Multiple Airport Systems in the United States: Current Status and Future Prospects

MARK HANSEN AND TARA WEIDNER

This study examines existing multiple airport systems (MASs) in the United States and assesses the prospects for new MASs in the future. Using FAA and other data, we identify 14 MAS regions in the United States, which account for 2.8 percent of all communities with commercial air service and 43 percent of total enplaned passengers. The 14 MASs divide into roughly five clusters, based on their market size, and the concentration of traffic within them. Twelve of the MAS regions are "hubs" as defined by the FAA, whereas the others are MASs because of exceptional circumstances. Analyzing the 11 "large" and "medium" hub MASs, we model concentration, as measured by the Herfindahl concentration index, and find that it decreases with regional origin and destination (O&D) traffic and increases with connecting traffic. Next we use a binary logit model to find determinants of MAS status. We find that the probability of a region being served by a MAS increases with the total traffic in the region, with some evidence that the probability decreases with the ratio of total enplanements to O&D traffic. Using the two models and FAA forecasts for the year 2000, we find that 13 regions currently served by a single airport have a significant MAS probability, and that about half of these are likely to be fairly unconcentrated MASs. We conclude that the U.S. air transport system has reached the point in which MASs could become increasingly common, and in which airports could, therefore, become a competitive industry in many regions.

Many of the world's larger urban areas are served by more than one commercial airport. Such multiple airport systems (MASs) offer several advantages over single airport systems (SASs). Access costs are reduced, since travelers can choose the airport closest to their true origin or final destination. This is not only more convenient, but also reduces social costs of vehicle travel, such as congestion and emissions. In addition, airports in a MAS will, *ceteris paribus*, be smaller than a single airport serving the same region. This implies reduced walking times, less costly parking facilities, and a less formidable wayfinding challenge for airport users. In short, when a region is served by a MAS, the cost and inconvenience of getting to the airport, and of getting through the airport, are reduced.

More generally, a MAS offers the possibility for increased consumer choice and competition in the supply of airport services. As Garrison and Gifford (*1*) point out, airline deregulation has given passengers more choice with regard to airlines and service classes, but commercial airports continue to operate as state-run monopolies in most areas. The lack of airport choice, combined with the high level of standardization among the products of most airlines, sharply limit opportunities for air travelers to make choices and thereby reveal their service preferences. The mere existence of alternative airports ensures somewhat greater consumer choice. If the airports actively compete to provide the most attractive amenities and services, consumers may benefit still further. Finally, airport competition might allow less government interference in airport pricing and investment decisions. Creager (*2*) argues that such airport deregulation is the natural counterpart of airline deregulation.

Despite these advantages, MAS development is opposed by a number of factors. Travelers value service frequency, which is obviously maximized when all flights leave from a single airport. There are also certain fixed station costs that encourage airlines to serve only one airport in a region. Indivisibilities associated with other airport assets—runways, control towers, and so forth—may exert a similar influence. A third consideration favoring a SAS is the economies of hubbing, which depend on being able to fly passengers in and out of a single hub airport. Finally, there are political and institutional barriers to the transition from a SAS to a MAS. These include resistance from incumbent airlines, political opposition to building a new airport, and risk averseness on the part of airport financiers.

This report argues that, the above factors notwithstanding, conditions are ripe for a period of MAS development in the United States. We begin by inventorying existing MASs in the continental United States (Section 1). Next, in Section 2, we analyze the concentration of passenger traffic in MASs, an indication of whether they are truly competitive. In Section 3, we consider the factors that determine whether an urban region is served by a MAS or a SAS. Then, in Section 4, we assess the potential of existing SASs to become MASs. Section 5 offers conclusions.

1. MULTIPLE AIRPORT SYSTEMS: AN INVENTORY

This section identifies urban regions served by a MAS (MAS regions) in the continental United States. The identification of these regions involves a two-step process. Initially we identify regions with more than one commercial airport in the classification structure defined by the FAA (*3*). However, this list omits certain MAS regions, while including others that, while nominally served by a MAS, have one airport that is so dominant that for all intents and purposes it is a SAS. Therefore, we adjust the FAA list by consolidating regions into MASs, and redesignating certain highly concentrated MASs as SASs.

Table 1 shows the 13 MASs recognized by the FAA in 1991 (3). This list includes all urban regions (termed "Communities" by the FAA) served by two or more airports with scheduled commercial air passenger service. We exclude cases in which the secondary airports provide only air cargo, nonscheduled passenger, or general aviation service, as well as regions located outside the continental United States.

