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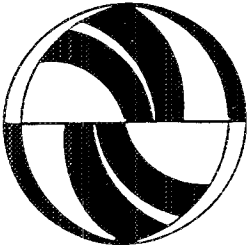
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**International Airline Hubbing in a
Competitive Environment**

Mark M. Hansen
Adib Kanafani

Working Paper
UCTC No. 402

The University of California
Transportation Center
University of California
Berkeley, CA 94720

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**International Airline Hubbing in a
Competitive Environment**

Mark Hansen
Adib Kanafani

Institute of Transportation Studies
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Working Paper
June 1987

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Abstract

Changes in the U.S. domestic airline route system have increased competition between international gateways. To assist in understanding this phenomenon, a system of models that predicts airline passenger flows resulting from different airline gateway hubbing strategies has been developed. The calibrated models predict baseline passenger flows quite accurately. The system was then used to project future traffic at a specific airport under alternative hubbing strategies of an airline. The results show that future international traffic at this airport is strongly sensitive to the airline's choice of strategy.

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1. Introduction

Spurred by the changes brought by deregulation, research on airline networking behavior in a competitive environment has been ongoing at the University of California over the past several years. The goal of this activity has been to improve our understanding of how airlines configure their networks when they are at once unconstrained and unprotected by government regulation. Such an understanding is valuable, in the short term, in guiding infrastructure management and deployment. More fundamentally, it is an important aspect of the larger debate surrounding the comparative virtues of regulated and unregulated transportation systems.

The research has focussed on hub-and-spoke route systems. In such systems, two examples of which are shown in Figure 1, non-stop service is offered between a single "hub" airport and between ten and a hundred "spoke" airports. This strategy concentrates traffic between many city-pairs on a small number of links, thereby allowing the use of larger, more economical aircraft and higher service frequencies. The hubbing airline can thus offer relatively low cost, high quality, one-stop service in spoke-spoke markets while maintaining a very strong, usually dominant, position at its hub.

Our research has centered on these systems for a number of reasons. Most importantly, hub-and-spoke systems have proliferated in the U.S. domestic industry since deregulation. As of 1985, approximately fifty such systems could be identified. Accompanying the development of new hub systems has been the strengthening of old ones. Operations of most major domestic airlines have, like those shown in Figure 2, trended toward increased concentration, a fact that is all the more striking in light of the growth in the total number of their operations. Unlike most other consequences of deregulation, increased hubbing was largely unforeseen.

Interest in this trend is heightened by its impacts on the airport system and on the geographical distribution of airline service and traffic. Hubbing causes unevenness in the distribution of both the benefits and the costs

associated with air transport, while at the same time closely coupling that distribution with the competitive fortunes of individual airlines. The net result is increased uncertainty among and rivalry between airports, as well as the communities they serve.

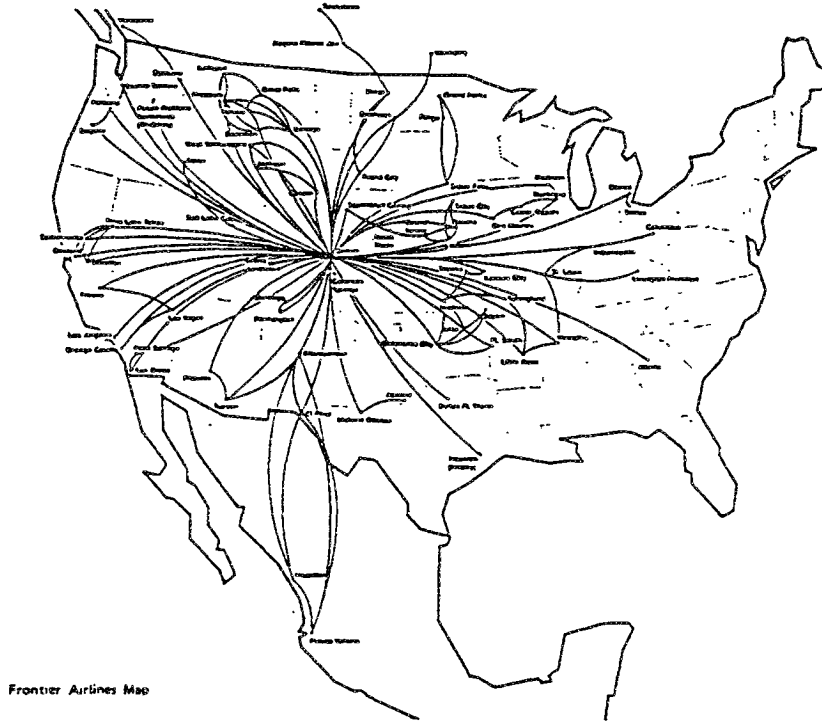
The context of this research dictates an approach in which equilibration rather than optimization is stressed. The primary objective is to portray a system where airlines, travelers, and various public sector institutions, each in pursuit of its own distinct interests, interact. How such a system compares with a hypothetical optimum is a question of great interest, but the immediate goal is to better understand the former rather than construct the latter. So far, the effort has focussed on one aspect of this interaction: that between passengers choosing routes and airlines scheduling flights. As the research progresses, we hope to be able to incorporate more of these actors into our analyses, and in more realistic ways.

What follows is an example of how this approach is being used to develop an understanding of the hubbing phenomenon as related to the networking of international traffic and the competition among international gateways.¹ In Section 2, the background for this application is presented. Section 3 describes our model. Calibration and validation of the model are discussed in Section 4, while Section 5 describes its application. Finally, in section 6, we summarize our results and discuss the prospects for improving our model.

