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**Multiple Hub Network Choice
in the Liberalized European Market**

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1. Air transport liberalization: the consequences for airports.

A key question that so far has received relatively little attention in the germane literature is that of the changes at various airports as a result of the EU liberalization policies. That is, presently, most major European airports still benefit from the so-called home-carrier phenomenon where the country's publicly or semi-publicly owned carrier uses the country's main airport as its gateway hub and, consequently, the home-carrier is also the principal user of this airport (in terms of proportion of total aircraft movements, number of passengers transported, connections, slots ownership, etc.). The country's main airport has substantially benefited from these monopoly conditions of airline captivity, strongly determined by the bilateral system of international air transport regulation. Therefore European major airports were used to operate in essentially different markets, compared to the increasingly competitive markets of their home based carriers. This partly explains relative stability of transport volumes and financial results of European major airports compared to the relatively volatile financial results of most European national airlines.

However the liberalization of European aviation is likely to change this situation. Market access is open now to all community carriers, i.e. carriers with majority ownership and effective control in the hands of EU citizens. Ticket prices are free, governments can only intervene in case of dumping or excessive pricing. A community airline can choose its seat in any of the 15 member states. Licensing procedures are harmonized between member states. Since a few months community carriers have unrestricted route access within the EU. Most probably this development will be extended to countries inside and outside Europe. Last year the European Commission got the mandate to start negotiations with 10 other European countries. In the meantime the EC has also started negotiations with the USA on so-called soft rights. In the meantime open skies agreements have been concluded between the USA and most of the EU member states to facilitate strategic alliances between airlines of the states involved.

As a result of this on-going liberalization the model of the single 'national' carrier using the national home base as its single hub for the designated third, fourth and sixth freedom operations will stepwise disappear. Within the EU the concept of the national carrier has already been replaced by that of the community carrier. State ownership in more and more European carriers is reduced. On the longer run mergers or even bankruptcy will further undermine the 'single national carrier - single national hub' model in Europe. In the meantime strategic alliances between national carriers in Europe will already reduce the airlines' loyalty to a single airport. Profit maximization and accountability to share holders will supersede the loyalty of these newly emerging alliances, probably looking for the opportunities of a multiple hub network to adequately cover the whole European market.

As a consequence some European airports might see a substantial decline in arriving, departing and transfer traffic, thus in revenues and financial solvency, as well as in their connection to other inter-continental and intra-European destinations. At the same time other airports might realize a significant increase in traffic as they will be sought after by the profit maximizing airlines as their major gateway hubs. Which will be the losing airports and which will be the winning ones? Can airports anticipate the actions of airlines in deregulated markets and utilize policies which will improve their relative position? If so, what should be

these anticipatory policies? These questions become the more urgent, since an increasing number of major European airports will be privatized in the near future. Although increasing airport congestion in Europe will also be reflected in a growing demand pressure for airport slots, this is not a guarantee for a stable transport volume growth of individual airports. The more volatile the market is, the more vulnerable privatized airports become.

Therefore the main issue of this study is the analysis of the opportunities of major European airports to become a central hub as a result of the network choices made by the new European airlines in a completely liberalized market.

In a previous study (Berechman and de Wit, 1996), we already explored the potential of Amsterdam Airport Schiphol of becoming the major West-European hub, once European aviation markets are deregulated. A major hindrance of that study was the use of a single hub-and-spoke network. For example that model could not analyze the viability of different combinations of European hubs within a multiple hub network of alternative airline alliances.

In this study we have formulated *the model of a multi-hub network where two West-European airports are used for inter-continental and intra-European travel to enable a more realistic analysis of hub choice.*

Like the previous one also this multi-hub model is primarily used to assess the potential ability of Amsterdam Airport Schiphol for becoming a major West-European hub. Thus in particular the policy tests focus on this airport in a double hub network.

2. The Economic Model and Mathematical Program

In this section we first describe the microeconomic model on which the mathematical program is based.

