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INFLUENCE OF GEOGRAPHIC LOCATION AND LOCAL DEMAND ON THE ATTRACTIVENESS OF AIRPORTS TO TRANSFER TRAFFIC

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ABSTRACT

Passenger transfers have become a significant market for mid-sized and large airports. At some airports, more than half of the total passenger enplanements and deplanements is comprised of connecting passengers. Eyeing that market, many airports attempt to develop and market themselves as hubs, in an attempt to attract transfer passengers. However, their ability to do so will depend on many factors. In a large competitive market, most of these factors will be driven by two main variables: the geographic location of the airport with respect to the market it is serving; and the level of local demand, i.e. the passengers who are either starting or ending the air portion of their trips at the airport. In this paper, we use regression analysis to evaluate the influence that these two variables have on the observed level of transfer traffic at airports. Data from more than 400 U.S. airports was used. The U.S. market was chosen for this analysis because of its high competitiveness and data availability. It is shown that a large portion of the variation in transfer traffic can be explained by the variation in the geographic location and local demand. This work provides invaluable insight for airport operators and planners when designing their facilities and marketing their product.

INTRODUCTION

Airports are conceived primarily to facilitate the provision of air services to their surrounding communities. As such, several issues related to their location, their integration with the ground transportation system, and the urban fabric in which they are inserted are of prime importance to airport planning. However, since it is impossible to have non-stop, point-to-point

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routes between each pair of airports on the network, many airports end up serving another purpose that is not related to the local community: to provide a point of connection between flights, so that passengers can fly to a destination that is not connected to their origin by a non-stop flight. For some airports, this connectivity function has become so important that they simply transfer substantial portions of passengers between flights, without passengers ever leaving the terminal. . Such airports are known as hubs. Table 1 shows the proportion of transfer passengers with respect to total passenger volume at some hub airports in the United States.

Table 1: Transfer rates for select U.S. airports, 2005

Airport	**Ratio transfers/ enplanements (2005)**
Charlotte	75%
Cincinatti	75%
Memphis	69%
Atlanta	66%
Houston/Bush	60%
Dallas/Fort Worth	60%
Salt Lake City	57%
Minneapolis/St. Paul	56%
Chicago/O'hare	55%
Detroit	55%
Denver	51%
Washington/Dulles	45%
Phoenix	43%
Miami	41%
Philadelphia	37%
Houston/Hobby	35%
San Francisco	35%
Pittsburgh	33%
Saint Louis	32%
Cleveland	32%

The existing literature on the subject frequently discusses problems of airport hub location and network configuration. Many of these studies either take the perspective of the entire network or individually assess airports for factors such as their competitive position or connectivity. At the airport level, however, the interests of airport planners, regional governments, and commercial enterprises lie in effectively planning for airport layout, growth, upgrade, and expansion. The needs of an airport are dependent on their traffic pattern. For instance, hub airports need to accommodate transfer passengers and baggage, whereas airports with predominant local traffic – also known as originating/destinating (OD) passengers – have to pay more attention to passenger and baggage processing functions such as check-in, security checks, baggage screening and baggage claim. Even airside design and operations may be affected by this traffic pattern, as a large proportion of transfer traffic may increase the load on the runway and terminal airspace systems.

Transfer passenger traffic may be attracted to an airport either naturally or through incentives. In either case, transfer passenger traffic will be heavily dependent on connectivity, i.e. the number of destinations served as well as the frequency and capacity of the flights serving those destinations. As an airport's local demand grows and more flights are added to more destinations, its connectivity increases, thereby naturally attracting more transfer traffic. In addition to this intrinsic attractiveness, an airport operator may enter an agreement with one or more large airlines so that the airline(s) will concentrate their flight operations at the airport, further boosting its transfer passenger traffic. In either case, the ability to understand how traffic patterns are formed and thus predict the distribution between OD and transfer traffic allows one to evaluate the potentials of airports as hubs, assess locations for new airports, plan for expansion, and stimulate the growth of airports. This is of particular interest in developing markets that seek to start up passenger air travel, expand their airports and airline networks, and compete with other airports to become hubs. Competition to become key international hubs is particularly high in developing markets which are rapidly expanding and do not have entrenched, incumbent hubs. The Asia-Pacific rim is one region experiencing intense competition between airports to become major international air traffic hubs (de Wit et al, 2009). To become a hub is strategically important for logistics and also carries the benefits of high demand, such as increased revenue generated from the large volume of passengers and from airlines purchasing terminal space. Cities with airport hubs can also transform into tourist destinations (Lohmann et al, 2009). Understanding the factors that influence transfer traffic patterns is of interest not only to those who seek to establish hub airports (Lee and Yang, 2003) but also to forecast and effectively plan for future growth.

