Comparative study of hub-airports in Europe: Ticket prices, travel time and rescheduling costs

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Abstract:

This paper investigates the strategic position of four European airports in the aviation network by means of a generalised cost function. The performance of the hub-airports London, Paris, Frankfurt and Amsterdam are compared. This analysis concerns flights from smaller European airports via these hubs to intercontinental destinations and vice versa. The relative position 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 distinguished (business, tourists). We find that the relative 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 limited part of the market.

Contents

2 Introduction

The aviation sector is one of the most dynamic transport sectors. Large investments in airports are needed 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 substantially from a growth in demand at relatively low costs. A related phenomenon is the presence of economies of scope for airports. When an airport attracts more passengers implying a larger number of destinations and flights, its attractiveness as a node for an additional carrier increases. Given these features of the airport business (Doganis, 1992) it is no surprise that many airports are looking urgently for opportunities to increase the number of their customers.

Airports basically operate on two markets: the regional (or 'home') market and the transfer market. On both markets substantial competition may take place.

The first market concerns passengers and freight having the region around the airport as an origin or a destination. In many large metropolitan areas residents may choose between more than one airport. Competition between airports in the region takes place in various ways. Passengers will pay attention for example 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.;

3a local aspects of accessibility at the airport: parking regime, parking prices, car rentals, location of public transport terminal;

3b additional services of the airports: such as tax-free shopping, restaurants, casino, etc.

This list of quality aspects underlines the multiplicity of actors involved in the production of aviation services and the complementarity of their activities. For 1-3b we note inputs from among others 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 activities of these actors is essential.

The above situation where 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 and Nijkamp, 1975 and Greenhut et al., 1987) may be used for example to identify the orientation of regions without an own airport towards neighbour regions which do have one.

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

When one compares the airport competition on both markets, the transfer market is usually more competitive than the regional market since in many cases people in a region have little choice for a direct flight (there is only one airport nearby), whereas for indirect flights they may use several competing hub-airports. In this respect it is important to note that the two markets are not independent. A large 'home market' of an airport implies that it easily

achieves high frequencies, which makes the airport stronger as a basis for operations as a hub-airport.

In this paper we will focus on the second type of competition between airports, i.e., competition on the transfer market. We will address the quality of hub-airport services from a generalised cost perspective taking into account fares, travel times and rescheduling costs of travellers. Other determinants of the quality of an airport, which are more difficult to evaluate monetary, are not included in the analysis.

This paper is structured as follows: section 2 describes the airports that are subject of the analysis. Next, the methods used in the research will be explained and justified in section 3. The results of the research are presented in section 4. Also, this section will examine in what way the position of Schiphol airport (Amsterdam) will be influenced by changes in ticket price or the frequency of service by means of a sensitivity analysis. The consequences of the possible accomplishment of the high-speed rail network in Europe with an important role as an entrance or exit mode of European hubs for intercontinental flights will be analysed in section 5. Section 6 concludes.

2 Exploring the airports[1]

In this section, first the quality of the included European hub-airports will be quantitatively compared. Second, competition between airlines and airports will be highlighted. Liberalization in intra-European aviation, implemented by the European Commission, will possibly result in concentration and mergers resulting in the existence of a few dominant airlines. This may further stimulate the development of hub-and-spoke systems on a limited number of large hub-airports. Considering these developments, it will be interesting to investigate the position of the present large hub-airports in Western Europe: Charles de Gaulle, Heathrow, Frankfurt and Schiphol.

2.1 International comparison of the airports

In section 3 the position of the four hub-airports will be determined by means of a generalised cost function. Ticket prices, travel time, frequencies and rescheduling times are included in this function. Other factors which are important in airport competition are: local market potential, capacity of the runways, quality of the handling of passengers and goods, the number of destinations and the facilities and tariffs of the airport. This section offers an overview of a number of these factors for the four airports included in our empirical analysis.

Table 1 shows that the potential market area concerning population is almost the same, while the size of the city and the national population are quite divers. The hinterlands of the four airports are hardly overlapping. Considering the competition with other regional airports, like Brussels and Düsseldorf, a good accessibility of 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.

