Airline Hubs: A Study of Determining Factors and Effects

by Paul W. Bauer

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Introduction

The Airline Deregulation Act (ADA) of 1978 caused many changes in the industry. For the first time in 40 years, new airlines were permitted to enter the industry, and all airlines could choose the routes they would serve and the fares they would charge. Airlines were also free to exit the industry (go bankrupt), if they made poor choices in these matters. Naturally, this has led to many changes in the way airlines operate.

Many aspects of airline behavior, particularly fares, service quality, and safety, have been subjected to intense study and debate. The development of hub-and-spoke networks is one of the most important innovations in the industry since deregulation, and it has affected all of these aspects. Yet comparatively little research has been done on this phenomena.

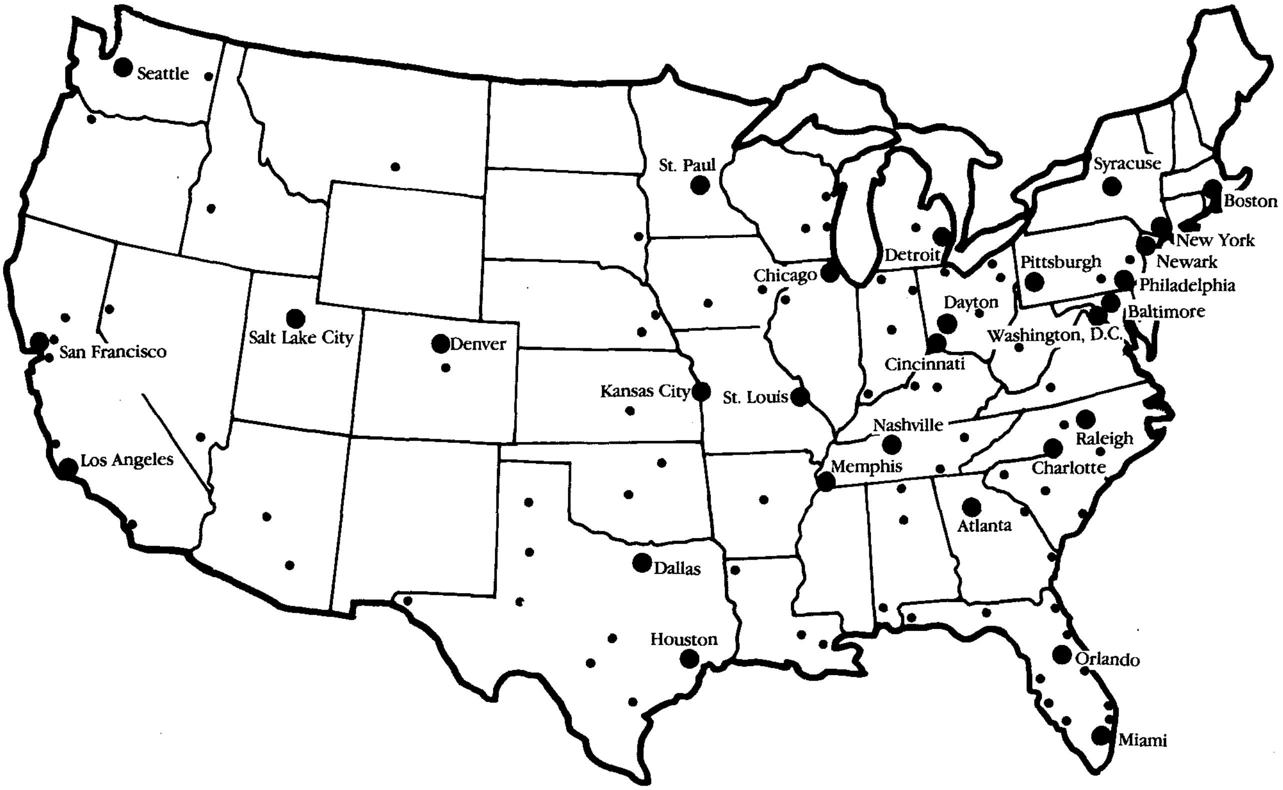
A hub-and-spoke network, as the analogy to a wheel implies, is a route system in which flights from many "spoke" cities fly into a central "hub" city. A key element of this system is that the flights from the spokes all arrive at the hub at about the same time so that passengers can make timely connections to their final destinations. An airline must have access to enough gates and takeoff and landing slots at its hub airports in order to handle the peak level of activity.