2.1 The Economic Model

The observed phenomenon of increased hubbing, following the USA aviation market deregulation, has long been the subject of in-depth analysis in the germane literature. In general, the question is under what conditions will an airline's profit be greater when it uses a Hub and Spoke (HS) network vs. a Fully Connected (FC) network. The advantages of the HS network structure can be divided into three main branches (see Berechman and de Wit, 1996, for a detailed analysis):

Cost Economies: A number of authors have argued that cost considerations, mainly economies of aircraft size coupled with scope economies, underlie the intensified use of HS networks.

Demand-Side Effects: Demand-side effects are another argument to explain the intensified use of HS network following deregulation. Two types of explanation fall under this approach: (a) demand elasticities relative to airfare and travel time; and (b) product differentiation in departure times.

Market Dominance: analysis shows that given the proper conditions the incumbent airline will operate a HS network when faced with the threat of entry, thus successfully obstructing entry.

In this study we adopt all three types of explanation by considering a hypothetical airline, which operates in a deregulated market, and which strives to maximize profits and gain market dominance by structuring its network as a hub-and-spoke. In doing so it takes advantage of demand and network cost economies. On each route it sets airfare, output level (number of passengers and frequency), and employs aircraft capacity in a way that deters entry by potential rival airlines. In structuring its HS network, the airline chooses as main hubs those airports which best contribute to its profits. The analytical model, which is embedded in the simulation model, explicitly contains all these elements.

It should be re-emphasized however, that in this study we do not regard a pure HS network. Instead, we consider two main hubs that can serve as intercontinental gateway hubs, intra-European hubs, or both. (See for example figure 1 and 2).

On the demand side, the utility of a business or non-business passenger traveling on the route from node i to node j is based on the airfare, frequency of flights and whether or not the flight is direct or indirect. If a passenger is flying indirectly, he or she must fly from node i to node j via one or two hubs because no direct link exists in the network configuration chosen. The utility is then measured according to the lowest frequency along any one of the maximal three legs of the route required ($i \xrightarrow{1} hub_1 \xrightarrow{2} hub_2 \xrightarrow{3} j$). As can be seen from the theoretical model (Berechman et al, 1995), this ensures non-entry of airlines that may consider providing a direct service between two nodes, at present unconnected, since the airfare paid will be low enough to render entry uneconomical.

It is assumed that the airline's operating cost function can be defined as a standard CES function. This class of function is general enough to capture the cost of operating different types of networks with a varying number of routes and layout patterns. It is monotonically increasing and exhibits increasing returns. This ensures scale economies in that as output (frequency, or ACM per week) increases, the cost per flight decreases. Therefore it is worthwhile increasing frequency in a HS system in order to deter entry into the marketplace by carriers attempting to provide a direct service from i to j , where this route does not presently exist.

Additional costs result from payments made by the airline to the airports in the form of landing and passenger charges. The landing charges (LC) are paid to the arrival airport and are based on the maximum take-off weight of the aircraft size. The LC per route is computed by multiplying the Maximum Take-Off Weight of the aircraft size chosen, by the cost per ton of landing at the specific airport, by the frequency per week. The passenger charges (PC) are paid to the departure airport for each passenger carried. Two passenger charges have been included: the full tariff paid at the first departure airport and a transfer charge paid at subsequent hubs, when the passenger is carried on two or more legs to reach her destination. This pricing system is in line with the present rules of most international airports. Since there are many different types of charges, the LC and PC have been modified to include other relevant charges such as night charges and noise charges etc. and will be referred to as landing related and passenger related charges.

The Airline's Objective Function: Given a particular hub airport, the airline's objective function consists of the revenue the airline earns from passengers that travel directly to their destination and are therefore willing to pay an additional charge, and those that travel via the hub. The costs defined in the objective function include the operational cost function and landing and passenger related charges at this hub. The profit function is thus defined as:

$$\begin{aligned} \text{Profit Function} = & \text{Revenue Function} \\ & - \text{Operating Costs Function} \\ & - \text{Landing Charges} \\ & - \text{Passenger Charges} \end{aligned}$$

Recall that in this analysis we consider networks with two primary hubs. Therefore, the optimization model produces a solution to the profit function in terms of the potential profitability of the network with these hubs. By repeating the analysis for all possible networks the model sets the one with the highest level of profits to equal 100 and subsequently, ranks all other networks accordingly.¹

2.2. *Mathematical Program*

The mathematical program consists of the above-mentioned objective function and four types of constraints that have been included in the program as follows:

Type 1: Aircraft Capacity Constraint

This restricts the size of the aircraft to a minimum and a maximum number of seats.

