on the – future – high-speed rail network. After applying these criteria the following cities have been selected: Copenhagen, Brussels, Vienna, Milan and Glasgow.

Operationalising the strategic position of airports – *Methodology of the generalised cost function* – The strategic position of the four cities in the aviation network is determined by a generalised cost function for both business and private travels. We can break down the cost function into three components: ticket prices, travel time valuation and rescheduling costs, and two types of ticket prices: the least expensive economy class tariff for non-business travellers and the least expensive business class tariff for business travellers. Travel time valuation has been set to 18 Dutch guilders an hour (about 8.2 euros) for the non-business traveller and 90 guilders an hour (about 40.9 euros) for the business traveller (in accordance with CPB (1997) and NEI (1994)). Since many business travellers fly economy class, the third category of the business traveller with a business travel time valuation who flies at economy class fares is added.

The travel time element consists of travel time itself and a penalty for not being able to fly at any preferred time: the rescheduling costs. With regard to travel time, we use the average travel time. In calculating the average travel time per connection, a flight with a short travel time is valued higher since this flight is more favourable (than a flight with a longer travel time) and therefore has a higher chance of realisation (for details see Ndoh *et al.* 1990; Bruinsma *et al.* 1999). The time needed to travel to the airport is excluded from consideration. These travel times are not discriminating for the four hubs (they concern the travel time to airports of origin and destination and are all identical). Still, the time needed to travel to the airport, check in and wait for departure will raise the generalised costs. The rescheduling costs are largely dependent upon the frequency of the service. The penalty has been set at 25% of the average time between two successive flight alternatives (in conformity with Bruinsma & Rietveld 1993). Regarding the rescheduling costs, it is important to note that as the frequency increases the penalty rapidly decreases. In other words, to add an extra flight to a high frequency connection results in a relatively small reduction in rescheduling costs, and, vice versa; to add an extra flight to a low frequency connection leads to a large reduction in rescheduling costs.

Method of data collection – According to the World Airways Guide (OAG 1998), all flights within the first week of October 1998 are analysed for the selected hub airports, with particular attention being given to departure and arrival times, travel times and frequencies.[3,4] On the Internet page of EasySabre the tariffs for all flights (leaving on December 10 and returning one week later) are inventoried.[5] Two rules are applied in this process. First, the flights are fulfilled by the home-carrier of the four hub airports (British Airways, Air France, Lufthansa and KLM), whereby the journey starts in the European city of origin.[6] We assume that, according to the hub-and-spoke system, the home-carrier of the airport examined conducts intercontinental flights. As described in the second section, in 1997 85% of flights by home-carriers was be performed via its own hub, despite the 'fifth-freedom and cabotage rights'. Second, the least expensive fares in the economy and business class per origin-destination relation are analysed for the examined home-carriers.

On the Paris–New York and London–New York connections the fares and travel times differ strongly. Concorde flies respectively seven and 14 times per week on these routes. Travel times by Concorde are much shorter but the price is considerably higher. Concorde is excluded from our comparative analysis because a relatively high weight is assigned to short travel times when one calculates the average generalised costs. In other words, the high fares for Concorde flights are also more important in weight, which means that a fast but expensive flight leads to a large increase in the generalised costs, since the other flights have not been differentiated for price. Concorde can only be included in the comparison if the specific fares for all flights are considered. However, the direct matching of 8,500 flights to their fares would be an almost insurmountable task.

Data collection – A total of 1,699 direct flights have been traced between the four hub airports and the ten selected intercontinental destinations from the World Airways Guide (OAG 1998).[7] A first analysis of this data reveals that the frequency of the intercontinental connection determines the frequency of services between European and intercontinental destinations. The frequency distribution of the flights over the days of the week indicates that an even distribution can be found for most connections.

For all flights between European airports via the hubs to intercontinental destinations and vice versa, the travel time is determined by accounting for the minimal transfer time per hub (according to the World Airways Guide (OAG 1998)), and the time differences due to the different time zones. Two weightings then take place:

- *Within a connection*: as travel time decreases the weight will increase. This expresses a preference for faster flights on a connection (in accordance with Ndoh *et al.* (1990)).
- *Between connections*: as the frequency of a connection maintained by the four hubs increases, the weight of the connection in question within the generalised cost function increases. In this way, the importance of a connection in the aviation network will be corrected. New York is the most important air connection (35.9% of all 1,699 flights involve flights from or to New York). The absolute importance of this relation in the random test also gives an indication of the relative importance of this connection in intercontinental air traffic in general, and is as such included with equal weight in the generalised cost function. The intensively-served intercontinental destinations are therefore more important in the generalised cost function than the less intensively-served intercontinental destinations, such as Buenos Aires and Mexico City (with 2.9% and 3.2%, respectively).