An example of a hub-and-spoke network can be seen in figure 1, which shows the location of the hub and spoke cities used in this study. From Pittsburgh, USAir offers service to such cities as Albany, Buffalo, Cleveland, Dallas-Fort Worth, London, New York, Philadelphia, and Syracuse to name just a few. Hub cities tend to have much more traffic than spoke cities. Much of the hub-city traffic centers on making connections. For example, over 60 percent of the passengers who use the Pittsburgh airport hub are making connections, vs. 25 percent at the Cleveland spoke airport.

The advantages of hub-and-spoke networks have been analyzed by several sets of researchers. Bailey, Graham, and Kaplan (1985) discussed the effects of hubbing on airline costs and profitability. Basically, hubbing allows the airlines to fly routes more frequently with larger aircraft at higher load factors, thus reducing costs. Morrison and Winston (1986) looked at the effects of hubbing on passenger welfare, finding that, on average, passengers benefited from the switch to hub-and-spoke networks by receiving more frequent flights with lower fares and slightly shorter travel times.

It is important to note, however, that while passengers benefit on average from hub-and-spoke networks, there are some detrimental effects such as the increased probability of missing connections or losing baggage and having direct service converted into connecting service through a hub (although this is partially offset in many cases by more frequent service). Current public perceptions about the state of airline service have been strongly influenced by the transitory problems many of the carriers have had integrating acquired airlines into their service network.

Hub and Spoke Network



Source: **Author**

FIGURE 1

McShan (1986) and Butler and Huston (1987) have shown another aspect of the switch to hub-and-spoke networks. McShan argues that airlines with access to the limited gate space and takeoff and landing slots at the most desirable hub locations before deregulation have benefited the most from deregulation. Butler and Huston have shown that the airlines are very adept at employing their hub market power, charging lower fares to passengers flying through the hub (who typically have more than one choice as to which hub they pass through) than to passengers flying to the hub (who have fewer options).

Some of these authors have speculated as to why hubs exist in some locations but not in others. Bailey, Graham, and Kaplan (1985) and McShan (1986) have suggested that an ideal hub network would have substantial local traffic at the hub and would be centrally located to allow noncircuitous travel between the airline's hub and spoke cities. However, no empirical exploration of this issue has yet been attempted.

In an attempt to more fully understand the hubbing phenomena, this paper looks for the main factors that airlines consider in evaluating existing and potential hubs, and investigates the impact of the hubbing decision on airport traffic.

The paper is organized as follows. Section I discusses the cost and demand characteristics of the airline industry that lead to hub and spoke networks. From these stylized facts about the airline industry, a two-equation empirical model is constructed in section II. The first equation predicts whether a city is likely to have a hub airline and the second equation estimates the total revenue passenger enplanements the city is likely to generate as a result of the hub activity. Empirical estimates are obtained for this model, using data from a sample of the 115-largest airports in the U.S., and are discussed in section III. The implications of these results on the present and future structure of the U.S. airline industry are discussed in section IV.

I. Characteristics of Airline Demands and Costs

To understand the factors that influence the location of hubs, it is first necessary to look at the demand determinants and costs for providing air service. Basically, people travel for business or pleasure. Travelers usually can pick from several transportation modes. The primary modes of intercity travel in the U.S., are automobiles, airlines, passenger trains, and buses. A traveler's choice of transport is influenced by the distance to be traveled, the relative costs of alternative transportation, and the traveler's income and opportunity cost of time spent traveling.

Aggregating up from individual travelers to the city level, the flow of airline passengers between any two cities is largely explained by the following factors:

1) the air fare between the two cities and the cost of alternative transportation modes,
2) the median income of both cities,
3) the population of both cities,
4) the quality of air service (primarily the number of intermediate stops and the frequency of the flights),
5) the distance between the two cities, and lastly,
6) whether either of the cities is a business or tourist center.

It is important to distinguish between business and tourist travelers. While both generate traffic, business travelers are more time-sensitive and less price-sensitive than tourist travelers. Business travelers would prefer to pay more for a convenient flight, whereas tourists would prefer to pay less, even if it means spending more time en route. These factors influence the demand for air service. The cost of providing that service can now be discussed.

As with any firm, airline costs are determined by how much output is produced and by the price of the inputs required to produce that output. Output in the airline industry is usually measured in revenue passenger miles (rpm), which is defined as one paying passenger flown one mile. Average cost per revenue passenger mile declines as either the average stage length (the average number of miles flown per flight) or the average load factor (the average number of seats sold per flight) increases.