Type 2: Airport Capacity

Airport capacity in terms of aircraft movements per unit of time (e.g. ACM per week) is affected by three components; runway, terminal and apron capacity. Runway capacity proved to be the most binding restriction in all cases, consequently other constraint types were redundant.

Type 3: Load Factor Minimal Capacity

This constraint requires a minimum percentage of seats filled (load factor) at all times, since the industry has an accepted minimal level, below which the airline will not break even.

Type 4: Network Constraint

The last set of constraints requires all frequency levels to be positive, ensuring that all nodes are connected in the network configuration specified.

The algorithm that solves the mathematical program searches for a solution using a modification of Goldfarb's conjugate-gradient projection algorithm for a non-linear objective function with linear constraints. The algorithm has been modified to deal with a set of non-

¹ The choice of a network (thus hubs) is also based on the quality level of these hubs to indicate additional costs associated with the use of these airports (e.g., costs due to delays, congestion and handling). Therefore, schematically the ranking of a network is:

$$\text{Network Ranking} = \text{Profitability Rank} + \text{Quality Score of Hub 1 and of Hub 2}$$

Analysis of this subject is beyond the scope of this study and is the main theme of a follow-up study.

linear constraints that require the load factor to be above a certain percentage in a feasible solution. (Adler et al., 1996).

3. Network Structure

In this study two internodal demand matrices, one for business and one for non-business, have been composed for 18 major European airports² (resulting in 16 routes to be assigned to the two airports selected as hubs), a U.S. airport JFK and a Far-East airport NRT. We assume that all North-Atlantic traffic is aggregated into one international route (i.e. all North-American departures first fly to New York and then to a West-European hub). Similarly all Far-East routes are first connected to Tokyo and then to a West-European hub. In the simulation model it is possible to distribute the 2 inter-continental and the 16 European routes in any order (e.g. the two international routes to one hub and the 16 European airports evenly distributed between the two hubs), though a geographical distribution seems most sensible (see Figures 1 and 2).

So the structure of the network is determined by three factors: a) the location of the major hubs; b) the number of intra-European routes and inter-continental routes that are connected to each hub; c) the allocation of European routes between the hubs. In this analysis we distinguish between two types of hub: a gateway-hub and a Euro-hub. A gateway hub is a point of transfer between inter-continental routes and intra-European routes. In this regard, a gateway hub has a feeder function by feeding the intra-European network with inter-continental passengers (e.g. long-haul: New York \Rightarrow Amsterdam \Rightarrow Zurich), vice versa. A Euro-hub, is a transfer point connecting short-haul to short-haul routes inside Europe. The same airport can, of course, serve the two functions but what counts is the *proportion* of trips that are long- or short-haul.

Figure 1 shows a base case where all 16 European routes are distributed between an intercontinental hub (e.g. London) and an intra-European hub (e.g. Milan) whereby all North-Atlantic and Far-East international routes go to London. The division of the European routes is geographically based, i.e., all airports east of Milan are linked to Milan whereas all airports west of Milan with London. A shuttle service links the main two hubs.

Figure 2 shows a case where each hub connects with one international route (North-Atlantic with London and Far-East with Milan).

4. Base Run Simulation

Above we have defined a network by its main hubs and by the distribution of international and intra-European routes between these hubs. It should be understood that the simulation model is flexible enough to handle any assumed network configuration. The ones described below serve mainly as examples.