Studying transfer passenger traffic is important to airport managers and planners because the traffic pattern determines the layout and design of the airport. Transfer passengers want to change flights as quickly and painlessly as possible. During the wait between flights, they can make use of retail services: refreshments, gifts, entertainment, and business services such as internet, phones, and communications. Transfer passengers would have preferably already passed through security and checked in their luggage, which now has to be transferred onto their next plane instead of onto baggage claim carousals. For an airport that facilitates a large number of transfer passengers, priorities would include: placing departure and arrival gates in close proximity with one another, meeting the large requirements of behind the scenes operations for transferring baggage and replenishing aircrafts, and providing retail and business services for waiting transfer passengers. A more OD focused airport will prioritize passenger and luggage movement between airport gates and airport exit; such airports need a greater number of security queues, check-ins, baggage claims, taxis, transit, and parking Transfer passenger traffic also has the advantage of imposing a lower unit cost per passenger(?) to the airport; Fewer passenger and baggage processing facilities are required, without a proportional reduction in the airport's potential revenue generation.

The majority of evaluations of hub location have been from the framework of the entire network. Since the hub location problem was introduced in 1987 as a quadratic programming problem (O'Kelly, 1987), studies focused on reducing total transportation cost through mathematical formulations and solution procedures (Aykin, 1994, 1995a, 1995b, Campbell ,1996 and 1994). Proposed methods have included problem specific heuristics (Klincewicz, 1991), tabu search (Calik et al 2009, Skorin-Kapov and Skorin-Kapov, 1994), genetic algorithms (Abdinnour-Helm 1998, Topcuoglu 2005) and neural networks (Smith K.A. et al 1996). Other proposed objectives for determining hub location include hub covering and hub centers (Campbell, 1996), which once again uses the framework of the entire network. This paper, on the other hand, takes perspective of the airport.

Other studies ranked individual cities to hypothesize the development of an European hub (Berechman and de Wit, 1996). However, the aim of this study is to find a quantitative relationship for the extent that an airport is a hub. Perhaps the most closely related study in the literature is the work of Bania et al. (1992) that individually examined each city to find the relationship between various city characteristics, such as weather and average income, and the extent to which the city is a hub. The study concluded that hub location was most dependent on a city's population, distance to other cities, and whether or not the city was an 'international gateway'. However, since transfer traffic is so heavily dependent on connectivity, and connectivity develops from flights that are initially added to serve local demand, there seems to be enough evidence to hypothesise that the transfer passenger traffic is correlated to the OD passenger traffic – with this last parameter being actually dependent on geo-economic factors such as population, income and distance to other cities. Thus, in this study, we attempt to model and evaluate the influence of OD traffic volumes on transfer passenger traffic volumes. Other airport characteristics that may affect its attractiveness to transfer passengers, such as their location with respect to the market they serve, will also be included in the model.

METHODOLOGY

As discussed in the previous section, transfer passenger traffic can be influenced by incentives given by airports and local authorities to airlines. However, in an open, competitive market, these incentives tend to balance themselves out, with market forces driving the distribution of demand. Thus, to assess how OD passenger traffic and airport location affect transfer passenger traffic, it is important to use a market that is as close as possible to being open and competitive. In that sense, the U.S. airport market provides the best test bed for this experiment.