It is easy to see why costs behave in this manner. First, every flight must take off and land. These activities incur high fixed costs. In addition to the usually modest takeoff and landing fees, much more fuel is used up when taking off than at other stages of the flight. Taxiing to and from the runways also takes up a significant amount of time. Those costs are unrelated to the distance of the flight or to the number of passengers. By comparison, flying at the cruising altitude is relatively inexpensive. Thus, with each mile flown the high fixed costs per flight are distributed over more and more miles, which lowers the average cost per revenue passenger mile. Second, average cost per revenue passenger mile declines as the average load factor is increased, because it is cheaper to fly one airplane completely full than it is to fly two planes half full.

Studies have shown that the cost of airline operations do not exhibit increasing returns to scale.[1] In other words, large airlines do not enjoy cost advantages over small airlines if load factors and stage lengths are taken into account. This does not mean that large airlines may not have other advantages over their smaller rivals. One advantage that they may have is that they have more flights to more destinations with more connections, so that they may be able to achieve higher load factors, which reduces cost. Frequent-flyer programs also tend to favor larger airlines, since passengers will always try to use one airline to build up their mileage credits faster. The larger airlines, having more flights and more destinations, are more likely to be able to satisfy this preference.

Under these cost and demand conditions, the chief advantage to establishing a successful hub is the increase in the average load factor, which lowers average cost. Hubbing enables an airline to offer more frequent nonstop flights to more cities from the hub because of the traffic increase from spoke cities. Passengers originating from the hub city thus enjoy a higher level of service quality than would have been possible if spoke travelers were not making connections there. Passengers from the spoke cities may also enjoy better service, because they can now make one-stop flights to many cities that they may have only previously reached by multistop flights.

Hubbing has a significant effect on the demand for air travel through its effects on both air fares and the quality of air service. Passengers prefer nonstop flights to flights with intermediate stops, and if there are intermediate stops, passengers prefer making "online" connections (staying with the same air carrier) to making "interline" connections. Nonstop and online flights minimize flying time and are less stressful and exhausting to passengers. The development of a new hub increases the number of nonstop and one-stop flights in a region, while reducing multistop flights, which were common on some routes prior to deregulation. In general, service

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[1] See Bauer (1987 working paper) and White (1979).

quality increases for both the hub city and the spoke cities when a hub-and-spoke network is created. However, some of the larger spoke cities could end up worse off, because they may lose some nonstop service to other cities that may now have to be reached by flying through the hub.

Now the problem of how to determine whether a particular city might make a successful hub, and the resulting implications for the volume of air traffic at the airport, can be considered.

II. Empirical Model of the Hubbing Phenomenon

The potential for airlines to serve a number of city pairs and the flow of passengers between those city pairs depends upon the demand and cost factors discussed in the last section. Given these factors, airlines trying to maximize profits face the simultaneous problem of choosing which cities to serve and how to serve them, that is, which cities to make hubs, which cities to make spokes, and which pairs to join with nonstop service. This is a complicated problem since the choice of a hub affects fares and service quality and, hence, passenger flows. Decisions by the airline's competitors will also affect the passenger flows within its system.

To investigate how important each of the various demographic factors discussed below is in deciding whether a given city would make a viable hub, a data-set containing information on 115 cities with the largest airports in the U.S. was compiled. These cities range in size from New York City, to Bangor, Maine and are shown in figure 1 with the hub cities in green and the spoke cities in orange. Notice that most of the hubs are located east of the Mississippi in cities surrounded by a large population base.

The data were collected from several sources. Information on whether a city was considered to have a hub airline (if the i-th city had a hub airline, then $h_i = 1$, otherwise $h_i = 0$) and the total revenue passenger miles handled by the city was obtained from 1985 Department of Transportation statistics. Data on the population (pop), and the per capita income (*inc*) of the city were obtained from the State and Area Data Handbook (1984) and from the Survey of Current Business (April 1986 issue).

In addition, a set of variables was collected to identify whether the city was a business or tourist center. The first of these variables (*DBTP,* "Dummy Business-Tourist-Proxy") is a dummy variable that is set equal to one if the total receipts from hotels, motels, and other lodging places for each city is greater than an arbitrary threshold, and is zero if otherwise. This series was also collected from the State and Area Handbook (1984). A value of one for this variable should correspond to cities that are either a business or tourist center. Unfortunately, this variable only measures the joint effect of both activities and does not distinguish between business and tourist travelers.