THE STRATEGIC POSITION OF FOUR NORTH WESTERN EUROPEAN AIRPORTS

Table 3 shows the results of the analysis for business and non-business travellers, where business travellers are subdivided into passengers travelling at economy class or business class fares. The ticket price for business passengers in the business class and non-business passengers in the economy class apparently contributes most to the generalised costs. The percentage of travel time and the frequency is larger for business trips, which is caused by the relatively large increase in travel time valuation – non-business 18 guilders an hour and business 90 guilders – compared to the increase in ticket price between economy class (non-business) and business class (business). What is clearly different is the composition of the generalised costs for the business traveller flying at economy class fares.[8] Travel time now becomes the most important component with a percentage of more than 50%. The financial benefit for business travellers flying economy class seems obvious: generalised costs – despite the equal and high travel time valuation of business travellers – are more than halved for the business traveller who travels economy class instead of business class.[9]

If travel time required to arrive at the airports had been taken into account, the percentage of travel time in the generalised costs would have been higher. Assume for example that total travel time between the start of the trip at home and the departure of the plane is 2.5 hours. According to Furuichi and Koppelman (1994) business travellers value travel time to the airport (access time) twice as high as time on board the aeroplane (line-haul time). However, non-business travellers value the access time 20% lower compared with the on board time. Nevertheless, the impact on the share of travel time costs in total generalised costs is limited, although there are some differences between the categories of passengers and fares. For the non-business passenger at economy class fare, the business class passenger at business class

Table 3. *Results of the analysis of the strategic position of the hub airports; average generalised costs of a European-intercontinental return trip.*

	Percentage price	Percentage travel time	Percentage frequency	General costs (in guilders)	Percentage Score
Non-business passenger, Economy class:					
Amsterdam	76	20	3.8	2,388.07	100.0
Paris	78	20	2.1	2,503.81	95.4
London	78	20	1.6	2,613.05	91.4
Frankfurt	80	18	2.0	2,745.76	87.0
Business passenger, Economy class:					
Amsterdam	39	52	9.6	4,697.22	100.0
Paris	41	53	5.5	4,735.66	99.2
London	42	54	4.2	4,905.07	95.8
Frankfurt	44	50	5.4	4,965.83	94.6
Business passenger, Business class:					
Paris	74	24	2.5	10.537.22	100.0
Frankfurt	74	23	2.5	10,802.12	97.5
Amsterdam	73	22	4.1	10,870.72	96.9
London	74	24	1.9	11,032.37	95.5

fare, and the business passenger at economy class fare, the increase of the travel time percentage in the generalised costs would be about 1%, 3% and 4% respectively for all airports.

Another interesting finding is that the differences in scores of the airports (last column) in the business segment (both business class and economy class) are smaller than in the non-business segment. An explanation for business travellers in the economy class is that the travel time valuation is identical for all business travellers. Given the large share of travel time valuation in the generalised costs, the differences between the airports are limited. The score for London on the business segment with business class tariff is only 4.5% lower than that of the most competitive airport, Paris. If we consider the economy class fares, Amsterdam scores best on both the business and the non-business market and Frankfurt scores the worst, lagging behind with 5.4% and 13.0% points respectively. The relative positions of the airports differ strongly depending on the chosen tariff. Paris scores best with a first position in the business class segment and a second position in the economy class segment; Amsterdam follows with a third and first position respectively; Frankfurt is third with a second and fourth position, and finally London is last with a fourth position in the business class segment and a third position in the economy class segment. The infelicitous positions of Frankfurt and London seem to stem from the relatively large percentage of the price in the generalised costs of these airports.

At this juncture of our analysis it would be interesting to examine the stability of the relative position of the four hub airports, since we want to analyse the effect of improvements in the airport infrastructure. The competitive position within the model can be improved in two ways whereby the generalised costs are reduced: to increase the airport capacity, thus enabling an increase in frequency of service, or decrease ticket prices. An increase in the frequency of the service leads to a reduction in generalised costs as a result of lower travel time because the rescheduling costs decrease.