There are over 400 airports in the U.S. certified to handle scheduled passenger service operations. The vast majority of those airports are managed and operated by local governments, either directly through departments of aviation or indirectly through airport authorities. With few exceptions, each airport is a different business entity competing with all others. There are virtually no legal entry barriers to airlines in the market and, even with the recent wave of consolidation in the industry, competition is still very fierce, with no single airline holding a market share greater than 20%. The market size, with over 700 million annual passenger embarkations, provides sufficient statistical significance for this study. An evaluation of the impact of airport location is also made possible by the extension of the territory and the relatively uniform distribution of airports and demand throughout the country.

Another import factor is the availability of data for U.S. airport trafficData on airport passenger enplanements is available online through the Bureau of Transportation Statistics (BTS, 2007). Also available online through the BTS is a database containing the details of 10% of all domestic tickets sold in the U.S. Among other information, this database contains the true origin and destination airports for each trip. Using this information, the total OD passenger traffic for each airport can be estimated by multiplying the sum of all trips starting or terminating at the airport by 10. The transfer passenger traffic can then be calculated by subtracting the estimated OD demand from the total passenger enplanements.

The geographic location of the airport with respect to its market is included by calculating the sum of the great circle distances to all other airports in the market. The more centrally located an airport is with respect to the system, the lower its sum of distances. This calculation, however, does not account for the market sizes. Therefore, an additional measure of centrality was calculated by weighing the distances by market size – the OD traffic for all other airports.

Lastly, some airports are already used as hubs by the largest US airlines. Because the airlines will concentrate significant portions of their flights at these airports, these airports will attract even more passenger transfer traffic because………………………..

To account for this effect, a binary variable was created and was assigned a value of 1 if the airport serves as a hub for a large airline and zero otherwise.

Thus, we created a database for the 388 major U.S. airports listing, for each airport: the number of domestic OD passengers, the number of domestic transfers, international enplanements, sum of distances, weighted sum of distances, and an indicator for whether the airport is an already an airline hub.

The number of OD passengers reflects the local demand for air services, thus indirectly reflecting socio-economic attributes such as the population of the airport's catchment area and its average income. Data on the number of OD passengers is relatively easier to gather than on these other variables. We define domestic OD passengers as either passengers originating from a given city who are flying to domestic destinations or passengers flying from domestic locations with the final destination of the given city. Another reason for the choice of domestic OD passengers is that international OD passengers introduce problems of definition; passengers may be directly flying internationally, or connecting to or from an international flight to a domesticflight. We, however, did consider international enplanements as a measure of international connectivity.

We also included as independent variables the relative location of an airport with respect to other airports in the network and the number of international enplanements. These two factors are unaccounted for by domestic OD and are also inspired by the results of Barnia et al (1992). They discovered that two of the three main factors that determine hub location are relative distance and a binary value of whether the airport was an 'international gateway'. We use the sum of the distances to other airports as our measure of relative distance; International enplanements reflect international connectivity or the extent that an airport is an 'international gateway'. We also include a sum of distances weighted by the number of passengers flying between the cities because distances for popular flights are more important than rare or non-existent flights in determining the transfer potential,.

ANALYSIS

To find a model for the database of United States airports, a regression analysis was ran using the number of domestic transfers as the dependent variable and the others as the independent variables. Visual analysis of preliminary scatter plots ruled out the possibility of periodic models. To simultaneously test models based on roots, exponents, and logarithmic functions, linear regressions can be run on the natural logarithms of the variables. Thus, the natural logs of each of the variables were calculated for each city and added to the database.

The sum of distances and the weighted sum of distances are already very large values. To avoid extremely large natural logs, we first divide the original values by one million before taking the logarithm; mathematically, the coefficients calculated by regression analysis are unchanged.

We visually analyze plots of the variables and calculate linear regression statistics on combinations of linear variables and logarithmic variables. Models with low values of r-squared indicate poor fits; the variations in the independent variables account for only a small percentage of the variations in the dependent variable. Likewise, low F values that give high probabilities also signify weak relationships. The F-value must be significant enough that the hypothesis that the coefficients of the regression model are zero can be rejected. We remove cases with low r-squared values and low F-values to find the optimal model for predicting airport transfer traffic patterns.