[1] **This section is mainly based on: 'International comparison infrastructure', Ministry of Transport (1996) and 'The Single European Aviation Market: the first five years', Civil Aviation Authority (1998).**

Table 1 Main figures airports (data from 1994)

	Schiphol	Frankfurt	De Gaulle	Heathrow
Home market (mln. inhabitants)				
◊ Urban region	5	7,8	8,7	7,7
◊ Radius of 200 km.	24	25	24	24
Airport infrastructure				
◊ Number of runways	4	3	2	2
◊ Annual runway capacity*	320,000	370,000	350,000	400,000
◊ Terminal capacity (in mln.)	27	42	29	54
Performance airports				
◊ Flights per year	287,000	357,565	318,718	411,200
◊ Utilisation rate runways (in %)	89.7	96.6	91.1	102.8
◊ Passengers (in mln. per year)	23.6	35.1	28.7	51.7
◊ Utilisation rate terminal (in %)	87.4	87.8	99.0	95.7
◊ Freight (in 1.000 ton per year)	838	1,246	786	967
Average annual growth 1990-1994				
◊ Flights (%)	9	3	9	3
◊ Passengers (%)	11	6	7	5
◊ Freight (%)	10	3	7	9
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

* Number of flights per hour

** Charles de Gaulle incl. Orly and Heathrow, incl. Gatwick, Luton, Stansted & City

Sources: Ministry of Transport, 1996

Adapted from OAG, 1998

Considering airport infrastructure, it is remarkable that Schiphol has a smaller runway capacity despite of having four runways. This can be explained by the fact that the runways can only be used in one way. Terminal capacity will not be a major problem in the long run, since it can be extended in a relatively short period. Serious bottlenecks can be found in runway capacity and noise nuisance. Considering utilisation of capacity in 1994, Charles de Gaulle is reaching the limit of the utilisation rate of runways and Heathrow is already exceeding its limit of the runway capacity. Schiphol performs relatively well; both in runways as in terminal capacity Schiphol has most reserves. Regarding the average annual growth in flights, passengers and freight in 1990-1994, the four airports are likely to be confronted with capacity problems in the short run. For example, Schiphol has grown to 353.000 flights in 1997, which is more than the officially stated capacity from 1994. The transport performance has increased to almost 31 million passengers (capacity 1994: 27 million) and to 1.1 million tonnes of freight (Ministry of Transport, 1997). In general, the capacity restrictions result not only of runway capacity, but also of environmental quality limitations. This mainly concerns noise nuisance caused by arriving and departing planes. Chapter 3 and chapter 4 planes cause less noise than chapter 2 planes. This means that avoiding chapter 2 planes can increase capacity.

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 the concerning urban area (Paris: Charles de Gaulle and Orly; London: Heathrow, Gatwich, Stansted, Luton and City). Transfer connections, irregular flights and charters are left out of consideration. Regarding the number of countries, and destinations, London, Paris and Frankfurt perform equal. However, with respect to the frequencies of service London performs best and Paris is placed at a second

spot. Amsterdam clearly lags behind the competition with respect to the number of countries and destinations, but the average frequency of the connections is higher than in Frankfurt and almost the same as in Paris.

In table 2, the flights in 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 over-represented. 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 in the German air traffic is not as dominant as the position of the other analysed cities in their respective countries. Given the small home market, the number and share of flights of Amsterdam to domestic destinations are low: Schiphol needs to attract passengers from the larger European market for intercontinental flights.

Table 2 Flights to destination in 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	3,830	100	8,507	100	6,721	100

Source: adapted from OAG, 1998

The position in intercontinental air traffic is an important factor for the strategic position as hub-airport in Europe. In absolute numbers London is the main player, Frankfurt and Paris score the same (the supply in frequencies is in both cases two third of the supply of the London airports) and Amsterdam lags behind (London has twice as many intercontinental flights). Considering the share of intercontinental destinations, Amsterdam (24.0%) performs equal to London (24.2%) and better than Paris (19.9%). Note the intercontinental orientation of Frankfurt: almost 35% of all flights have an intercontinental destination.