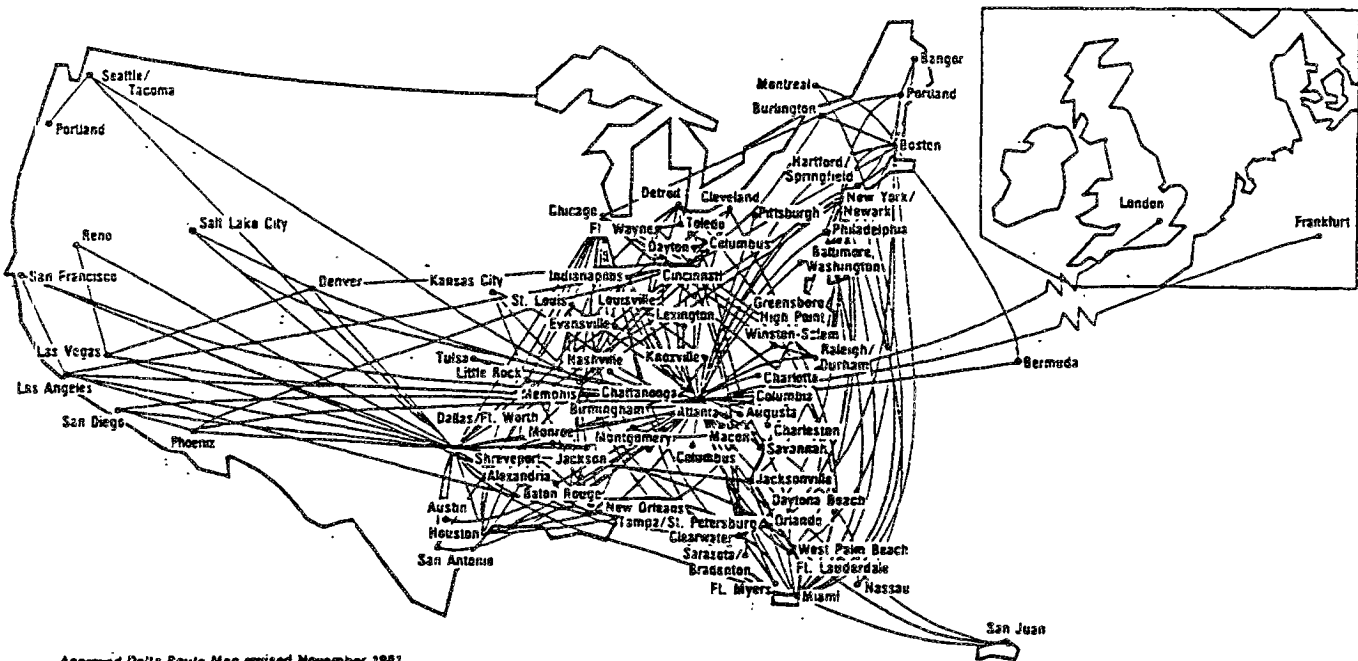
¹A gateway is defined as an airport that is used by carriers providing direct service to an international destination. Gateways in the U.S. include New York, Boston, Chicago and Dallas.

Figure 1 - Examples of Hubbed Route Systems

FRONTIER AIRLINES ROUTE SYSTEM ON JUNE 1

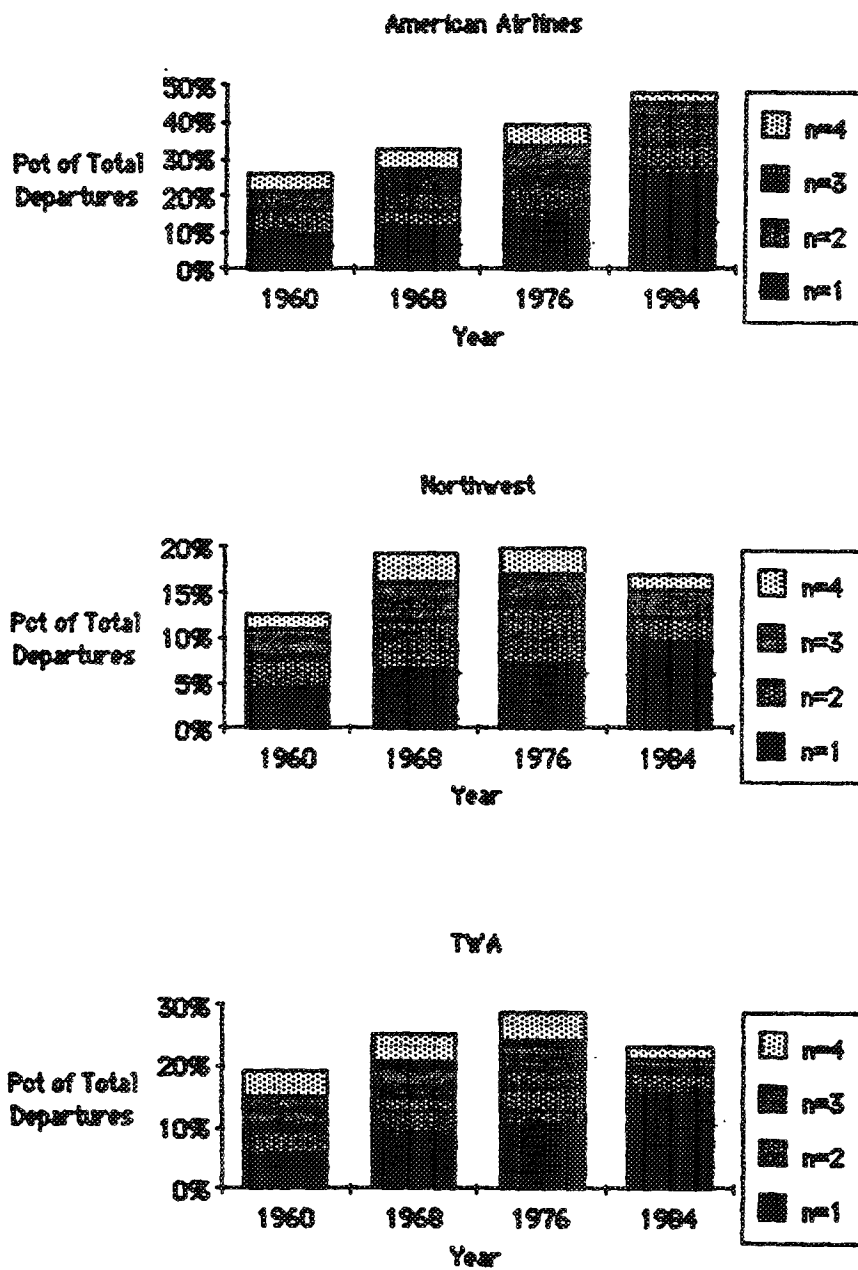


DELTA ROUTE MAP
As Of November 1981



Approved Delta Route Map revised November 1981.