The results of the simulation are presented in Table 4. The table portrays the potential

Table 4. *The position of Amsterdam after increasing frequency and decreasing ticket price (in guilders) for the three market segments.*

	Non-business economy class	Business economy class	Business business class
Starting point:			
Generalised costs	2,388.07	4,697.22	10,870.72
Score	1	1	3
Frequency + 50%:			
Generalised costs	2,358.15	4,547.61	10,721.11
Score	1	1	2
Difference in costs	−29.92	−149.60	−149.61
Frequency + 100%			
Generalised costs	2,343.19	4,472.81	10,646.31
Score	1	1	2
Difference in costs	−44.88	−224.40	−224.41
Ticket price − 10%			
Generalised costs	2,207.00	4,516.14	10,072.29
Score	1	1	1
Difference in costs	−181.07	−181.08	−798.43

changes if Amsterdam could successfully increase the frequencies by 50% and by 100%. The effects of a decrease in ticket prices by 10% by the home-carrier – in this case KLM – are presented. First we will discuss the effect if there is an increase in frequencies. In the random test 245 intercontinental flights from/to Amsterdam are included. For Frankfurt, Paris and London these numbers are 347, 397 and 710 respectively. Doubling the frequency of flights from Amsterdam roughly means that Amsterdam offers intercontinental flights more frequently than Frankfurt and Paris, but will still lag behind London.

A change in the frequency of flights affects travel time and is therefore dependent on the travel time valuation of business and non-business travellers. Amsterdam has the lowest generalised costs for the economy class fares. Nevertheless, a number of interesting findings are also noteworthy. First, the decrease in generalised costs reduces as the frequency of the service rises. This is as expected: adding one more flight to an already frequently served destination will have less of an effect on the rescheduling costs compared to that of adding an extra flight to a connection that is less frequently served. Second, a 10% reduction in ticket price leads to a larger effect on generalised costs than a large increase in frequency. Doubling the frequency results in a decrease in the generalised costs with 1.9% for the non-business traveller. A 10% decrease in ticket price leads to a 7.6% reduction of generalised costs. For business travellers flying business class these percentages, 2.1% and 7.3% respectively, are not much better, despite the larger share of travel time valuation in total generalised costs. With regard to the increase in frequency, the business traveller in economy class benefits from his high travel time valuation – in conformity with the business traveller in business class – but his financial benefit if the ticket price is reduced is the same as that of the non-business traveller in economy class. The business traveller flying economy class benefits less from a 10% reduction in ticket price than from a doubling in frequency. However, the differences in the reduction in generalised costs are small, with 3.9% and 4.8% respectively.

This exercise reveals that it is not straightforward to improve the strategic position of a hub airport by means of an increase in the capacity of the airport infrastructure. Given that the high frequencies already offered, a further increase in frequency allowed by a capacity expansion has a relatively small effect on generalised costs.

An improvement in the capacity or a reduction in tariffs of a hub airport is not the only factor affecting its competitive position. It is also possible that improvements in the airport infrastructure or a reduction in the tariffs of competing airports influence the competitive position. Therefore, the consequences for a hub airport – in our example Schiphol – of an increase in the frequency of service by 50% and a 10% price reduction by the competitors are presented in Table 5.

As can been seen in this table, an increase in the frequency of service in the category business travellers flying economy class leads to a shift in positions: Amsterdam loses its first position and slips into second place. Amsterdam falls in the generalised costs in the other two cases. As the airport with the most frequent service, London benefits least from the increase of frequency. For the other airports the benefits are also less than for Amsterdam if frequency increases by 50% (Table 4: Amsterdam: non-business 29.92 guilders and business 149.61).

Amsterdam falls one place if the ticket price is reduced and takes second position for economy class and last place for business class. The decrease in generalised costs for Amsterdam is fairly small if we consider the low fares (especially for economy class trips but also for business class trips) of airlines flying via Amsterdam.