Concentrating more specifically on different continents, Frankfurt appears to be, also because of its geographic location, the gateway for East-European and Asian destinations. London serves all continents relatively frequently and extensively with a small preference for North-American destinations. France has a strong orientation on Africa, due to colonial relations, and other French speaking regions like Canada. Amsterdam has a relatively strong orientation on Eastern Europe, Asia, Middle East and South America.

Next to capacity, also the user's opinion and financial aspects play an important role in the competitive position of airports (table 3). According to the World Competitiveness Report, the opinion of the user concerning the quality of airports, Schiphol has lost its leading position in 1995. For Frankfurt and Paris, the appreciation is rising – above the level of Schiphol - in the period 1990-1995. Concerning Heathrow, the opinion has not changed and is less positive than for the competing airports. However, the results differ strongly among the various studies: according to the magazine Business Traveller in 1994, Schiphol is considered to be the best airport, followed by Heathrow. Airport tariffs are, next to labour costs, an important cost factor of airlines. Nowadays airport fees consist of a fixed and a variable part, differentiated according to: passengers, noise, navigation, parking, et cetera. Also, handling and fuel are important cost factors for an airline.

Table 3 Other quality factors airports (1994)

	Schiphol	Frankfurt	De Gaulle	Heathrow
User's opinion				
• 1990	8.8	8.1	7.6	7.7
• 1995	8.1	8.4	8.2	7.7
Airport taxes				
• Boeing B737-200 (index)	100	171	111	120/52*
• Boeing B737-500 (index)	100	110	83	112/46*
• Airbus A-300 (index)	100	107	86	92/32*
• Boeing B747-400 (index)	100	112	113	87/30*
• Passengers taxes in guilders p.p.	18/4**	20	16/14***	35/8*

* high tariff/low tariff
** destination/transfer
*** intercontinental/European
Source: Ministry of Transport, 1996

2.2 The influence of world-wide alliances of airlines

A 'hub-and-spoke' system in aviation is a system where continental passengers fly via a hub before they start 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 over Europe. The co-operation usually is 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 strategy usually leads to strategic alliances between the airlines. Both companies serve their own continent where they can collect and distribute passengers and freight for the partner. For the intercontinental connections agreements are made for code sharing. For example, the code sharing between KLM and Northwest Airlines made it possible for KLM to serve 177 destinations in the US (transfer in the US) 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) and KLM) are increasingly involved in code sharing within Europe in the period 1992-1997. 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.

In 1997, four intercontinental alliances had been formed between airlines. Three of these alliances contained a home-carrier, which is included in our analysis: only Air France is not involved in these alliances. For the European airlines the connection between Europe and the US is the most important intercontinental route. The destinations where partners from European home-carriers are based (St. Paul, Houston, Dallas, Washington and Chicago) are not considered in our empirical study.

The percentage of flights carried out by home-carriers via their own hub has increased from 77% to 85% in the period 1992-1997. This is remarkable since the European Commission is trying to increase competition in the European market with the 'fifth-freedom and cabotage rights'. Until now Lufthansa and Air France have not used the opportunities offered by the EC. British Airways took advantage of the possibilities to a small extent by trying to penetrate the German and French market by setting up the Deutsche BA (DBA) and

taking over TAT/Air Liberté. However, these sister companies have not succeeded in conquering a significant share of air traffic in the concerning market.

3. Operationalising the generalised cost function

3.1 Selection of airports

We have chosen the four largest airports in Western Europe 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
- Middle America: Mexico City
- South America: Rio de Janeiro, Buenos Aires
- Africa: Johannesburg
- Asia: Delhi, Singapore, Tokyo, Peking

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

3.2 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. Three components are distinguished: ticket prices, travel time valuation and rescheduling costs. Two types of ticket prices are distinguished; 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 ?) for the non-business traveller and 90 guilders an hour (about 40.9 ?) for the business traveller (in accordance to CPB, 1997 and NEI, 1994). Since many business travellers fly economy class, a third category needs to be added: the business traveller with a business travel time valuation flying at economy class fares.