Figure 2 - Trends in n-Airport Concentrations¹ for Selected U.S. Airlines



¹ The n-airport concentration is defined as the proportion of an airline's total flights which originate from its top n airports.

2. Background

Although deregulation directly effected the U.S. domestic air transport system, its impacts have been felt in the international sector as well. On the one hand, the U.S. government, convinced of the its success on the domestic front, has aggressively pursued liberalization of competitive restrictions imposed by bilateral agreements. Of greater relevance here are the impacts that have arisen through the strong inherent linkages between the domestic and international systems. These exist for two reasons. First, U.S. domestic airlines, in their search for new markets to cultivate, have sought to gain footholds overseas. In addition, relatively few U.S. points can economically support direct service to foreign destinations. A sizable proportion of international trips thus require travel on the domestic system.

In light of these circumstances, it is hardly surprising that increased domestic hubbing has affected patterns of international service. When passengers from many origins are funneled through a single point, that point becomes a likely candidate to receive international service. Conversely, airlines competing in international markets have every incentive to strengthen domestic services to their gateways. In short, the competitive forces unleashed by deregulation have created a situation in which hubs tend to become international gateways, and international gateways tend to become hubs.

Tables 1 and 2 illustrate these points. Table 1 shows that the number of U.S. airports with service to the most popular European destinations-- London and Frankfurt--increased significantly between 1978 and 1985. Because these points are themselves major connecting points, the increases affect service to all of Europe. Table 2 shows that U.S. airlines offering international service, greatly strengthened domestic feed into their gateways between 1978 and 1985. This trend underscores the strong complementarity between the domestic and international services of U.S.-flag carriers, a factor U.S. government tends to overlook in its pursuit of "open skies" in international air transport.

**Table 1 - Gateways to Selected Destinations,
1978 and 1985**

<u>Destination</u>	<u>Total Gateways</u>		<u>U.S. Flag Gateways</u>	
	<u>1978</u>	<u>1985</u>	<u>1978</u>	<u>1985</u>
London	13	17	12	17
Frankfurt	5	12	3	9
Paris	7	9	5	5
Amsterdam	5	5	2	1
Copenhagen	4	4	1	1
Rome	2	2	2	2

**Table 2 - Domestic Online Feed Strength,
1978 and 1985**

<u>On-Line Feed Category</u>	<u>Number of Gateways</u>	
	<u>1978</u>	<u>1985</u>
<10000 annual departures	11	13
10000-49999	3	5
>50000	0	6
mean	14632	29176

International gateways in the United States thus face many of the same uncertainties as domestic hubs. Passengers may choose between any of the gateways with direct service to their destination, or may alternatively select connecting service through a European point. Airlines, similarly, have increasing flexibility (though less than in the domestic context) in choosing from which gateways to offer what service. The close coupling between domestic and international services amplifies the impact of these choices on airport traffic, and thus on facility requirements and revenue streams at gateway airports.

This research is concerned primarily with looking for a method to incorporate the effects of international hubbing behavior on airport traffic

forecasting. In order to do this, we attempt to build a model of traffic distribution among gateways and among airlines. The model represents market response to airline network configurations and gateway strategies.

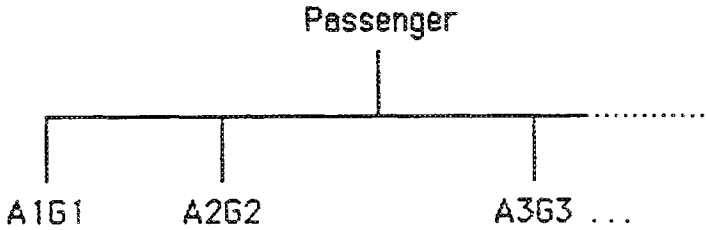
Airlines compete in the international market on many levels. The most obvious of these is fare competition. However, a review of fares at any point in time reveals that carriers typically manage to match each other's fares. They then continue to compete by adjusting their service patterns. Here they can adjust capacities, service patterns (direct versus connecting) and other aspects such as schedules, aircraft types and so forth. We are concerned here with the selection of gateways for international connections, and with the provision of domestic feed (connecting) services at these gateways. Passengers with demands between origin and destination city pairs will then respond by selecting carriers and gateways to use for their international journeys. Our model attempts to capture this behavior.

3. The Model

The choice process involved in the problem as defined above is a two-level process and described as follows: a U.S. passenger with an international destination³ has a choice among carriers, and among gateways offering international services. Even for a passenger who originates at a city which is itself a gateway, the option remains, as is often taken, to fly via another international gateway. There are numerous ways to characterize this choice process, among them:

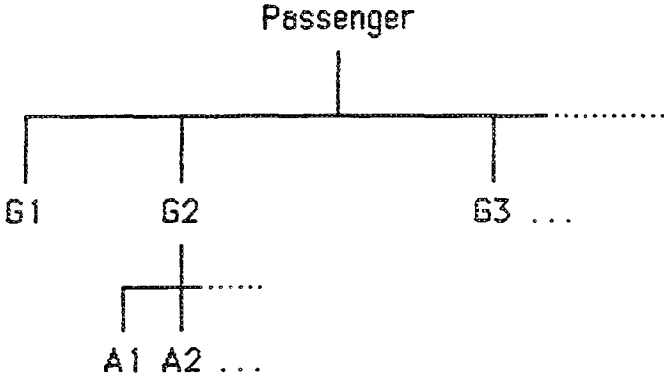
³To fix ideas, both our discussion and model focus on travel *from* the United States *to* Europe. We assume, however, that both would apply equally to travel in the opposite direction.