To construct separate measures of business and tourist activity, three variables are introduced. The number of Standard and Poors 500 companies headquartered in each city (*corp*) was compiled to be used as a proxy for the business traffic that each city is likely to generate. Measures of the likelihood that a city will generate significant tourist activity are obtained from the Places Rated Almanac published by Rand-McNally. The measures are respectively the rank of the city in recreation (*rec*) and the rank of the city in culture (cult). These variables were transformed so that the higher the rank the higher the city's scores were in that catagory.

In this study, a long-run approach is implicitly taken that ignores individual airport characteristics. In the long run, runways, gates, and even whole airports can be constructed.[2] The decision concerning where to locate hubs in the long run is determined by the location of those cities and by demographic variables that determine the demand for travel between cities. Unfortunately, deriving an economically meaningful measure of location is difficult in this context. Hubs can be set up to serve either a national or regional market, or to serve east-west or north-south routes. Thus, while location is an important factor in determining the location of hubs, constructing an index that measures the desirability of a city's location is beyond the scope of the current study.[3]

A more formal model of the hubbing decision can be constructed as follows. Let the viability of a given airport as a potential hub be a log linear function of the demographic variables discussed above where:

$$(1) \quad h_i^* = a_0 + a_1\, ln(pop_i) + a_2\, ln(inc_i) + a_3\, \mathrm{DBTP}, + a_4\, ln(corp_i) + a_5\, ln(rec_i) + \mathrm{a},\ ln(\mathrm{cult},) + v_i .$$

Here, h_i^* measures the viability of a hub in the i-th city. If this index is above a given threshold (at which point the marginal cost of setting up the hub is equal to the marginal revenue that the

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[2] For short-run analysis, information on individual airport characteristics is required, This approach will be employed in future research.

[3] Future research will attempt to look at this question more directly.

Parameter Estimates from Decision to Hub Equation

Parameter	Estimate	*t*-statistic
Constant	-0.347	-0.627
pop	0.869	1.60
inc	-1.57	-0.795
DBTP	0.478	0.920
corp	0.138	1.29
rec	-0.00232	-0.902
cult	0.0110	1.46

Percentage of predictions correct = 87.0.
Chi-squared statistic = 69.4
SOURCE: **Author.**

TABLE 1

hub brings in), then an airline will set up a hub there. Thus, b_i^* is related to b_i as follows:

$$(2)\quad b_i = \begin{cases} \mathbf{1}, \text{ if } b_i^* \geq k \\ \mathbf{0}, \text{ otherwise,} \end{cases}$$

where k is the threshold between hubs and nonhubs and v_i is statistical noise.

The traffic an airport can be expected to handle will depend on the same demographic variables that also influence whether a city is a hub, and by whether or not the city actually is a hub. Thus, traffic, as measured by revenue passenger miles (rpm), can be modeled as a log linear function of the demographic variables and the hub variable:

$$(3)\quad \ln(rpe_i) = b_0 + b_1 \ln(pop_i) + b_2 \ln(inc_i) + b_3\, DBTP_i + b_4 \ln(corp_i) + b_5 \ln(rec_i) + b_6 \ln(cult_i) + b_7 b_i + e_i.$$

where e_i is statistical noise.

Since the model is diagonally recursive (only one of the equations includes both endogenous variables and it is assumed that there are no cross equation correlations), each equation of the model can be estimated separately.[4] The equation predicting the viability of the hub was estimated using the Probit maximum likelihood method. The traffic equation was estimated by ordinary least squares.

Estimates from Revenue Passenger Enplanements Equation

Parameter	Estimate	t-statistic
Constant	16.6	118.0
pop	0.545	5.13
inc	1.15	2.73
DBTP	0.914	5.53
corp	-0.0131	-1.46
rec	0.00101	1.71
cult	0.00107	0.922
hub	0.795	4.98

R-squared = 0.850.
Fstatistic = 86.3.
SOURCE: Author.

TABLE 2

III. Results

Results from estimating the above model are presented in tables **1** and 2. Table **1** presents the parameter estimates from the equation that predicts the viability of a hub in any given city. The overall prediction power of the model is quite good. The point estimates of the parameters all have the expected signs except for the coefficient on per-capita income, though the level of statistical significance is very weak. The high correlation among most of the demographic variables suggests that multicollinearity is a problem and that the standard errors are inflated leading to lower *t*-statistics. Even with this problem, estimates from this equation do correctly predict whether or not a city will be a hub **87** percent of the time.