The travel time element consists of two components: travel time itself and a penalty for not being able to fly at every chosen moment: 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 flights with longer travel times) and therefore have a higher chance of realisation (for details see Ndok et al., 1990, and Bruinsma et al., 1999). The time needed to travel to the airport is left out of consideration. These travel times are not discriminating for the four hubs (it concerns the travel time to the airports of origin and destination and these are all the same). Still, the time needed to travel to the airport, to check in and to wait will increase the generalised costs. The rescheduling costs are dependent on the frequency of the service to a large extent. The penalty has been set to 25% of the average time between two successive flight alternatives (conform to Bruinsma and Rietveld, 1993). Regarding the rescheduling costs, it is important to note that as the frequency increases the penalty decreases rapidly. In other words, adding an extra flight to a high frequency connection result in a relatively small reduction in rescheduling

costs, and, vice versa, adding an extra flight to a low frequency connection leads to a large reduction in rescheduling costs.

Method of data collection

From the World Airways Guide (OAG, 1998), all flights in the first week of October 1998 have been considered for the selected hub-airports, concentrating on departure and arrival time, travel time and frequency. On the Internet page of EasySabre, one of the largest booking agencies, the tariffs for all flights (leaving on December 10 and returning one week later) have been inventoried. In this process, two rules have been applied. First, the flights are carried out by the home-carrier of the four hub-airports (British Airways, Air France, Lufthansa and KLM). We assumed that the home-carrier of the airport considered, according to the hub-and-spoke system, carries out intercontinental flights. As described in section 2.2, in 1997 85% of the flights by home-carriers will be carried through the own hub, despite of the 'fifth-freedom and cabotage rights'. Second, the least expensive fares in the economy class and the business class are considered per home-carrier per origin-destination relation.

On the connections Paris – New York and London - New York the fares and travel times differ strongly. The Concorde flies respectively 7 and 14 times per week on these relations. Travel times by Concorde are much shorter, but the price is considerably higher. The Concorde is left out of consideration in determining the comparison, because in calculating the average generalised costs a relative high weight is assigned to short travel times. For the Concorde flights this means that the high fares are also more important in weight, which means that offering a fast but expensive flight leads to a large increase in the generalised costs, since the other flights have not been differentiated for price. The Concorde can only be included in the comparison if for all flights the specific fares are considered. The direct matching of 8500 flights to their fares would be an almost insurmountable task, however.

3.3 Data collection

In the World Airways Guide (OAG, 1998) 1,699 direct flights have been traced between the four hub-airports and the ten selected intercontinental destinations. A first analysis on these data shows that the frequency of the intercontinental connection determines the frequency of services between European and intercontinental relations. The frequency distribution of the flights over the days in the week shows that for most connections an even distribution can be found.

For all flights between European airports via the hubs to intercontinental destinations and vice versa, the travel time is determined, accounting for the minimal transfer time per hub (according to World Airways Guide, OAG, 1998) and the time differences as a result of the different time zones. Next, two weightings 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 concerning connection in 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 concerns 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. In this way, the intensively served intercontinental destinations are of more importance in the generalised cost function than the less intensively served intercontinental destinations, like Buenos Aires and Mexico City (respectively 2.9% and 3.2%).

4 The strategic position of four North-western European airports

Table 4 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 appears to have the largest contribution to the generalised costs. The share 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). Clearly different is the composition of the generalised costs for the business traveller flying at economy class fares. Travel time is now the most important component with a share of more than 50%. The financial benefit for business travellers flying economy class appears to be obvious: the generalised costs are – despite of the equal and high travel time valuation of business travellers - more than halved for the business traveller when he travels economy class instead of business class[2].

Table 4 Results of analysis of the strategic position of the hub-airports; average generalised costs of a European-intercontinental return trip

	Share Price	Share Travel time	Share Frequency	Generalised costs (in guilders)	Score
Non-business passenger Economy class					
Amsterdam	76 %	20 %	3.8 %	2,388.07	100 %
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 %
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 %
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 %

We note that if access times to airports had taken into account, the share 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. For the two standard cases (business class passenger at business class fare, and non-business passenger at economy class fare) the increase of the travel time share in the generalised costs would be

[2] A simplifying assumption in our analysis is that all business passengers have the same value of time. Probably business passengers flying economy class have a lower income and hence lower value of time than 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.

about 4% for all airports. In the mixed case (business passenger at economy class fare) the increase of the travel time share is about 10%.