We begin by presenting the results from, what we call, the "base run simulation". The choice of the following 13 networks in this base run simulation was made on the grounds that airlines

² AMS, ARN, ATH, BCN, BRU, CDG, CPH, FBU, FCO, FRA, GVA, LHR, LIN, MAD, MAN, MUC, VIE, ZRH.

that use these hubs are potential alliances and that from geographical and demand considerations it is useful to distribute the intra-European routes as in the networks below. In each case, the 16 European routes have been split evenly between the two designated hubs, based on geographical considerations (distance to nearest hub). The two international routes are allocated to one hub which represents the international gateway (the one chosen provides the airline with the highest profits)³. The key parameters to notice are the potential profits of the (hypothetical) airline from using a particular network and the relative ranking of this network. Profits or losses to an airport are also noted. In some cases, however, these profits are from ACM and PAX related income and costs only as no information is available on the fixed income and costs of a particular airport. It is important to emphasize that it is not possible to attribute any "real-world" meaning to the numerical results from the simulations which stem from theoretical conditions of network choice and market structure under complete deregulation.

In this section we report only principal results from the base-run simulation. Two main conclusions can be derived from the results of table 1. First, the networks which contain London (Heathrow) as one of their hubs rank the highest in terms of airline's potential profits. In this base run simulation, the choice of London (LHR) and Rome (FCO) as the main hubs proves to be potentially the most profitable one (potential profit rank = 100). Amsterdam receives second ranking only when it is part of the network that includes London (potential profit rank = 86).

A second conclusion is that when an airline designs a profitable network, the hubs in this network do not necessarily earn positive profits. For example, in the case of the London (LHR) and Rome (FCO) network, which earn the airline the highest potential profits, Rome airport suffers a loss. Apparently, what is good for the airline is not necessarily good for the airports. The question, what can an airport do in order to increase its use without suffering a loss, will be further explored in policy analysis section.

5. Policy Tests

5.1. Objectives of Policy Tests

There are two main objectives for the policy tests. The first is to examine the network choice and performance of airlines and of airports under varying external conditions. The second objective is to determine optimal policy for Amsterdam airport Schiphol with respect to traffic and financial performance.

In terms of the simulation model, attainment of the first objective requires that we introduce into the program changes in basic demand and operating conditions and, subsequently, a comparison of the model's results with those obtained from the base run. Attainment of the second objective requires a search process by which the best combination of policy means available to Schiphol (e.g. change in ACM and PAX charges) is identified.

³ One might expect that the gateway hub will serve all 16 European routes due to inter Gateway-European transfer flows. We have thus run these networks on the basis of demand considerations alone. The results were quite similar in terms of profit to the airline.

Table 1. Summary of the Results from the Base Run Simulation

	Potential Profit in \$'s	routes assigned	Relative Position
hub 1	- to airline		Network
hub 2	- to hub 1	- to hub 1	
	- to hub 2	- to hub 2	
airline	22524964		24
ZRH	4120282	Euro: 9 Interc'l: 0	
AMS	826803	Euro: 9 Interc'l: 2	
airline	30740134		33
FRA	-11436754	Euro: 9 Interc'l: 2	
MAD	1865857	Euro: 9 Interc'l: 0	
airline	38417272		41
MAD	1760099	Euro: 9 Interc'l: 0	
AMS	896383	Euro: 9 Interc'l: 2	
airline	92710360		100
LHR	3361255	Euro: 9 Interc'l: 2	
FCO	-13523035	Euro: 9 Interc'l: 0	
airline	48660468		52
FCO	-9109776	Euro: 9 Interc'l: 0	
AMS	1933525	Euro: 9 Interc'l: 2	
Airline	9087265		10
BRU	4328177	Euro: 9 Interc'l: 2	
ZRH	3494701	Euro: 9 Interc'l: 0	
Airline	40734660		44
CPH	1541480	Euro: 9 Interc'l: 0	
CDG	-1829261	Euro: 9 Interc'l: 2	
Airline	11021846		12
CPH	3117824	Euro: 9 Interc'l: 0	
FRA	-14378592	Euro: 9 Interc'l: 2	
Airline	33637388		36
CPH	1876608	Euro: 9 Interc'l: 0	
MAD	2359777	Euro: 9 Interc'l: 2	
Airline	61958164		67
LHR	1924944	Euro: 9 Interc'l: 2	
BRU	1684258	Euro: 9 Interc'l: 0	
Airline	69006952		74
LHR	1895986	Euro: 9 Interc'l: 2	
FRA	-15216546	Euro: 9 Interc'l: 0	
Airline	66057220		71
CDG	-1982632	Euro: 9 Interc'l: 2	
FCO	-15034719	Euro: 9 Interc'l: 0	
Airline	79428896		86
LHR	3047660	Euro: 9 Interc'l: 2	
AMS	-1294053	Euro: 9 Interc'l: 0	