The domestic transfer versus domestic OD passengers is plotted in Figure 1. It can be seen that the transfer traffic consistently grows with the OD traffic, but the variance begins to grow larger starting around 3 million OD passengers. In this region, the airports that are airline hubs lie on top of the non-hub airports. Likewise, one would intuitively expect that airports with airline hubs have more transfer passengers than airports without hubs. This suggests one model for airports with less than 3 million domestic OD passengers, and two models for airports with more than 3 million: one model for the development of airports as hubs and one model for airports that remain non-hubs. Tables 1-4 summarize the results. We removed the cases with low r^2 values which indicate poor models and F values that give high probabilities that the coefficients are zero.

To keep our model simple, we chose 3 million as the division; the smallest number of domestic OD passengers for a hub airport in our database is 3,435,750. Three million domestic OD passengers is thus a branching point or threshold that signals the end of the model that small airports follow and the beginning of the two possibilities for larger airports: hub or non-hub.

The best model for the traffic pattern of domestic transfers in all three cases is the linear model. However, the coefficients and the factors vary. Nonetheless, the number of OD passengers influences the number of transfer passengers in all three cases. Table 5 presents the regression results and statistics for each of the cases. The threshold is 3 million domestic OD passengers for the United States Market. Figure 1 illustrates the three different models.

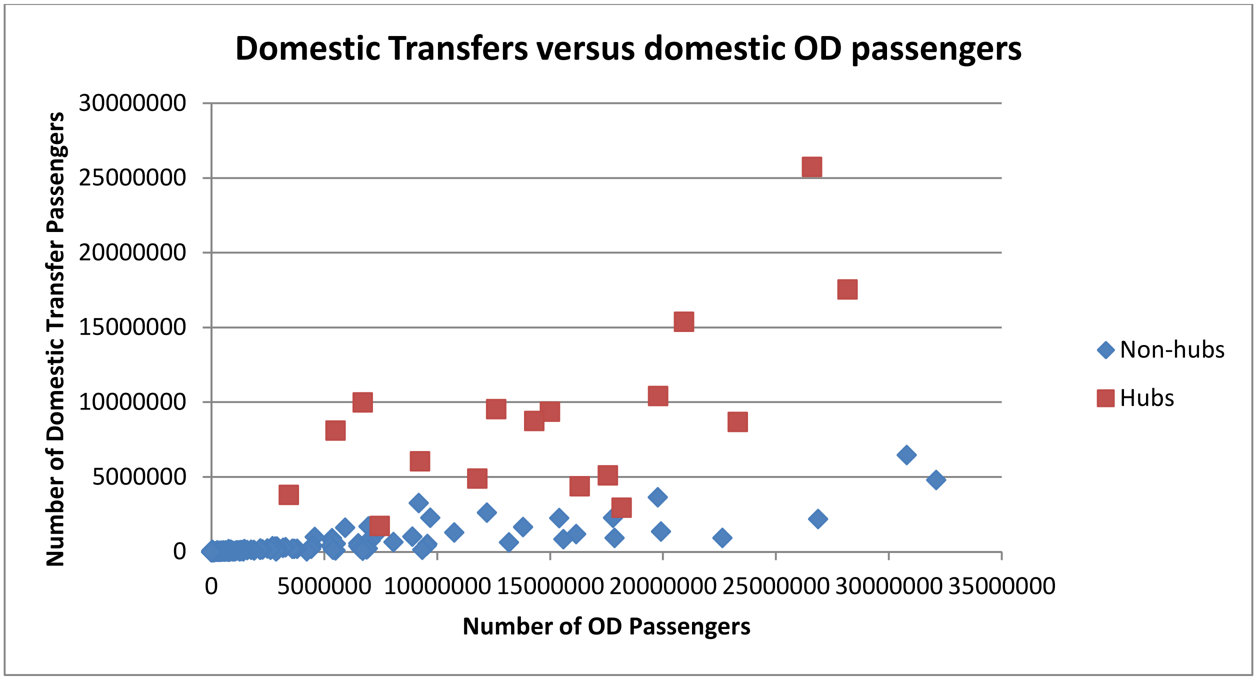

Figure 1 Number of domestic transfer passengers and OD passengers for U.S. airports and airline hubs

Table 2 Results of linear regression analysis on U.S. airport data using data for all airports.