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 the same 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 for 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 worst, lagging behind with respectively 5.4 and 13.0% point. It is remarkable that the relative positions of the airports strongly differ dependent 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 respectively a third and first position; 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 bad positions of Frankfurt and London seems to be determined by the relatively large share of the price in the generalised costs of these airports.

At this point it would be interesting to examine the stability of the relative position of the four hub-airports, since one wants to analyse the effect of improvements in the airport infrastructure. Within the model the competitive position can be improved in two ways (the generalised costs are reduced): increasing the airport capacity, which enables an increase in frequency of service or decreasing the ticket price. 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.

Table 5 shows the potential changes if Amsterdam would succeed in increasing the frequencies by 50% and by 100%. Also, the effects of a decrease in ticket price by 10% by the concerned airline - in this case KLM – are presented. First we will discuss the increase in frequencies. In the random test 245 intercontinental flights from/to Amsterdam are included. For Frankfurt, Paris and London these numbers are respectively 347, 397 and 710. Doubling the frequency of flights from Amsterdam roughly means that Amsterdam offers intercontinental flights more frequently than Frankfurt and Paris, but Amsterdam will still lag behind London.

In table 5, the results of the simulation are presented. 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. For the economy class fares Amsterdam evidently has the lowest generalised costs. Still, also here a number of interesting findings may be mentioned. First, the decrease in generalised costs appears to reduce as the frequency of the service increases. This is as expected: adding one more flight to an already frequently served destination will have less effect on the rescheduling costs compared to adding an extra flight to a connection that is less frequently served. Secondly, 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. At the same time, a 10% decrease in ticket price leads to a 7.6% reduction of generalised costs. For business travellers flying business class these percentages, respectively 2.1% and 7.3%, are – despite the larger share of travel time valuation in total generalised costs – not much better. Concerning the increase in frequency, the business traveller in the economy class benefits from his high travel time valuation - conform the business traveller in the business class - but his financial benefit if the ticket price is reduced is the same as for the non-business traveller in the

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, with respectively 3.9% and 4.8%, small.

Table 5 The position of Amsterdam after increasing the frequency and decreasing the 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

This exercise shows that it is not easy to improve the strategic position of a hub-airport by means of an increase in the capacity of the airport infrastructure: given 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 the competitive position of this hub-airport. It is also possible that improvements in the airport infrastructure or a reduction in the tariffs of competing airports influences the competitive position. Therefore, the consequences for a hub-airport – in our example Schiphol - of an increase in the frequency of service with 50% and a 10% price reduction by the competitors are presented in table 6.

Table 6 shows that an increase in the frequency of service in the category business travellers flying economy class leads to a shift in positions: Amsterdam looses its first position and takes the second position. Obviously, in the other two cases, Amsterdam relatively falls concerning generalised costs. London, the airport with the most frequent service, benefits the least from the increase of frequency. Also for the other airports, the benefits are less than for Amsterdam if the frequency increases by 50% (table 5: Amsterdam; non-business 29.92 guilder and business 149.61).

Amsterdam falls one place if the ticket price is reduced. Amsterdam takes the second position for the economy class and last for the business class. The decrease in generalised costs for Amsterdam is relatively small, considering the low fares (especially for economy class trips but also for business class trips) of airlines flying via Amsterdam – in this case KLM.

Table 6 The position of Amsterdam in terms of generalised costs (in guilders) after increasing the frequency and reducing the 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

5 The influence of the high-speed rail network

In section 2, the importance of a good accessibility of the airports by road and rail infrastructure was pointed out. If the pressure on the available airport capacity increases, it becomes more interesting to use land transport as entrance and exit mode for passengers with an intercontinental destinations/origins in order to create airport capacity for intercontinental flights, for which no alternatives are available. In general, the high-speed train can be used for the collection and spread of intercontinental passengers from a relatively large part of the European hinterland (up to a distance of about 700-800 km from the hub-airport). Since the beginning of the nineties, plans for a trans-European high-speed rail network are available. Some countries have already started building tracks: France (TGV), England, Germany (ICE), Italy (ETR), Spain (AVE), Sweden (X2000) and Belgium already have one or more tracks in use. Also the Netherlands are likely to start in the short run; probably two systems will be used: the French TGV-system in southern direction and the German ICE-system towards the east. Because of all these national initiatives, uniformity hardly exists and international co-operation is difficult to realise: only the French-Belgium-Dutch-British parts (Eurostar and Thalys) on the international tracks are being tuned.