THE INFLUENCE OF THE HIGH-SPEED RAIL NETWORK

The importance of a good accessibility of the airports by road and rail infrastructure was pointed out in the second section. If pressure on available airport capacity increases, it becomes more appropriate to use land transport as the entrance and exit mode for passengers with intercontinental destinations/origins. To do so would create airport capacity for intercontinental flights for which no alternatives are available. The high-speed train can be used

Table 5. *The position of Amsterdam in terms of generalised costs (in guilders) after increasing frequency and reducing ticket price in the competing airports.*

	Basic value	Frequency + 50%			Price – 10%		
		Price	Difference	Position	Price	Difference	Position
Non-business economy class:							
Amsterdam	2,388.07	–	–	1	–	–	2
Paris	2,503.81	2,486.33	−17.48	2	2,309.23	−194.58	1
London	2,613.05	2,599.40	−13.65	3	2,409.05	−204.00	3
Frankfurt	2,745.76	2,727.87	−17.89	4	2,526.68	−219.08	4
Business economy class:							
Amsterdam	4,697.22	–	–	2	–	–	2
Paris	4,735.66	4,648.27	−87.39	1	4,541.08	−194.58	1
London	4,905.07	4,836.85	−68.22	3	4,701.07	−204.00	3
Frankfurt	4,965.83	4,876.40	−89.43	4	4,746.75	−219.08	4
Business business class:							
Paris	10,537.22	10,449.83	−87.39	1	9,762.48	−774.74	1
Frankfurt	10,802.12	10,712.69	−89.43	2	9,999.42	−802.70	2
Amsterdam	10,870.72	–	–	3	–	–	4
London	11,032.37	10,964.15	−68.22	4	10,215.64	−816.73	3

for the collection and dispersal of intercontinental passengers from a comparatively large segment of the European hinterland (up to 700–800 km from the hub airport). Plans for a trans-European high-speed rail network have been drawn up since the early 1990s. Some countries have already begun building tracks: France (TGV), UK, Germany (ICE), Italy (ETR), Spain (AVE), Sweden (X2000), and Belgium already have one or more tracks in operation. The Netherlands are also likely to start and will probably use two systems: the French TGV in the southern direction and the German ICE travelling easterly. Due to the variety of national initiatives, uniformity barely exists and international co-operation is difficult to realise. For the time being, only the French-Belgium-Dutch-British sections (Eurostar and Thalys) on the international tracks are fully integrated.

Operationalising the high-speed rail network[10] – Information on travel times, frequencies, exploitation, and prices are unavailable, which is not surprising, given the lack of information on the construction of the network (with trajectories and their estimated date of opening of operation, and so on). In order to include the high-speed train as an entrance and exit mode for passengers connecting for intercontinental flights, we must make a few assumptions about the network, prices, travel times, frequencies and quality of service. The assumptions are:

- The network as proposed by the Community of European Railways (CER, 1992) is implemented.
- Airlines participate actively in the collection and dispersal of passengers through the high-speed rail network. This has a number of consequences:
  - An integrated ticket will be introduced. Given the available margins in the current ticket price between train and airline of 5%–15%, the possibilities seem to be restricted to that of giving intercontinental passengers using a high-speed train a reduced fare.
  - Passengers will be able to check in on the high-speed train, which lowers the minimal transfer time at the airport to one hour. This almost equals the minimal connecting time between two flights at most airports.
  - European air connections that can be served by high-speed rail will be terminated.
- Allowing for a lack of information on frequencies, we assume that every high-speed train will have a one-hour service, with the exception of trains to and from Brussels and the connection Glasgow-London, which will offer a half-an-hour service. This will have the following consequences:
  - The average waiting time for the one-hour service will be 30 minutes (+ transfer time).
  - The average waiting time for the half-an-hour service will be 15 minutes (+ transfer time).
- Given the lack of information on travel times, it will be calculated on the basis of the road distance (Michelin, 1988), and the average speed of the high-speed train, which is 170 km/hour on trajectories with numerous stops (see Table 6).

The high-speed train used as an entrance and exit mode – Table 7 presents the consequences for the generalised costs of including the high-speed train as an entrance and exit mode for intercontinental connections. The table shows that in all cases the generalised costs will increase. This means that both the current travel time per aeroplane and the transfer time at the airport are more favourable than the travel time with the high-speed train, including the short transfer time at the airport. This is partially caused by the comparatively long distances to the European cities under consideration, which makes travel time long on the high-speed train. By considering all markets, the generalised costs increase the least in Frankfurt, whereas for the other airports the increase is about equal. There is nevertheless a regular pattern in which the increase in Paris is the smallest and in London it is the largest. Although the difference in increase between Paris and Amsterdam is comparatively small, it is large enough for Paris to pass Amsterdam in the ranking of airports in the category of business travellers (high value of time) flying economy class (low fares).