A. A simultaneous gateway-airline choice model postulates that the attributes of each airline and gateway are considered simultaneously in the same equation. The implied model structure would be:

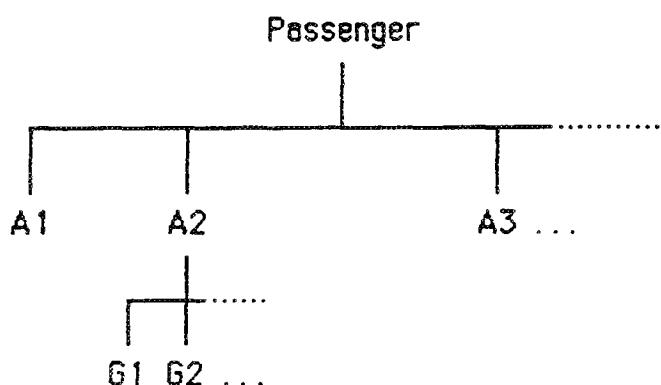


B. A nested choice postulates that the two choices are sequenced such that one is considered conditional on the other. Both are then combined in a Bayesian manner. In this case the structure of the choice model would be either of the following two:

1) Airline choice conditional on gateway choice:



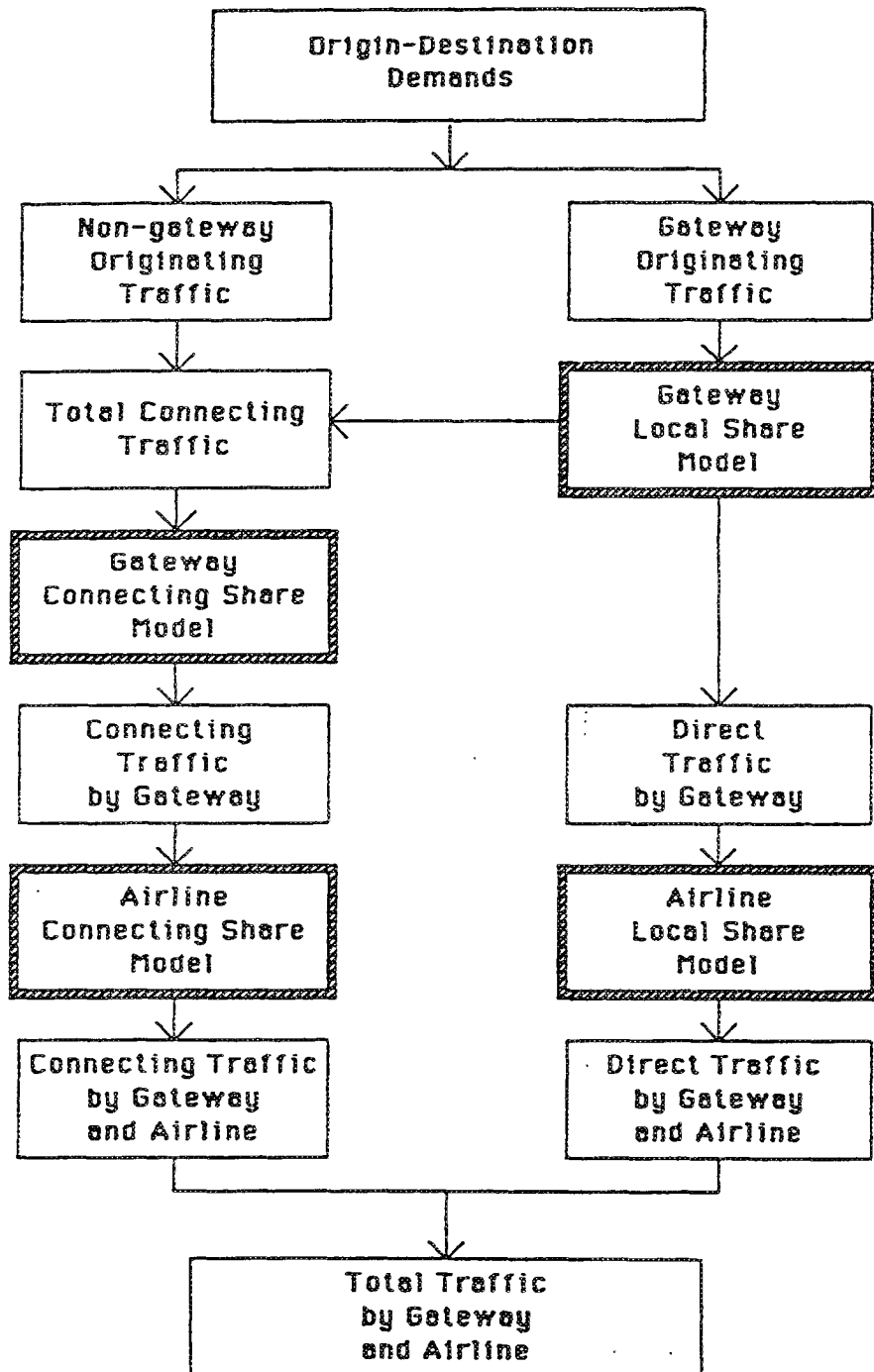
2) Gateway choice conditional on airline choice:



While it is possible to empirically determine which of these model structures best represents the real world, one can also favor one over the others on theoretical or practical grounds. The complexity of the simultaneous choice structure, particularly when the number of option combinations is large, makes it more cumbersome than the nested structures. Of the latter, it would appear that the choice of gateway would in many cases dominate the choice of carrier, especially since the geographic arrangements of these gateways (in the continental U.S.) makes some gateways infeasible for some cities of origin. We have therefore opted, at least as a start, to look at a model with the nested hypothesis, in which gateway choice occurs first and is followed by airline choice. This means that total demand from any city in the U.S. is first allocated to a gateway, and then among the carriers serving that gateway.