5.1 Operationalising the high-speed rail network

Information on travel times, frequencies, exploitation and prices are not available, not surprisingly given the lack of information on the construction of the network (which trajectories and when). In order to include the high-speed train as entrance and exit mode for passengers for intercontinental flights, it is necessary to make some assumptions concerning prices, travel times, frequencies and quality of service. The assumptions are[3]:

[3] The authors wish to thank Fons Savelberg from the Adviesdienst Verkeer en Vervoer for his contribution in determining the assumptions. The authors are fully responsible for using these assumptions.

- Airlines participate actively in collecting and spreading 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 aeroplane of 5-15%, the possibilities seems to be limited to give intercontinental passengers using a high-speed train a reduced fare;
    - Passengers will be able to check in on the high-speed train, what reduces the minimal transfer time on the airport to one hour. This is almost equal to the minimal connecting time between two flights on most airports;
    - European air connections that can be served by high-speed rail will be terminated.
- Given the lack of information on frequencies, the assumption is made that every high-speed train will have an one-hour service with the exception of trains to and from Brussels and the connection Glasgow-London that will offer an 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 time, this will be calculated on the base of the road distance (Michelin, 1988) and the average speed of the high-speed train of 170 km/hour on trajectories with various stops (see table 7).

Table 7 Road distance and assumption on travel time (in hours) with 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

5.2 The high-speed train used as entrance and exit mode

Table 8 presents the consequences for the generalised costs of including the high-speed train as entrance and exit mode for intercontinental connections. The table shows that in all cases the generalised costs will increase. This means that the current travel time per aeroplane and the transfer time on the airport are more favourable than the travel time with the high-speed train including the short transfer time on the airport. This is partially caused by the relatively long distances to the European cities considered, which makes the travel time on the high-speed train relatively long. Considering all markets, the generalised costs increase the least in Frankfurt, whereas for the other airports the increase is more equal in size. Still, there is a regular pattern in which the increase in Paris is the smallest and in London the largest. Although the difference in increase between Paris and Amsterdam is relatively small, it is large enough for Paris to pass Amsterdam in the ranking of airports in the category business travellers (high value of time) flying economy class (low fares).

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 relatively high weight of the high business class fares. The generalised costs of the business traveller flying economy class increase relatively fast due to the relatively high travel time valuation and the relatively cheap tariff. This becomes evident if the airlines would compensate the loss in time by giving a discount on ticket prices: business travellers would have to receive a discount of nearly one-third on the economy class fare in the case of Amsterdam. For the non-business travellers and the 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 complete ticket price including the intercontinental part. Concerning the share of the European trajectory this means that the margin in the ticket price of 5-15% of the European trajectory, as defined in section 5.1, will not be feasible. Secondly, 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 has to receive a discount of 24.2% on his business class ticket if he travels via Frankfurt in stead of the 4.8% mentioned in table 8.

Table 8 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 %

Also concerning the distribution of passengers over the different segments, an explanation may be given. The share of travellers with a business purpose in intercontinental flights is estimated to be about 40 % (see, for example, Metropolitan Transportation Commission, 1996). The number of business class seats on intercontinental flights is 15-20%. We may assume that 20-25% of the passengers on intercontinental flights concerns business travellers flying at economy class fares. Consequently, these passengers want to be compensated to a large extent 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 looked at: distances less than 600 kilometres. For this purpose, Brussels has been investigated as the market from which the hubs collect their passengers by high-speed train. We assume every airport has an half-an-hour service with Brussels, which limits the maximum

transfer time from high-speed train to the intercontinental flight and vice versa to 75 minutes. However, table 9 shows that the travel time for all four airports increases. For Amsterdam (204 km.), London (258) and Paris (308 km.) the travel time loss is limited to respectively 3, 20 and 45 minutes. However, for Frankfurt (402 km.) the extra travel time of using the high-speed train as entrance or exit mode is 1 hour and 45 minutes.

