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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. 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 our 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.

Contents

1 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 market 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.;
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 variety of actors involved in the production of aviation services and the complementarity of their activities. For 1-3b 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 and Nijkamp, 1975 and Greenhut et al., 1987) may be used to identify the orientation of regions without an airport towards neighbour 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 farther 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 3a 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 on 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 will focus on competition between airports on the transfer market. We will 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 the quality of an airport, which are more difficult to evaluate monetarily, are not included in the analysis.

Our paper is structured as follows: section 2 describes the specific airports of this analysis. The methods used in the research will be explained and justified in section 3. The results of the research are presented in section 4. This section will also examine 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 section 5. Section 6 concludes.

2 Exploring the airports'

The quality of the included European hub airports will first be quantitatively compared in this section. Second, competition between airlines and airports will be 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. 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.

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 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 Dusseldorf, 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.

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[1] This section is based mainly 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 for the airports (data from 1994)

	Schiphol	Frankfurt	De Gaulle	Heathrow
Home market (mln. Inhabitants)				
0 Urban region	5	7.8	8.7	7.7
0 Radius of 200 km.	24	25	24	24
Airport infrastructure				
0 Number of runways	4	3	2	2
0 Annual runway capacity*	320,000	370,000	350,000	400,000
0 Terminal capacity (in mln.)	27	42	29	54
Performance airports				
0 Flights per year	287,000	357,565	318,718	411,200
0 Utilisation rate runways (in %)	89.7	96.6	91.1	102.8
0 Passengers (in mln. per year)	23.6	35.1	28.7	51.7
0 Utilisation rate terminal (in %)	87.4	87.8	99.0	95.7
0 Freight (in 1,000 tons per year)	838	1,246	786	967
Average annual growth 1990- 1994				
0 Flights (%)	9	3	9	3
0 Passengers (%)	11	6	7	5
0 Freight (%)	10	3	7	9
Supply of international direct lines**				
0 Number of countries (first week Oct. 1998)	93	114	116	114
0 Destinations (first week Oct. 1998)	225	259	249	269
0 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, Stanstead & City
Sources: Ministry of Transport, 1996
Adapted from OAG, 1998

Insofar as airport infrastructure is concerned, it is remarkable that Schiphol has a smaller runway capacity despite it having four runways. This can be explained by the fact that the runways at Schiphol can only be used in one direction. Terminal capacity will not be a major problem in the long run, since it can be extended within a fairly short period of time. Serious bottlenecks can be found however, in runway capacity as well as noise nuisance.

If we take note of the utilisation of capacity in 1994, Charles de Gaulle is reaching the limit of its utilisation rate of runways and Heathrow is already exceeding its limit of runway capacity. Schiphol performs relatively well; in both runways and terminal capacity Schiphol has the most reserves. When we examine the average annual growth in flights, passengers and freight between 1990-1994, the four airports are likely to encounter capacity problems in the short run. For example, Schiphol has grown to 353,000 flights in 1997, which is more than its officially-stated capacity of 1994. The transport performance has increased to almost 31 million passengers (capacity 1994: 27 million) and to 1.1 million tons of freight (Ministry of Transport, 1997). In general, the capacity restrictions not only result from runway capacity, but also emerge from environmental quality limitations. This mainly concerns the noise nuisance caused by arriving and departing planes. Chapter 3 and chapter 4 planes create less noise than chapter 2 planes. This means that restricting the flights of 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 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 in second place. 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 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 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.

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	3,830	100	8.507	100	6.72 1	100

Source: adapted from OAG, 1998

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 destinations, Amsterdam (24.0%) 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.

If we concentrate on specific continents, Frankfurt appears to be the gateway for East-European and Asian destinations, partly due to its geographic location. London serves all continents relatively frequently and extensively with a small preference for North American destinations. Paris has a strong orientation towards Africa, due to its colonial relations, and to other French speaking regions such as Canada. Amsterdam has a relatively strong orientation towards Eastern Europe, Asia, the Middle East, and South America.