The general structure of the model is shown in Figure 3. Two gateway share submodels are built. One explains the distribution of traffic originating at a gateway city among available gateways, and the other looks at the choice of gateway for the connecting traffic flows. These are followed by two airline choice submodels. Again one of these looks at the choice by traffic flows that originate and actually travel from a particular gateway city, i.e. non-stop traffic to the European destination. The other looks at the choice by traffic flows connecting at each hub. A more detailed discussion of these models appears in the next section.

Figure 3 - Model System Structure



Before proceeding further, an important limitation of the model should be noted. This is the absence of consideration of European hubbing. In other words, the choice set of gateways is limited to the U.S. gateway. The choice of flying directly to a European hub, such as London or Frankfurt, and then connecting to a European final destination was not included in this model. The reason for this is simply that data required to incorporate this type of option into our model were not available. Consequently, the model poses the first European destination of a trip originating in the U.S. as the primary, or perhaps final destination. Put another way, the model implicitly assumes that the choice behavior of travelers who make connections at a particular European gateway is similar to those who are destined to those gateways, at least as far as the choice of U.S. gateways and airlines.

4. Specification and Calibration

The four submodels described in Figure 3 were specified and then calibrated using 1985 (third quarter) origin destination demand data from the U.S. The data used had numerous deficiencies and it would be outside the scope of this paper to describe them. Suffice it to say that we consider our results rather provisional and think that they would certainly benefit from improvements to the data base. Nonetheless, the results obtained appear on the whole to be quite reasonable.

Gateway Local Share Model

This model predicts the proportion of traffic originating in the local area of a gateway that will use direct service between that gateway and a European point. In general, passengers prefer direct to connecting service, but other considerations (a more convenient departure time, availability of space, lower fares, etc.) will outweigh the advantages of direct service in some cases. The probability of this occurring would be expected to increase, the greater the number of flights from other gateways, and the smaller the number of flights from the local gateway. Furthermore, the probability of using the local gateway is clearly 0 when that gateway has

no flights to the desired destination and 1 when that gateway has all the flights. Finally, choosing the local gateway would be expected to be more likely the closer the gateway is to Europe, because this would imply a greater circuitry disadvantage for alternative gateways. These considerations suggested a model of the form:

$$(1) \quad S_{ij}^{lt} = (DP_{ij}/DP_j)^{\beta D_i},$$

where

- S_{ij}^{lt} is the share of traffic from gateway i to destination j using the local gateway;
- DP_{ij} is the number of non-stop departures from gateway i to destination j ;
- DP_j is the total number of non-stop departures from the U.S. to destination j ;
- D_i is the distance to London (a proxy for distance to Europe) of gateway i , in thousands of miles;
- β is a parameter to be estimated.

β was estimated by performing ordinary least squares on the log-transformed version of equation (1). The results are summarized in Table 3. The fit of the model is fairly poor, but the hypothesis that $\beta = 0$ (which would imply that all passengers use direct service when available) can be rejected with a high confidence. The model was also found to slightly outperform ones where S_{ij}^{lt} is a fixed constant, and in which the exponent in equation (1) is a fixed constant rather than a function of distance.

**Table 3. Summary of Estimation Results,
Gateway Local Share Model**

<u>Statistic</u>	<u>Value</u>	<u>Significance Level</u>
β Estimate	.0325	.0000
R Squared	.1776	--
F-Statistic (1,26)	5.617	.0254
No. of Observations	27	--

Gateway Connecting Share Model

Transatlantic passengers who do not use direct service from a local airport--either because none exists or because they prefer some alternative--use connecting service instead. The gateway connecting share model predicts the share of connecting passengers that will fly through a particular gateway. The gateway connecting share model was assumed to be of the logit form. If the alternative gateways to a European destination k are indexed 1 to n , it is assumed that the proportion of passengers using gateway i , S_{ik} , is:

$$(2) \quad S_{ik} = \frac{\text{EXP}(V_{jk})}{\sum_{j=1}^n \text{EXP}(V_{jk})} = \dots$$

The V_{jk} are utilities associated with each alternative gateway, and are assumed to be linear functions of gateway attributes.

The specification of a logit model for the gateway choice problem implies that the relative advantage of a particular gateway in terms of the attributes that constitute the choice function will diminish as the level of service continues to increase. If this model specification is borne out by the empirical evidence, one possible implication is that there is a limit to what airlines can do in consolidating flights at a specific gateway in terms of attracting increasing shares of the market. But it also means that until

this limit is reached, consolidation will be to the airline's, and the passengers', advantage. Of course the extent to which we can verify this empirically depends on the specification of the choice function $V(\cdot)$. A priori, we would expect the choice of a gateway to depend on a number of factors. One is the capacity offered out of it. In our model we specify two variables for this, the weekly U.S. flag flights, and the weekly foreign flag flights, from each gateway to each European destination. The distinction between the two is important since it reflects the fact that with foreign flag carriers interlining is necessary at the gateway, while the U.S. flag carriers might offer online connection. This of course depends on the carriers' domestic feed, which is the next variable specified in the model. The domestic feed variable is currently specified in an aggregate way. It is the total number of weekly domestic flights into a gateway, by all carriers and from all U.S. origins. It is later disaggregated by airline in the airline choice submodel.⁴

In order to account for the geographic effect of gateway location, since the need to backtrack in order to use a particular gateway is likely to reduce its choice probability, we specified the air distance to London as a variable to distinguish among gateways. Other potentially significant variables which we ignore in this specification, but which could be of importance for gateway choice, include airport congestion and delays, weather conditions, and characteristics of the domestic feed. These omissions reflect limitations in data availability and resources.

The a priori specification of the choice function is then:

$$(3) \quad V_{jk} = \alpha \text{USD}_{jk} + \beta \text{FD}_{jk} + \gamma \text{DF}_j + \delta D_j,$$

where USD_{jk} is the number of weekly U.S. Flag departures between U.S. gateway k and Europe destination k ;
 FD_{jk} is the number of weekly Foreign Flag departures between j and k ;

⁴The existing version of our model does not disaggregate by city of origin. This is a serious detriment which we hope to remove in the near future.