Table 6. *Road distance and assumption of travel time (in hours) using high-speed train.*

		Copenhagen	Brussels	Milan	Glasgow	Vienna	Total
Amsterdam	Km	738	204	1,088	1,289	1,150	
	Time	4h20min	1h12min	6h24min	7h35min	6h46min	26h17min
Frankfurt	Km	785	402	670	1,498	710	
	Time	4h37min	2h22min	3h56min	8h49min	4h11min	23h55min
London	Km	1,411	258	1,188	612	1,566	
	Time	8h18min	1h31min	6h59min	3h36min	9h13min	29h37min
Paris	Km	1,196	308	855	944	1,226	
	Time	7h02min	1h49min	5h02min	5h23min	7h13min	26h29min

Table 7. *Consequences of the high-speed train for generalised costs.*

	Air	HST	Difference in guilders		Difference in hours	Price compensation needed
Non-business:						
Amsterdam	2,388.07	2,505.58	117.51	4.9%	6h32min	6.5%
Paris	2,503.81	2,610.26	106.45	4.3%	5h55min	5.5%
London	2,613.05	2,739.17	126.12	4.8%	7h	6.2%
Frankfurt	2,745.76	2,823.34	77.58	2.8%	4h19min	3.5%
Business-economy:						
Amsterdam	4,697.22	5,284.73	587.51	12.5%	6h32min	32.4%
Paris	4,735.66	5,267.90	532.24	11.2%	5h55min	27.3%
London	4,905.07	5,535.73	630.66	12.9%	7h	30.9%
Frankfurt	4,965.83	5,353.74	387.91	7.8%	4h19min	17.7%
Business-business:						
Paris	10,537.22	11,069.46	532.24	5.1%	5h55min	6.9%
Frankfurt	10,802.12	11,190.03	387.91	3.6%	4h19min	4.8%
Amsterdam	10,870.72	11,458.24	587.52	5.4%	6h32min	7.4%
London	11,032.37	11,663.03	630.66	5.7%	7h	7.7%

As a result of the low travel time of non-business travellers, the increase of the generalised costs in this segment is proportionally small. For business travellers flying business class, the increase of the generalised costs is proportionally small as a result of the higher weight of the business class fares, which are over twice those of economy class fares. The generalised costs of the business traveller flying economy class increase fairly rapidly due to the higher travel time valuation and the cheaper tariff. This becomes evident if the airlines were to compensate the time loss by giving a discount on ticket prices: business travellers would require a discount of nearly one-third on the economy class fare in the case of Amsterdam. For non-business travellers and business travellers flying business class, the discounts for compensating time loss are not too extreme. At this point two remarks have to be made. First, the discounts concern the total ticket price including the intercontinental part. With regard to the percentage of the European trajectory, this means that the margin in the ticket price of 5%–15% of the European trajectory, as defined in the last section, will not be feasible. Second, the discount will increase rapidly for the business travellers flying business class with an above average travel time valuation. For example, a lawyer with an hourly tariff of 450 guilders must receive a discount of 24.2% on his business class ticket to break even if he travels via Frankfurt, instead of the 4.8% mentioned in Table 7.

When we consider the distribution of passengers across the different segments, an explanation can be offered. The share of travellers having a business purpose is estimated at about 40% (Metropolitan Transportation Commission 1996). The number of business class seats on intercontinental flights is 15%–20%. We may assume that 20%–25% of passengers on intercontinental flights are business travellers flying at economy class fares. These passengers therefore want to be fully compensated for extra travel time due to the use of the high-speed train as an entrance or exit mode.

Finally, the market where the high-speed train should be competitive with air transport has been examined: this market entails distances of less than 600 km. For this purpose, Brussels has been selected as the market from which the hubs collect their passengers by high-speed train. We assume that every airport has a 30-minute service with Brussels, which thus limits the maximum transfer time from high-speed train to the intercontinental flight and vice versa to 75 minutes. However, Table 8 reveals that the travel time for all four airports increases. For Amsterdam (204 km), London (258 km) and Paris (308 km), the travel time loss is limited to 3, 20 and 45 minutes respectively. However, for Frankfurt (402 km) the extra travel time of using the high-speed train as an entrance or exit mode is 1 hour and 45 minutes.