Data range	**Dependent variable**	**Independent variables**	**r^2**	**F value**	**Probability**
All airports	Domestic transfer	OD passengers, sum of distance	0.521	209	0.000
	LN(Domestic transfer)	OD passengers	0.513	405	0.000
	LN(Domestic transfer)	LN(OD passengers))	0.662	754	0.000
	Domestic transfer	LN(OD passengers))	0.149	68	0.000
Non hubs	Domestic transfer	OD passengers, sum of distance	0.742	528	0.000
	LN(Domestic transfer)	OD passengers	0.413	258	0.000
	LN(Domestic transfer)	LN(OD passengers)	0.629	624	0.000
	Domestic transfer	LN(OD passengers))	0.291	93	0.000
Hubs	Domestic transfer	OD passengers, weighted sum of distance	0.635	12	0.001
	LN(Domestic transfer)	OD passengers, weighted sum of distance	0.514	7	0.006
	LN(Domestic transfer)	LN(OD passengers), LN(weighted sum of distance / 1E6)	0.252	5	0.04
	Domestic transfer	LN(OD passengers), LN(weighted sum of distance / 1E6)	0.570	9	0.003

Table 3 Results of linear regression analysis on U.S. airport data divided by airports with more than or less than 3000 domestic OD passengers.

Domestic OD passengers > 3000	Domestic transfer	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.493	335	0.000
	LN(Domestic transfer)	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.513	363	0.000
	LN(Domestic transfer)	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.797	467	0.000
	Domestic transfer	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.312	78	0.000
Non hubs with Domestic OD passengers > 3000	Domestic transfer	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.808	458	0.000
	LN(Domestic transfer)	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.412	230	0.000
	LN(Domestic transfer)	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.746	966	0.000
	Domestic transfer	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.359	184	0.000
Domestic OD passengers < 3000	Domestic transfer	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.020	0.25	0.865
	LN(Domestic transfer)	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.030	0.37	0.776
	LN(Domestic transfer)	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.051	0.65	0.590
	Domestic transfer	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.017	0.2	0.893

Table 4 Results of linear regression analysis on U.S. airport data divided by airports with greater than or less than 5000 total enplanements.

Total enplanements > 5000	Domestic transfer	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.546	135	0.000
	LN(Domestic transfer)	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.540	397	0.000
	LN(Domestic transfer)	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.758	531	0.000
	Domestic transfer	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.310	76	0.000
Total enplanements < 5000	Domestic transfer	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.016	0.22	0.881
	LN(Domestic transfer)	OD passengers, international enplanements, sum of distance, weighted sum of distance	0.189	10	0.003
	LN(Domestic transfer)	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.117	6	0.02
	Domestic transfer	LN(OD passengers), LN(international enplanements), LN(sum of distance / 1E6), LN(weighted sum of distance / 1E6)	0.014	0.2	0.899

Table 5 Results of linear regression analysis on U.S. airport data divided by airports with more than or less than 3 million domestic OD passengers.

Domestic OD passengers greater > 3 million	Domestic transfer	OD passengers, sum of distance	0.478	28	0.000
	LN(Domestic transfer)	OD passengers, sum of distance	0.604	47	0.000
	LN(Domestic transfer)	LN(OD passengers), LN(sum of distance / 1E6)	0.661	60	0.000
	Domestic transfer	LN(OD passengers) LN(sum of distance / 1E6)	0.447	25	0.000
Domestic OD passengers > 3 million and not-hubs	Domestic transfer	OD passengers, sum of distance	0.631	38	0.000
	LN(Domestic transfer)	OD passengers, sum of distance	0.604	34	0.000
	LN(Domestic transfer)	LN(OD passengers), LN(sum of distance / 1E6)	0.680	48	0.000
	Domestic transfer	LN(OD passengers), LN(sum of distance / 1E6)	0.541	26	0.000
Domestic OD passengers < 3 million	Domestic transfer	OD passengers	0.706	768	0.000
	LN(Domestic transfer)	OD passengers	0.436	248	0.000
	LN(Domestic transfer)	LN(OD passengers	0.457	269	0.000
	Domestic transfer	LN(OD passengers)	0.307	142	0.000

Table 6 Model of domestic transfers and the impact of OD passengers, international enplanements and relative location