The following policy tests were performed:

- (A) effect of doubling demand;
- (B) effect of doubling demand and increasing airport capacity;

- (C) effect of decreasing landing charges (at Schiphol);
- (D) effect of decreasing passenger charges (at Schiphol);
- (E) effect of a change in a mix of policies on Schiphol's position;

Two additional policy tests focused on the effects of changes in network structure on Schiphol's position.

- (F) effect of splitting international routes;
- (G) effect of changing intra-European routes;

In many of these tests the introduction of an exogenous change is also likely to affect the quality of airports from the point of view of airlines which, in turn, could affect their choice of a primary hub. Since in this study we did not model airlines' reaction to changes in airport quality attributes, we disregard airports' quality effects arising from these policy changes. As mentioned above, such an analysis is the subject of a follow-up study. Below we report the major findings from these policy tests.

5.2. Policy Test Results

A. Effect of Doubling Demand: the demand data used here represents approximately 45% of actual demand. The reason being that in Europe non-scheduled and charter operations constitute a very large proportion of total demand. In addition, in this study we have used only 18 European airports (albeit the major ones), thereby not considering trips from smaller airports. To account for this discrepancy and to assess the effect of future growing demand we have doubled both the business and non-business demand matrices. Compared with the base-run the results show that while the network with London (LHR) - Rome (FCO) as its hubs still ranks the highest, other networks become a viable option. Thus, for example, whereas in the base-run London (LHR) - Brussels (BRU) ranked fifth after London (LHR) - Rome (FCO), now it ranks second. On the other hand, the network London (LHR) - Amsterdam (AMS) which ranked second in the base-run is now down to fifth position. Apparently, as demand increases the strategic position of other airports (such as Brussels in combination with London) becomes an attractive option for airlines. This conclusion should be qualified, however, as we did not consider the effect of greater demand on congestion and delays, thus on the attractiveness of airports from airlines' viewpoint.

B. Effect of Doubling Demand and Increasing Airport Capacity: It can be seen from the doubled demand test results that certain airports are used to their full capacity. One solution is to expand runway capacity. Of the 5 major airports in our study, London (LHR) and Frankfurt are unlikely to see any increase in runway capacity. Amsterdam, Paris (CDG) and possibly Brussels, can expect such a development⁴. Thus, in this policy test the runway capacity of these 3 airports is increased according to their projected capacity per week in the year 2000 (SRI, 1991) as follows:

⁴ In cases where it is not possible to increase capacity the solutions to congestion will be either decline in service level (e.g. longer delays) or higher charges, or both.

Hub Airport	Original Runway Capacity	Runway Capacity for the year 2000
Amsterdam	11,424	15,120
Brussels	7,392	10,080
Charles de Gaulle	12,096	12,600

The main conclusion from this analysis is that compared with the previous test (A) the position of Amsterdam will not improve while that of Paris (CDG) will (compare, for example the positions of CDG - FCO and LHR - AMS in tests A and B). The profit level of different networks might change as well but in evaluating these results it should be point out that we did not account for the capital costs of these capacity development projects and their possible effect on airlines' costs.

C. Effect of Decreasing Landing Charges (at Schiphol): In this study we have lumped all charges into two main categories: landing or Aircraft Movement (ACM) and Passengers (PAX) charges. In general, all charges need to be approved by governmental authorities thus, except for inflation adjustments, the margins for a change are rather limited. However, as explained above, our objective is to examine the effect of charges on network structure and the choice of a particular hub, independent of how applicable is this policy at present. To that end, in this test we reduce ACM charges at Schiphol by 15 percent. Compared with the base-run the results from this test indicate no effect on Schiphol's ranking (LHR - AMS is second place in both cases) with a slight improvement in potential profits for airlines (due to the drop in charge costs).