A city is more likely to become a hub as its population, lodging receipts (DBTP), or number of S&P **500** corporations increase, or as its ranking for recreation or culture improves. Business travelers (being more time-sensitive and less price-sensitive) should be more important to an airline than tourist travelers in the location of hubs, so that the number of S&P **500** corporations should be more important than either recreation or culture. One-tailed tests conducted at the **90** percent confidence level indicate that increasing a city's population and number of S&P **500** corporations, and improving the cultural ranking, all have nonnegative effects on the viability of a hub for a given city, other things being equal. It would have been reasonable to expect that increases in per-capita income would also increase the viability of the hub, but higher per-capita incomes reduce the likelihood of a city being a hub, although this result is not statistically significant.

The results from the estimation of the traffic equation are presented in table **2.** Most of the parameter estimates are statistically significant in this equation. All the estimates have the expected sign, except the coefficient on the number of S&P **500** corporations, although it is not statistically significant.

Given the construction of the model, some of these parameters can be interpreted as elasticities. For example, a one percent

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[4] The results reported here are not sensitive to the assumption of no cross equation correlations.

Outlier Cities

Likely, but do not have a hub	Unlikely, but do have a hub
Cleveland	Raleigh
San Diego	Syracuse
New Orleans	Orlando
Phoenix	Nashville
Tampa	Kansas City

SOURCE: Author.

TABLE 3

increase in a city's population would lead to a 0.55 percent increase in revenue passenger enplanements, while a one percent increase in a city's per capita income would lead to a 1.15 percent increase in revenue passenger enplanements. The coefficient of lodging receipts (DBTP) can be interpreted as follows. From these estimates, it can be calculated that cities classified as business/tourist centers have roughly *2.49* times the traffic that other cities have.

The coefficient for the hub variable has a similar interpretation, given its construction. If two cities are identical, except that one has a hub and the other does not, then the city with the hub can be expected to have over 2.19 times more revenue passenger enplanements than the other city. For example, Cleveland and Pittsburgh have very similar demographic characteristics, yet as a result of USAir's hub, Pittsburgh has about *2.3* times the revenue passenger enplanements that Cleveland has. It was noted earlier that passengers making connections in Pittsburgh account for most of this difference because only 25 percent of the passengers who use Cleveland's airport are there making connections, whereas over 60 percent of the passengers at Pittsburgh's airport are there making connections. Clearly, the creation of a hub greatly increases the activity occurring at an airport.

Table *3* presents two lists of outliers as a by-product of the estimation process. The first list is of cities that the model predicts should be hubs, but are not. The second list is of cities that the model predicts should not be hubs, but are. It is likely that San Diego, Phoenix, and Tampa would not be outliers if a location variable were included in the model, since these cities lie in the southwest and southeast corners of the country (see figure 1). Cleveland and New Orleans, on the other hand, appear to be more likely candidates for future hubs. Other midwest cities to watch are Indianapolis and Columbus.

Two factors can explain why most cities made the second list: location and measurement problems with the hub variable. Although it is hard to develop an index for location, it is easy to get an intuitive feel for it. Both Kansas City and Nashville are situated near the center of the country, giving them an advantage over Phoenix or San Diego in the competition for hubs. The second factor involves the problem of deciding what constitutes hub service at a city. Clearly the activity going on in Chicago by both United Airlines and American Airlines is quantitatively different from what USAir is doing in Syracuse, yet in this study both cities are counted as hubs.

IV. Summary and Implications for the Future

This paper has explored the characteristics that influence hub location and the effect on airport traffic as a result of hub activity. The results indicate that population is the most important factor determining hub location. An increase in per-capita income leads to a larger proportional increase in revenue passenger enplanements, whereas an increase in population leads to a less than proportional increase. One of the most interesting findings was that the creation of a hub at a city leads to a more than doubling of revenue passenger enplanements generated at that city.

The framework developed here is implicitly long run: airlines, passengers, and airports are assumed to have fully adjusted to the new deregulated environment. Given the recent merger wave in the industry, this does not appear to be the case, and many changes are likely in the coming years. More cities will probably become hubs, as traffic cannot increase much further at some large airports that have almost reached their capacity limits using current technology.

The only question is where to hub, not whether to hub. As the airline industry evolves, it will be interesting to track what happens to the air service provided to the communities listed in table 3. Given the expected growth in future air travel, cities on the first list are more likely to receive hub service than cities on the second list are to lose hub service.

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