Table 9 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

Two remarks need to be made concerning these results. First, the block system that is 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.

Secondly, in the analysis, the time to check in and the transport time to the airport or to the high-speed train station have not been taken into account. If the possibility to check in for intercontinental flights exists on the train, this decreases travel time by at least 45 minutes since travelling by high-speed train requires presence 15 minutes before departure at most, while one needs to arrive at the airport at least one hour before departure when travelling by aeroplane. Also, a high-speed train station usually is located within urban agglomerations and is therefore accessible by public transport. On the other hand, transport to airports, usually located outside the urban area, may take more time.

In our example of Brussels, the high-speed train will reduce travel time concerning Amsterdam, London and Paris. Whether this is also the case for Frankfurt is questionable. In the case of small travel time losses, the possibility exists of compensating these losses by giving discounts on ticket prices. However, the possibilities are limited: only for the European trajectory a price margin exists of 5 to 15%. Especially for the business traveller flying economy class, according to our estimation about 25% of the passengers, this margin is given away easily.

6 Conclusion

In this paper, the strategic position of a number of potential European hub-airports (intercontinental hubs) has been investigated with the generalised cost method. In our study we analysed how the ‘hubs’ 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, considering an area of 200 km around the airports, the market potential of all airports included in the analysis is comparable (about 24 million inhabitants). The airports will soon face capacity problems. The problem of runway capacity appears to be of a more structural nature than terminal capacity, which can be extended relatively easily. The accessibility by road and rail is good. In the near future the airports – except for 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 from the concerning urban area (Paris: Charles de Gaulle and Orly, London: Heathrow, Gatwick, Stansted, Luton and City). Transfer connections, irregular flights and charter flights are left out of 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 third of the supply of the London airports) and Amsterdam lags behind (London has almost twice as many intercontinental flights). Considering the share of intercontinental destinations, Amsterdam scores the same as London, better than Paris, but clearly worse than Frankfurt.

In the analysis the relative position of the cities in the aviation network is determined with a generalised cost function in which travel costs, travel time and rescheduling time (as a function of the frequency of the service) are included. Three comparative studies have been carried out: 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 respectively 90 and 18 guilders per hour.

The ticket price for business travellers flying business class and the non-business travellers flying economy class appears to contribute 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 – despite of the high travel time valuation – halved when business travellers fly economy class instead of business class.

It is remarkable that the relative positions of the airports strongly differ dependent 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 respectively a third and first position. Frankfurt comes third with a second and fourth position and London scores 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 relatively small decreases in the generalised costs due to changes in the rescheduling costs compared to the effect of lower fares. One element, which has not been taken into account in this study is that the airport capacity can also be utilised by increasing the number of destinations instead of increasing the frequencies. One other complicating factor which might be mentioned here is that an improvement in the quality of the airport, for example by decreasing transfer times, may result in an increase in the price of transfer flights of the home-carrier, especially if the airport increases the airport taxes to cover the quality improvement. Thus, investments in improvements in airports do not only lead to a reduction in the time component in the generalised costs, but possibly also to an increase in the fares. This may lead to a disappointing result.

Including the high-speed train as a European entrance or exit mode for intercontinental flights in the analysis shows that for an area of about 350 km around the airport the high-speed

train can result in travel time gains for the passengers. A limited extension of the area is possible if passengers are compensated for their time losses by lower ticket prices. Especially for business travellers flying economy class – according to our estimation about 25% of the passengers – the possibilities for compensation are limited given the combination in this category of high travel time valuation of business travellers and low fares of economy class tickets. The analysis shows that the high-speed train is only partially suitable as entrance or exit mode within the European continent. Most opportunities for high-speed rail connections with hub-airports are to be found in regions located not too far from the hub-airports and where an regional airport is missing.

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