D. Effect of Decreasing Passenger Charges (at Schiphol): In the following policy test we have decreased Schiphol's passenger related (PAX) charges, for both transfer and non-transfer passengers, by 15%. The results show that decreasing PAX charges has little to no effect on the outcomes (Schiphol's ranking and airlines' profits). Compared with the results of test C, decreasing Schiphol's landing charges by 15% has a greater impact on the airlines' profits than a decrease of PAX charges of a similar magnitude. In either case, decreasing charges has no effect on the ranking of preferable networks.

E. Effect of a Change in a Mix of Policies on Schiphol's Position: In this test we examined the combined effect of completely eliminating all charges at Schiphol (i.e., ACM and PAX charges are set to zero) while concurrently doubling demand everywhere. The main conclusion from this test is that demand has a much greater impact on network ranking and profitability than charges have. Compared with the results of test A, the decline in Schiphol's charges has improved the airline's level of potential profits but did not affect its relative ranking.

F. Effect of Splitting International Routes: In the base case analysis the two international routes (New York (JFK) and Tokyo (NRT)) are connected to one hub (the European gateway hub, e.g., London) while the other airport serves as an intra-European main hub. In this case each of the two hubs is connected to one of the two international hubs in order to determine the effect on potential profits and network ranking. The results (shown in Appendix F) imply that, based on potential profits, the splitting of the international routes reduces overall

profitability, compared with the base-run's results. Hence, from this perspective this is not a preferable approach. From network ranking point of view the network London (LHR) connected to JFK and Amsterdam (AMS) connected to NRT is superior (in terms of potential profits) to the network London (LHR) connected to JFK and Rome (FCO) connected to NRT which seems, from geographical viewpoint, to be the more logical one (than LHR connected to Tokyo and FCO connected to New York).

G. Effect of Changing Intra-European Routes: In the base case analysis each of the two main hubs is connected to 9 intra-European routes. The objective of this test is to ascertain whether a different split of these routes will affect potential profitability and ranking. Hence, in this run, the European domestic routes are alternately split 7 to 11 between the two European hubs (as well as between the two international routes). Compared with the base-run results, in general, profit level has been increased after this split. For example LHR - FCO weekly potential profit level has risen from \$92.7 million in the base-run to \$100.5 million. In this regard this policy is a preferable one. From network ranking viewpoint, Schiphol's position is not improved as another network, London (LHR) - Frankfurt (FRA) has a higher ranking. It is possible, of course, to test for any other routes' split to find out whether Schiphol's position can indeed be considerably improved.

Table 2. Summary of Policy Tests: Selected Results ^a

Test Type		Airline's Best Network Choice			Schiphol' Best Position			
		Hubs		Rank	Hubs		Rank	Position
	Base Run	LHR	FCO	100	LHR	AMS	86	2
A	Doubling Demand	LHR	FCO	100	FCO	AMS	77	4
B	Doubling Demand <i>and</i> Increasing Airport Capacity	LHR	FCO	100	FCO	AMS	76	5
C	Decreasing Schiphol's Landing Charges	LHR	FCO	100	LHR	AMS	87	2
D	Decreasing Schiphol's Passengers Charges	LHR	FCO	100	LHR	AMS	86	2
E	Mix of Policies	LHR	FCO	100	FCO	AMS	91	4
F	Splitting International Routes ^b	LHR	FCO	97	LHR	AMS	97	2
G	Changing Intra-European Routes	LHR	FCO	100	LHR	AMS	80	3

Note: ^a These results do not take into account possible changes in the quality level of airports resulting from these policies; ^b The combination LHR-FCO while ranking first, is somewhat doubtful from geographical viewpoint as it requires LHR to be connected to Tokyo (NRT) and FCO to be connected to New York (JFK)

5.3. Summary of The Policy Tests

As the focus of this study is on the effect of alternative policies on airlines' choice of best network (in terms of primary hubs) and on the position of Amsterdam (Schiphol) airport, the following table summarizes the main results from the above policy analyses.

Several conclusions can be drawn from these results. **First**, the combination of London (LHR) and Rome (FCO) airports appears to be superior, in terms of its potential ability to generate profits for airlines, under all policy test conditions (save for the implausible case of test F). This is mainly due to the very strong position of London's Heathrow airport in Europe and the effective geographical division of European routes between London and Rome.