- DF_j is the domestic feed into gateway j , in thousands of flight per week;
- D_j is the gateway distance to London, in thousands of miles;
- α , β , γ , and δ are parameters to be estimated.

Substituting (3) into (2) and performing some algebra yields:

$$(4) \quad \begin{aligned} \text{LOG}(S_{mk}/S_{nk}) = & \alpha(\text{USD}_{mk} - \text{USD}_{nk}) \\ & + \beta(\text{FD}_{mk} - \text{FD}_{nk}) \\ & + \gamma(\text{DF}_{mk} - \text{DF}_{nk}) \\ & + \delta(D_m - D_n) \end{aligned}$$

The coefficients were estimated by performing ordinary least squares on the above equation.

This approach allows some flexibility in constructing the pairwise comparisons. If traffic is distributed over N alternatives, there are $N-1$ degrees of freedom and thus only $N-1$ of a possible $N(N-1)$ pairs should be chosen. In this analysis, observations were constructed by pairing one airport, hereafter referred to as airport X , with each competitor gateway. This procedure in effect normalizes utility resulting from unobserved service attributes so that it is zero for airport X .

Initial results suggested that the model was misspecified with respect to the departure variables. This was indicated, first, by a negative estimate for β , and second, by a negative correlation between the U.S. flag departure variable and the residuals. In addition, the residuals tended to vary systematically with the European destination. The specification was therefore modified to:

$$(5) \quad \begin{aligned} \text{LOG}(S_{mk}/S_{nk}) = & \alpha((\text{USD}_{mk})^5 - (\text{USD}_{nk})^5) \\ & + \gamma(\text{DF}_m - \text{DF}_n) + \\ & + \delta(D_m - D_n) \\ & + \lambda \text{LON} + \phi \text{FRA} + \pi \text{PAR}, \end{aligned}$$

where USD_{ij} , DF_i , and D_i are defined as in equation 3;
 LON , FRA , and PAR are dummy variables corresponding
to London, Frankfurt, and Paris;
 α , γ , δ , λ , ϕ , and π are parameters to be estimated.

As explained above, index m in equation 5 always refers to airport X , while index n refers to some competing gateway.

The calibration results for this model are summarized in Table 4. The estimated coefficients on the departure, feed, and distance variables all have the expected signs and fairly high significance levels. The London and Paris dummy variables are also statistically significant. We consider the R^2 of 0.76 to be fairly high for this sort of model.

**Table 4. Summary of Estimation Results,
Gateway Connecting Share Model**

<u>Statistic</u>	<u>Value</u>	<u>Significance Level</u>
α Estimate	.0325	.0000
γ Estimate	.0702	.0579
δ Estimate	-.2926	.0319
λ Estimate	-1.052	.0003
ϕ Estimate	-.1857	.4700
π Estimate	-.7652	.0230
R Squared	.7637	--
F-Statistic (5,41)	26.50	.0000
No. of Observations	47	--

Airline Local Share Model

The airline local share model predicts airline shares of local traffic between a gateway and a European destination. Airline local share was expected to depend primarily on airline share of departures. Previous work

has suggests that this relationship takes the form of an S-curve, so that airlines with high (low) departure shares have disproportionately high (low) traffic shares. This relationship results from the greater probability that high-departure-share carriers will offer the most convenient flight schedules, and from the resulting tendency for travelers to contact these carriers first when they make their travel plans.

Data limitations, combined with the low incidence of direct competition in transatlantic markets, precluded a statistically rigorous analysis of this relationship. To be included in the origin-destination sample, an itinerary must have at least one segment on a U.S. airline, so foreign-flag local traffic shares could not be obtained. On the other hand, head-to-head competition between U.S. carriers exists in only a handful of transatlantic markets. The few observations that were available suggested a straight-line relationship between departure share and local traffic share. Such a relationship was therefore assumed in our model.

Airline Connecting Share Model

This model, which predicts airline shares of connecting traffic between a given U.S. gateway and European point, was anticipated to have a specification analogous to the gateway connecting share model. Thus, in selecting an airline between a given gateway and European point, connecting passengers were expected to prefer airlines with higher service frequencies. Furthermore, these passengers were expected to prefer airlines with stronger feed. The a priori specification of the model was therefore a logit function in which the utility associated with each alternative airline is a function of the number of departures it offers between the gateway and European point, as well as the number of flights it offers from other U.S. points to the gateway.

This model was estimated using the same pairwise least squares procedure used for the gateway connecting share model, except that in this case, a specific carrier, airline A, was used as the utility normalizing alternative. The initial results suggested that the strength of the feed effect depended on the identity of the airline, apparently because of network or scheduling

differences. The model was therefore respecified to allow the feed variable to be airline specific. Because of data limitations, airline-specific feed variables could be estimated for only two airlines, airline A and airline B. The revised specification is thus:

$$(6) \quad \text{LOG}(S_{ijm}/S_{ijn}) = \alpha((DP_{ijm}) - (DP_{ijn})) \\ + \beta(FD_{im}) \\ + \delta(FD_{in} * B),$$

where S_{ijm} is airline m's share of connecting traffic between U.S. gateway i and European destination j ;
 DP_{ijm} is the number of weekly departures between U.S. gateway i and European destination j offered by airline m;
 FD_{im} is the domestic feed of airline m into gateway i, in thousands of flights per week;
 B is a dummy variable equal to 1 if airline i is B and 0 otherwise;
 α , β , and δ are parameters to be estimated.

In the data set used for calibration, airline m (the airline whose share is in the numerator of the left hand side of equation 6) is always airline A, and airline n is always some competing airline.

The calibration results for equation 6 are presented in Table 5. The R^2 indicates a reasonably good fit, and all coefficients are statistically significant. Nonetheless, the utility of this submodel is compromised by the restricted scope of the feed variable. In practice, this means that airline A market shares would be overestimated in situations involving competition with an airline other than B with a strong feed.