There are two noteworthy comments regarding these results. First, the block system used by airports, where planes depart and arrive in waves, appears to function rather well. When we compare it with a high frequency high-speed rail alternative, we find that travel time is hardly improved by a frequent service of the high-speed train.

Second, in the analysis the time required to check in and the transport time to the airport or to the high-speed train station has not been considered. If it is possible to check in for intercontinental flights from the train, this decreases travel time by at least 45 minutes, since travelling by high-speed train requires passengers to arrive at most 15 minutes prior to departure; whereas passengers must arrive at the airport at least one hour before departure when travelling by aeroplane. A high-speed train station is usually located within urban agglomerations and is therefore accessible by

Table 8. *Effect of the high-speed train on the generalised costs from Brussels.*

	Air	HST	Difference in guilders		Difference in hours
Non-business:					
Amsterdam	2,048.49	2,049.43	0.94	0.05%	3min
Paris	2,095.59	2,109.07	13.48	0.6%	45min
Frankfurt	2,276.62	2,308.16	31.54	1.4%	1h45min
London	2,298.07	2,304.06	5.99	0.3%	20min
Business-economy:					
Paris	4,169.23	4,236.62	67.39	1.6%	45min
Amsterdam	4,210.37	4,215.06	4.69	0.1%	3min
Frankfurt	4,340.50	4,498.20	157.70	3.6%	1h45min
London	4,471.54	4,501.50	29.96	0.7%	20min
Business-business:					
Frankfurt	9,607.26	9,764.96	157.70	1.6%	1h45min
Paris	9,712.41	9,779.80	67.39	0.7%	45min
Amsterdam	10,086.63	10,091.32	4.69	0.05%	3min
London	11,017.43	11,047.39	29.96	0.3%	20min

public transport. On the other hand, transport to airports, which are usually located outside urban areas, takes more time.

In our Brussels example, the high-speed train will reduce travel time from Amsterdam, London and Paris, but whether this is also the case for Frankfurt is dubious. In the case of small travel time losses, the possibility exists for compensation of these losses through ticket discounts. However, the possibilities are restricted: only for the European trajectory does a price margin of 5%–15% exist. Especially for the business traveller flying economy class which, according to our estimation is about 25% of the passengers, this margin is given away easily.

CONCLUSION

In this paper the strategic position of a number of potential European hub airports (intercontinental hubs) has been investigated through the use of the generalised cost method. We analysed how the 'hubs' of London, Paris, Frankfurt, and Amsterdam perform compared to one another with regard to flights from smaller European airports via the 'hubs' to intercontinental destinations and vice versa.

From the qualitative comparison of the hinterlands of these airports, we may conclude that, when considering an area of 200 km surrounding the airports, the market potential for all airports included in the analysis is approximately 24 million inhabitants. The airports will soon experience capacity problems. The problem of runway capacity appears to be of a more structural nature than terminal capacity, which can be extended fairly easily. Accessibility by road and rail is good. In the near future all the airports – with the exception of London – will have a direct link with the high-speed rail network.

The level of service is given by the supply of direct regular services in the first seven days of October 1998 from all airports in the urban areas of our concern (Paris: Charles de Gaulle, Orly; London: Heathrow, Gatwick, Stanstead, Luton, City). Transfer connections, irregular flights and charter flights are excluded from consideration.

In absolute numbers, London is the main player, Frankfurt and Paris are equivalent (the supply, measured in frequencies, is in both cases about two-thirds the supply of the London airports) and Amsterdam lags behind (London has almost twice as many intercontinental flights). With regards to the number of intercontinental destinations, Amsterdam scores the same as London, and is better than Paris, but is clearly worse than Frankfurt.

The relative position of the cities in the aviation network has been determined with the use of a generalised cost function in which travel costs, travel time and rescheduling time (as a function of the frequency of the service) are included. We have compared the three situations of the non-business traveller flying economy class, the business traveller flying business class and the business traveller flying economy class. The travel time valuation of the business traveller and the non-business traveller is 90 and 18 guilders per hour respectively.