The **second** conclusion is that the dominant factor affecting potential profitability and ranking of airports are actual demand patterns. Given demand elasticities, when more passengers use an airport as their origin or destination airport, the greater is the propensity of airlines to use this airport as their primary hub. It further seems that the demand factor supersedes many possible policy options like reducing landing and passenger charges. As suggested by the results of test A, if demand for air travel will indeed grow, (e.g., due to reduction in airfare following the European aviation deregulation), Schiphol's position is likely to decline as other airports, like Brussels and Paris (CDG), are more likely to be selected by airlines as their primary European hubs. This tendency will be further intensified if these other airports will also increase their runway capacity (see results of test B). A plausible corollary to this conclusion is that if Schiphol airport wishes to improve its relative position it needs to increase demand for its services relative to other airports. One sensible way of doing so is by expanding its catchment area, for example, by improving rail and bus link services to it.

A **third** conclusion is that the intercontinental linkages of an airport play an important role in determining its relative position. This can be seen from the results of test F which indicate that the combination of London (linked to New York (JFK)) and Amsterdam (linked to Tokyo (NRT)) is a viable alternative to the London-Rome combination. In general, it is the airlines which decide on the structure of their network and connectivity to international hubs.

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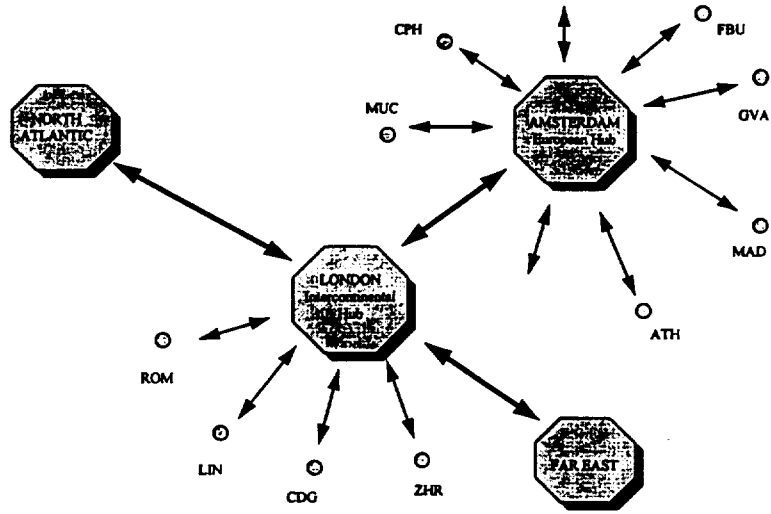


Figure 1: A network with London as the intercontinental hub and Amsterdam as the Intra-European hub

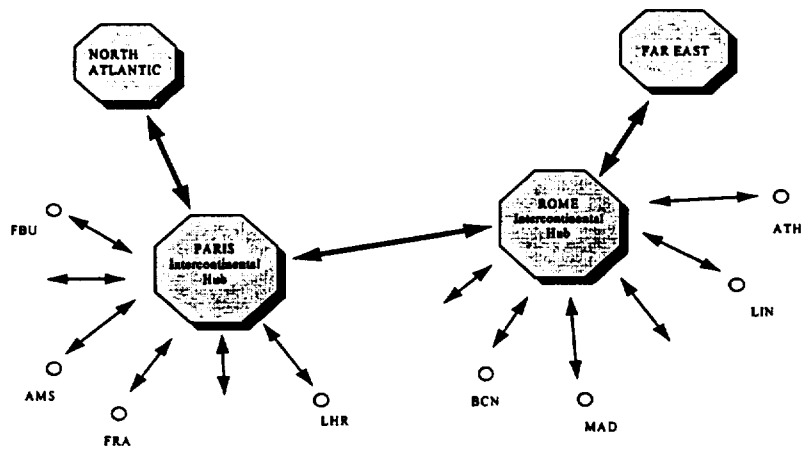


Figure 2: A network with both Paris and Rome as intercontinental hubs