**Table 5. Summary of Estimation Results,
Airline Connecting Share Model**

<u>Statistic</u>	<u>Value</u>	<u>Significance Level</u>
α Estimate	.1163	.0039
γ Estimate	4.911	.0002
δ Estimate	-8.686	.0060
R Squared	.6443	--
F-Statistic (3,24)	26.50	.0000
No. of Observations	27	--

Validation

The calibration results described above indicated varying levels of performance on the part of the four submodels. To assess the validity of the model system as a whole, its forecasted passenger flow values were compared with actual values. Figures 4, 5, and 6 show the results of some of these comparisons. In Figure 4, predicted and actual total passengers flows from airport X to each of nine European destinations are plotted. Model predictions of the flows are very accurate. In Figure 5, the predicted and actual connecting traffic flows between airport X and the European destinations are compared. Here, the accuracy is somewhat less. Figure 6 compares predicted and actual passenger flows on airline A between airport X and these destinations (as shown in the figure, A did not serve all nine destinations in 1985). The accuracy of this set of predictions is the lowest of the three. In general, therefore, the model performs well at higher levels of aggregation, its accuracy diminishing as the flow categories become finer.

5. Applications

To conclude our investigation, we used our model system to investigate the passenger flow impacts of alternative hubbing strategies of airline A. In the real world, an airline's hubbing decisions will be influenced by many factors not included in our model, so this application should be regarded as

Figure 4 - Total Passengers at Airport X

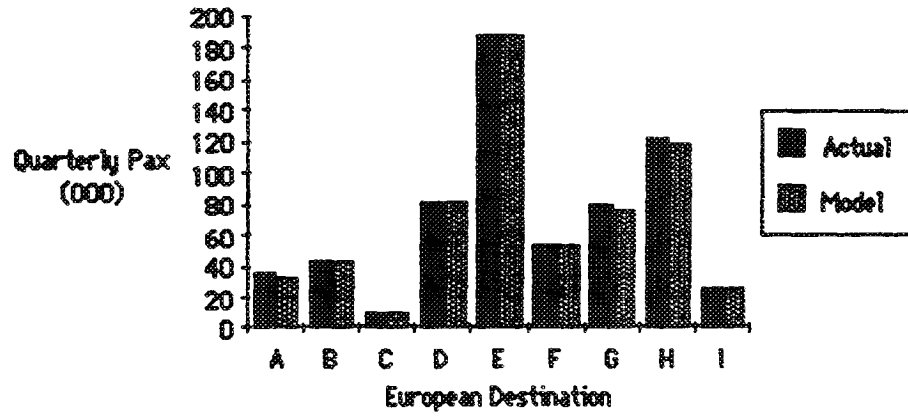
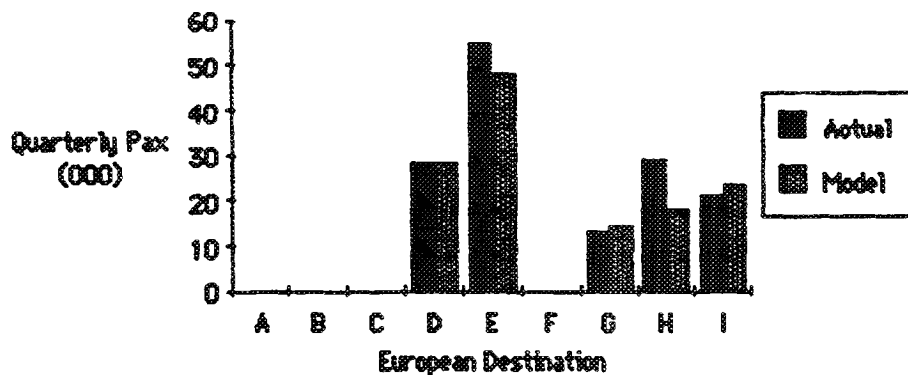


Figure 5 - Connecting Passengers at Airport X



Figure 6 - Airline A Passengers at Airport X



an exercise rather than an attempt to actually predict the airline's behavior. Nonetheless, the results underscore the sensitivity of passenger flows to specific hubbing strategies, and the consequent need for system planners and policymakers to take them into account.

The application was carried out by defining three alternative hubbing strategies airline A might consider. The strategies were defined against a third quarter, 1985 baseline, with each specifying a pattern of future operations growth focussed at a particular gateway. In one scenario, the focus was airport X, which in 1985 served as A's major gateway. The other scenarios posited a gradual shift away from airport X as the focus of A's operations. In accordance with observed airline behavior, the shift in the latter scenarios was assumed to take the form of accelerated growth at an alternative gateway rather than a wholesale transfer of operations. It might be motivated by either marketing considerations or constraints on facility availability at airport X.

Some of the key results of the analysis of are shown in Figures 7 and 8. Figure 7 projects the impact of airline A's strategy choice on total traffic between airport X and the nine European destinations considered in the model. If airline A focusses its growth at airport X, the traffic increase over 5 years is 40%. On the other hand, the increase is less than 10% if airline A chooses either of the alternative gateways. Figure 8 shows the implications of the three strategies for the performance of airline A, as measured by its passengers per departure to the nine European destinations. If airport A is chosen, passengers per departure is forecast to increase 20% over the five-year period, while 20 and 30 percent declines in this ratio are projected to result from the other strategies. Barring a significant downsizing of airline A's fleet, this would imply reduced load factors and earnings. Thus, our model system, while admittedly oversimplified, yields unambiguous results in this particular case: airline A's best strategy would be to focus its growth at airport X, an option which would mean substantial growth in X's international passenger traffic. Incidentally, this option is the one A appears to have chosen.