The ticket price for business travellers flying business class and the non-business travellers flying economy class apparently contributes most to the total generalised costs. Clearly different is the construction of the generalised costs for the business traveller flying economy class. The financial benefit for this segment seems obvious: the generalised costs are halved – in spite of the high travel time valuation – when business travellers fly economy class instead of business class.

It is remarkable that the relative positions of the airports strongly differ depending on the chosen fare. Paris scores highest with a first position in the business class segment and a second position in the economy class segment. Amsterdam scores second best with a third and first position respectively. Frankfurt comes in third with a second and fourth position, and London scores the worst with a fourth position in the business class segment and a third position in the economy class segment.

The most important finding of this research is that increasing the frequency results in insignificant decreases in the generalised costs due to changes in the rescheduling costs compared to the effect of lower fares. One aspect not considered in this study is that extra airport capacity can also be used to increase the number of destinations instead of increasing the frequencies. One other complicating factor worth mentioning here is that an improvement in the quality of the airport, for example the decrease of transfer times, may result in an increase by the home-carrier in the price of transfer flights, especially if the airport increases airport taxes in order to cover the quality improvement. Thus, investments in improvements in airports not only lead to a reduction in the time component in the generalised costs, but also possibly to an increase in fares. This could potentially lead to a disappointing result.

When we include the high-speed train as a European entrance or exit mode for intercontinental flights in the analysis, we see that for an area of approximately 350 km around the airport, the high-speed train can yield travel time gains for passengers. A wider but limited extension of the area is possible if passengers are compensated for their time losses with lower ticket prices. Especially for business travellers flying economy class – about 25% of the passengers according to our estimation – the possibilities for compensation are restricted, given the combination in this category of high travel time valuation of business travellers and low fares of economy class tickets. Our analysis reveals that the high-speed train is only partially suitable as an entrance or exit mode within the European continent. Most opportunities for high-speed rail connections with hub airports are in regions located near to hub airports, and where there are no regional airports.

Notes

1. This section is based mainly on *Internationale vergelijking infrastructuur*, Ministry of Transport (1996) and *The Single European Aviation Market: the first five years*, Civil Aviation Authority (1998).
2. The European–American alliances are KLM and Northwest, BA and American Airlines, Lufthansa and United Airlines and – formed just after the finishing our empirical study – Air France and Delta Airlines.
3. The shares of the departing flights towards the ten selected intercontinental destinations in the total number of flights departing to intercontinental destinations vary for the various hub airports. The share of the ten selected intercontinental destinations is the largest for London (18.1% of all departing flights) and smallest for Frankfurt (12.8%). The shares of Paris (16.1%) and Amsterdam (14.0%) are in between (for more details see the third section and Bruinsma *et al.* (1999). By the selection of the intercontinental airports we focused on a representative geographical world coverage of relatively frequently flown connections, avoiding too strong colonial dependencies. As mentioned in the second section intercontinental destinations where partners from the hub airport home-carriers are based have been excluded from our analysis. The impact of the existence of European alliances on the outcomes is limited since the frequency of services between the smaller European airports and the intercontinental airports (via the hub airports) is determined by the frequency of the intercontinental connections (see the third section).
4. There are some limitations in the OAG data (Burghouwt 1999, and note 7). The OAG data refers to scheduled flights. Non-scheduled flights, for instance charters, are not taken into account. However, we assume that the share of charters on intercontinental destinations is limited (only 10% of all passenger km and 14% of all freight tonnes km are performed by non-scheduled services (ICAO 1995)). Another limitation difficult to deal with is that a small number of scheduled flights may have been cancelled.
5. Airport taxes are not included in the prices listed on the EasySabre page. Airport taxes for international transfer passengers differ between the hub airports (Amsterdam dfl 8, Paris dfl 19, Frankfurt dfl 20 and London dfl. 26). The impact of these tax differences on the generalised costs is so small that it does not affect our findings. Another aspect of the prices is that they differ over the course of time. There is no reason to expect that the prices in the period studied were not representative.
6. The price of the journey starting in a non-European city might be different from the price of the trip starting in Europe.
7. Direct flights and direct flights with stops have been included in our analysis. Code-shared flights are traceable by their flight number and counted only once in our analysis. Transfer flights have been excluded from the analysis because only a small number of them are listed

in OAG since carriers have to pay for them (direct flights are free of costs). In personal communication with OAG, Andy Foster wrote: '... if you include just the indirect flights shown as "transfer connections" you would have a distorted view.' Given the systematic structure of the flight services offered by carriers in each season, the first week of October is representative for the winter season 1998–99.