Along with capacity, the user's opinion and financial aspects play important roles in the competitive position of airports (table 3). According to regular air passengers, Schiphol has lost its leading position as the best quality airport (World Competitiveness Report, 1995). For Frankfurt and Paris appreciation is rising – above the level of Schiphol - within the period 1990-1995. User opinion about Heathrow has not changed and is less positive than that of competing airports. However, the results differ strongly among the various studies: according to the magazine Business Traveller in 1994, Schiphol is rated as the best airport, followed by Heathrow. Airport tariffs and labour costs are important cost: factors of airlines. Nowadays, airport fees consist of a fixed and a variable segment which is, according to passengers, noise, navigation, parking, et cetera. Handling and fuel are also important cost factors for an airline,

Table 3 Quality factors of 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*
• Passenger 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 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 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 during the period from 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.

Four intercontinental alliances had been formed between airlines by 1997. 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 hubs has increased from 77% to 85% during 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'. Lufthansa and Air France have not yet used the opportunities offered by the EC. British Airways took advantage of the possibilities to a somewhat minor extent by trying to penetrate the German and French market and establishing the Deutsche BA (DBA) and acquiring TAT/Air Liberté. However, these sister companies have not yet succeeded in obtaining a significant share of air traffic in the German and French markets.

3 Operationalising the generalised cost function

3.1 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.

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. We can break down the cost function in 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 €) for the non-business traveller and 90 guilders an hour (about 40.9 €) 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 Ndok et al., 1990, and 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 to 25% of the average time between two successive flight alternatives (in conformity with Bruinsma and 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. On the Internet page of EasySabre the tariffs for all flights (leaving on December 10 and returning one week later) are inventoried. 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 IUM). We assume that, according to the hub-and-spoke system, the home-carrier of the airport examined conducts intercontinental flights. As described in section 2.2, in 1997 85% of flights by home-carriers will 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. The Concorde flies respectively 7 and 14 times per week on these routes. Travel times by Concorde are much shorter but the price is considerably higher. The 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. The 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.

3.3 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). A first analysis of these 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 involves 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).

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 apparently contributes the largest 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. 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 are - despite the equal and high travel time valuation of business travellers - more than halved for the business traveller who travels economy class instead of business class[2].

Table 4 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	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 %

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. 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

[2] 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.

percentage in the generalised costs would be about 4% for all airports. In the mixed case -- business passenger at economy class fare -- the increase of the travel time percentage 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 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, 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 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 5. The table portrays the potential 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. Firstly 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, also here a number of interesting findings are 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. 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. 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.

Table 5 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	4547.61	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	-224.4 1
Ticket price - 10 %			
Generalised costs	2,207.00	4,5 16.14	10,072.29
Score	1	1	1
Difference in costs	-181.07	-181.08	-798.43

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 6.

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 5: 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.

Table 6 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	-2 19.08	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

The importance of a good accessibility of the airports by road and rail infrastructure was pointed out in section 2. 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 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), England, 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.

5.1 Operationalising the high-speed rail network[3]

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 (which 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

[3] 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.

intercontinental flights, we must make a few assumptions about prices, travel times, frequencies and quality of service. The assumptions are:

- 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 airplane 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 7).

Table 7 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

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

Table 8 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 airplane 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 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	117.5 1	4,9 %	6h32min	6.5 %
Paris	2,503.81	2,6 10.26	106.45	4,3 %	5h55min	5.5 %
London	2613.05	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	587.5 1	12,5 %	6h32min	32.4 %
Paris	4,735.66	5,267.90	532.24	11,2 %	5h55min	27.3 %
London	4905.07	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 that 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 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 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 515% 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 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 8.

And when we consider the distribution of passengers across the different segments, an explanation can be offered. The share of travellers having a business purpose on intercontinental flights is estimated at 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 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 kilometres. 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 half-an-hour 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 9 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.

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

There are two noteworthy comments regarding these results. Firstly, 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.

Secondly, in the analysis the time required to check in and the transport time to the airport or to the high-speed train station have 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 airplane. A high-speed train station is usually located within urban agglomerations and is therefore accessible by 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 to 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.

6 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 and Orly, London: Heathrow, Gatwick, Stanstead, Luton and 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 of the supply of the London airports) and Amsterdam lags behind (London has almost twice as many intercontinental flights). When we regard 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, respectively, a third and first position. 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 treated 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.

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