Figure 7 - Projected Airport X International Passenger Growth Under Alternative Airline A Hubbing Strategies

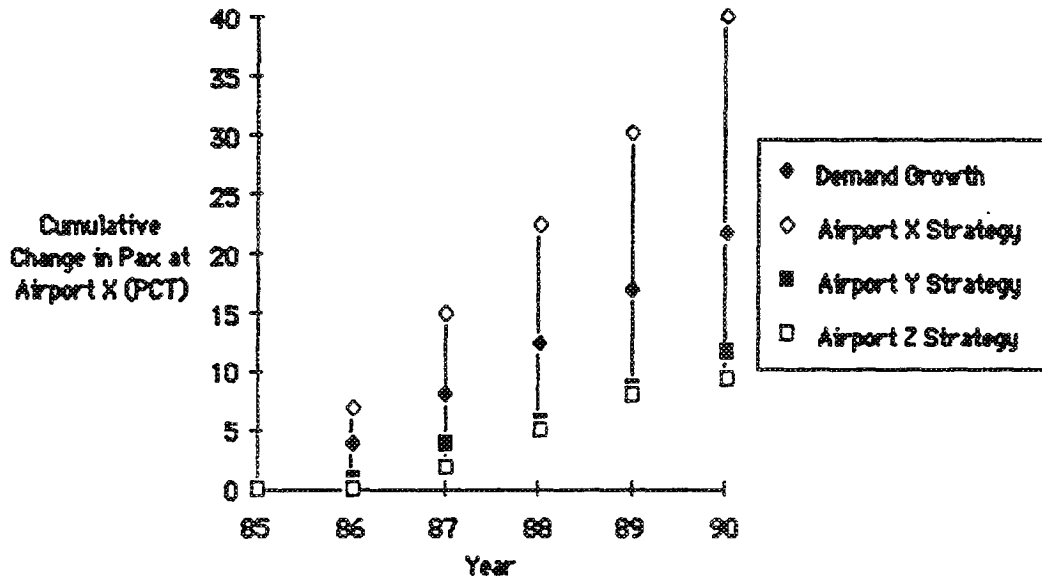
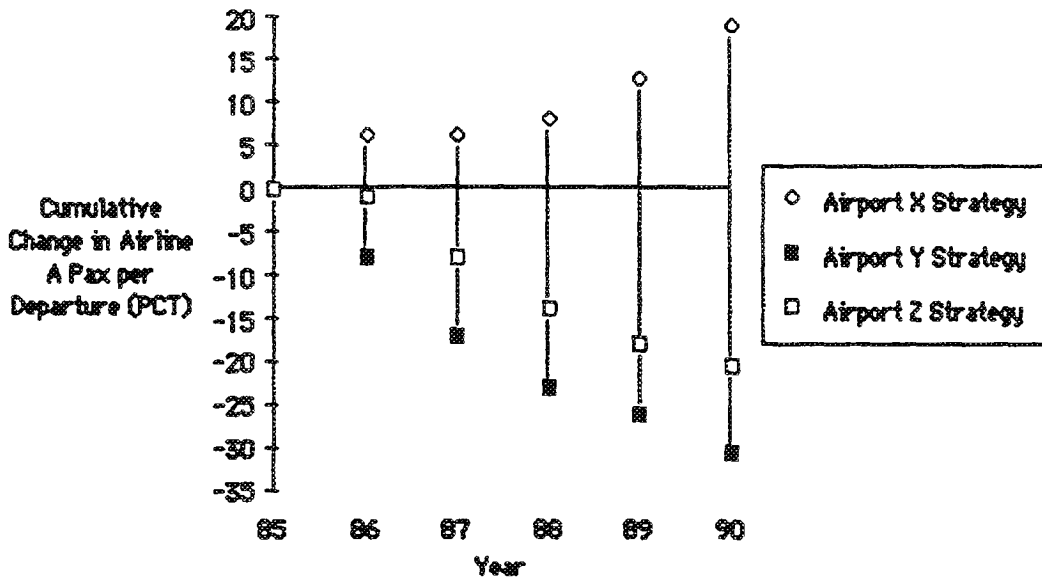


Figure 8 - Projected Airline A Passengers per Departure Under Alternative Hubbing Strategies



6. Conclusions and Directions for Further Research

Competition is contagious. The forces unleashed by deregulation of the U.S. domestic airline industry have impinged upon both the international air transport and the airport systems. This has resulted in a need to understand how the hubbing strategies of individual airlines affect both their own competitive performance and airport traffic levels. The model system presented here represents a first attempt at portraying these complex phenomena in a set of empirically estimated structural equations. Despite significant limitations in the scope and level of detail of the models as well as the data necessary to calibrate them, this initial effort has confirmed the viability of the approach while demonstrating the significance of airline hubbing decisions as determinants of airport traffic and airline performance.

It is clear that our system falls far short of fully capturing the economic forces that drive airline networking behavior. Airlines, airports, and would-be travelers may each be seen as economic entities with distinct objectives. The airlines may be seen as profit-maximizers seeking to fill their aircraft with paying customers. Airports might be viewed as growth maximizers subjected to a revenue constraint, or as profiteering monopolists. Passengers are presumably utility maximizers who will choose the service best suited to their individual preferences. In a competitive environment, airline networks represent the interactive outcome of decisions by these three sets of actors, as well as the countless others with whom these, in turn, interact.

When held up against this standard, the limitations of our work become abundantly clear. Only the choices of passengers are treated explicitly. Analysis of these is limited in the range of choices included, from which the options of not traveling at all and traveling via a European gateway are excluded, and the criteria used to make these choices, which exclude fare and origin-specific service variables. The model is weaker still in its treatment of the other actors. Only one airline objective--passengers per departure--is considered, a gross oversimplification. More importantly, instead of actually predicting airline routing decisions, the model requires

that these be entered exogenously. The role of airports, meanwhile, is left entirely out of the picture. Thus, we cannot claim that our models simulate the behavior of a competitive marketplace, but rather only that they model the response of one set of actors in that marketplace to the actions of another.

The next phase of our research is aimed at correcting some of these deficiencies. On the one hand, this implies improving the existing capability to model passenger flows. At a minimum, the steps to be taken in this direction include adding routings via European gateways to the choice set, and disaggregating passengers by origin. Equally important, we intend to develop some capability to simulate airline responses to passenger flows and to each other. With these enhancements, it is hoped that the model will better capture the competitive realities motivating its development.