8. Since our database did not distinguish between carriers, it is not possible to analyse price structures of individual carriers. However, for the hub airports the margin between the economy class rate and the business class rate of the average ticket given the airports of origin and destination can be subtracted from the data. The largest margin is found for Amsterdam: the economy ticket costs 22.7% of the business class rate. For London, Paris and Frankfurt this is 25.0%, 25.1% and 27.3% respectively.
9. In our analysis we proceed with the assumption that all business passengers value time in the same way. It is likely that business passengers flying economy class have a lower income and hence a lower value of time than do business passengers flying business class. An intermediate level of value of time (e.g. dfl 50 per hour) could have been used for this group.
10. The authors wish to thank Fons Savelberg from the Adviesdienst Verkeer en Vervoer for his contribution in the determining of the assumptions. The authors are fully responsible for the use of these assumptions.

Acknowledgements

Part of this paper is based on research funded by the Dutch Ministry of Transport. We thank Freddie Rosenberg, Hadewijch van Delft, and the anonymous referee for their constructive comments on earlier versions of the paper.

REFERENCES

BRUINSMA, F.R. & P. RIETVELD (1993), Urban Agglomerations in European Infrastructure Network. *Urban Studies* 30, pp. 919–934.

BRUINSMA, F.R., P. RIETVELD & M. BRONS (1999), De strategische positie van de belangrijkste luchthavens in Noordwest Europa. Research memorandum. Amsterdam: Vrije Universiteit.

BURGHOUWT, G. (1999), *In de vrije lucht, deregulering en de netwerkpositie van Europese luchthavens*. Utrecht: Universiteit Utrecht.

CER (1992), *High-Speed Railways: A Network for Europe*. Brussels: Community of European Railways.

CIVIL AVIATION AUTHORITY (1998), *The Single European Aviation Market: The First Five Years*. Cheltenham: CAA.

CPB (1997), *Grenzen aan Schiphol*. The Hague: Centraal Planbureau.

DENNIS, N.P.S. (1998), *Competition Between Hub Airports in Europe and a Methodology for Forecasting Connecting Traffic*. Paper presented at the 8th World Conference on Transport Research, 12–17 July, Antwerp.

DOGANIS, R. (1992), *The Airport Business*. London: Routledge.

FURUICHI, M. & F.S. KOPPELMAN (1994), An Analysis of Air Travellers' Departure Airport and Destination Choice Behaviour. *Transportation Research A* 28, pp. 187–195.

GREENHUT, M.L., G. NORMAN & C. HUNG (1987), *The Economics of Imperfect Competition, a Spatial Approach*. Cambridge: Cambridge University Press.

HAKFOORT, J.R. (1999), The Deregulation of European Air Transport: A Dream Come True? *Tijdschrift voor Economische en Sociale Geografie* 90, pp. 226–233.

ICAO (1995), *Civil Aviation Statistics of the World*. Montreal: International Civil Aviation Organisation.

METROPOLITAN TRANSPORTATION COMMISSION (1996), *Airline Passenger Survey 1995*. Oakland: MTC.

MICHELIN (1988), *Wegenatlas van Europa*. Amsterdam: Michelin Banden.

MINISTRY OF TRANSPORT (1996), *Internationale vergelijking infrastructuur*. The Hague: SDU.

NEI (1994), *Kosten-batenanalyse hogesnelheidslijn*. Rotterdam: Nederlands Economisch Instituut.

NDOH, N.N., D.E. PITFIELD & R.E. CAVES (1990), Air Transportation Passenger Route Choice: A Nested Multinomial Logit Analysis. In: M.M. FISHER, P. NIJKAMP & Y.Y. PAPAGEORGIOU, eds., *Spatial Choices and Processes*. Haarlem: North-Holland.

OAG (1998), *World Airways Guide October 1998*. Dunstable: OAG.

PAELINCK, J.H. & P. NIJKAMP (1975), *Operational Theory and Method in Regional Economics*. Westmead: Saxon House.