Region	Formula	r-squared	F value	Probability
Airports with less than the threshold number of OD passengers	Transfers = 0.075 (OD)	0.706	768	0.000
Non-hub airports above the threshold	Transfers = 0.122 (OD) + 0.256 (int enplane) + (-3.979) (Sum dist)	0.754	45	0.000
Hub airports above the threshold	Transfers = 0.598(OD) + (-19.683)(Weighted sum of distances)	0.635	12	0.001

The traffic pattern of domestic transfers at a small airport follows the first model until the demand of the local market exceeds the minimum threshold of 3 million domestic OD passengers. Thereafter, and airport can follow one of two models depending on whether they attract an airline to make them a hub. Airports that stay as non-hubs follow the second model; airports that become hubs grow according to the third model. This suggests that once airports reach the OD passenger threshold, they can consider becoming a hub or a non-hub. Airports that do not have the demand follow the pre-threshold model.

Small airports

For small airports below the minimum threshold number of OD passengers, the number of domestic transfers depends on the number of OD passengers. Increasing the local demand for domestic flights and demand for the city as a destination by 1000 OD passengers increases the number of transfer passengers by 75. Looking at it from a different angle, if the demand grows by 1000 domestic OD passengers, the airport can anticipate needing facilities to accommodate 75 extra transfer passengers. Resources for expansion can also be split between origin-destination and transfer in a ratio of 1: 0.75.

This also suggests that airports hoping to develop into hubs can raise the number of transfer passengersby stimulating local demand and the demand for the city as a destination.

Large non-hub airports

Once an airport passes the threshold of the minimum number of OD passengers, the number of domestic transfers is also determined by the number of international enplanements and the relative location of the airport to other airports. The relationship between the number of transfers, domestic departures and arrivals, and international departures is 1: 0.122 : 0.256. While relative location is not a factor for small airports, it comes into play for larger airports.

Hub airports

The number of transfers at airline hubs is determined by the number of OD passengers and their relative locations weighted by the passenger flow between the hub and other cities. A gain in two OD passengers correlates with an increase of one transfer passenger; Of all three cases, OD passengers have the largest role in determining transfers at airline hubs.

CONCLUSION

The results of the analysis support our hypothesis that the traffic pattern of the number of domestic transfer passengers at an airport is influenced by the number of domestic OD passengers. This relationship explains the transfer traffic pattern at small airports with less than a minimum threshold number of OD passengers, which is approximately 3 million for airports in the United States. Above this threshold, airports follow one model if they are hubs, and another if they remain non-hubs. For non-hub airports above this threshold, another factor of transfer traffic is the number of international enplanements, which is an indicator of international connectivity, and the relative distance of the airport city to other cities in the network, expressed as a sum of distances. Airports that act as hubs experience the largest relationship between transfers and OD passengers, while the sum of distance weighted by the passenger flow between the cities also plays a role.

Our results are consistent with the findings of Bania et al (1992); They found that the locations of airport hubs are most dependent on population size, relative distance, and whether an airport is an international gateway. In our study, the number of domestic OD passengers reflects the size of the population, the sum of distances is a measure of relative distance, and the number of international enplanements indicates the extent to which the airport is an international gateway. . Airport hubs can be defined as airports with high volumes of transfer traffic and Our versions of these variables account for about 70% of the transfer traffic at airports;

We used the United States market for our analysis because it is an established hub-and-spoke passenger airline network with readily available data. Future studies can apply the model presented here to other markets. One can investigate the thresholds of other markets and the factors that determine the threshold. While the number of OD passengers takes into account population, affluence, socio-demographic measures, and tourism, one can compare our results with directly using the individual values in regression analysis. One can also use another measure for international connectivity, such as the number of international cities serviced by the airport, or the number of international flights, instead of the number of international enplanements. Likewise, while sum of distances served to measure relative location and distance, one can also calculate the distance for only those OD pairs with direct flights between them. We chose to study transfer traffic patterns because of its applicability to the location of hubs and the planning and competition of airports to become hubs. Another avenue of study is finding dependences for other traffic patterns such as domestic versus international flights or business versus tourist passengers.

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