Air Transportation Research Center, Institute of Transportation Studies, University of California, Berkeley, Calif. 94720.

TABLE 1 MAS Airport Set Development

Region	FAA Airport Set	CMSA/MSA Additional Airports	Enplanement Concentration Index	MAS
Chicago, IL	ORD, MDW, CGX		0.818	X
New York City, NY	LGA, JFK	EWR, ISP, SWF, HPN	0.313	X
Los Angeles, CA	LAX, SNA, BUR, LGB	ONT, PSP, OXR, PMD	0.499	X
Dallas/Ft. Worth, TX	DFW, DAL		0.804	X
San Francisco, CA	SFO, OAK, CCR	SJC, STS	0.529	X
Washington, DC	DCA, IAD	BWI (1)	0.346	X
Miami, FL	MIA, FLL		0.608	X
Houston, TX	IAH, HOU, EFD		0.561	X
Detroit, MI	DTW, DET		0.937	X
Santa Barbara, CA	SBA, SMX		0.929	X
Oshkosh/Appleton, WI	ATW, OSH		0.830	X
Seattle, WA	SEA, BFI		1.000	(2)
Tampa, FL	TPA, PIE		0.999	(2)
Philadelphia, PA	PHL	TTN	0.994	(2)
Cleveland, OH	CLE	CAK	0.907	X
Norfolk, VA	ORF	PHF	0.911	X
Pensacola, FL	PNS	VPS	0.717	X

(1) Within 48 km (30 miles) of DCA in Washington DC MSA, an FAA "large hub" community.

(2) Not considered MAS due to extremely high enplanement concentration.

Note: Index refers to Herfindahl index of airport concentration, the sum of the squared airport market shares of the given passenger activity type.

Sources: FAA Airports - FAA Airport Activity Statistics, 1991.
CMSA/MSA Boundary - U. S. Bureau of the Census, 1990.

The set of MAS regions defined by the FAA is not complete. Several major metropolitan areas are divided into multiple communities. To rectify this, the FAA definition was modified to allow consolidation of airports located within the same 1990 Metropolitan Statistical Areas (MSA) or Consolidated MSA (CMSA) (4). This action allowed for the consolidation of MASs in major metropolitan areas as well as introducing four new MAS regions. Table 1 identifies these changes.

Additionally, an analysis was made of airports near all FAA "large hub" communities. Baltimore-Washington International (BWI) Airport emerged as a special case based on its close proximity to the Washington, D.C. MSA airports (48 km, or 30 mi, from National Airport) and large traffic relative to these airports (27 percent of the combined total). Furthermore, these airports have been planned cooperatively for many years, and the Baltimore and Washington MSAs were in fact combined into a CMSA in 1991 (*4*). Consequently, as shown in Table 1, we consolidate BWI with National and Dulles Airports to form a MAS serving the Baltimore-Washington region.

A final review reveals that our set of MASs includes several in which a second airport handles a tiny amount of traffic relative to the primary airport. Because of this large gap in activity, these communities effectively function as single airport systems. The Herfindahl concentration index (HCI) was used as a measure of the degree to which passenger activity is concentrated at a single airport within the region. It is calculated as the sum of the squared traffic shares of each airport in the MAS. ("Traffic" can mean enplaned passengers or origin and destination (O&D) passengers. In identifying MASs with excessive concentrations, we use the former.) For a SAS, the HCI is 1.0. For a MAS where traffic is evenly divided among *N* airports, the HCI is 1/*N*. Within our set of MASs, the HCI ranges from 0.9998, for Seattle, where one airport is highly dominant, to 0.313 for New York. Three of the MASs—Seattle, Philadelphia (HCI = 0.999), and Tampa (HCI = 0.994)—have concentrations well above that for any of the others (the next highest is Santa Barbara, Calif., with an HCI of 0.929). These three MASs were therefore redesignated SASs for purposes of our analysis.

We summarize the above discussion by offering a proposed definition of a MAS. In general we define a MAS as two or more airports operating in a contiguous metropolitan area in such a way as to form an integrated airport system. This integration is largely evident in the airports' competition for local passengers. More precisely, we define a MAS as consisting of two or more airports with scheduled passenger enplanements, and which satisfy both of the following criteria:

- Each airport is included in the same community by the FAA(3) *or* within 50 km (30 mi) of the primary airport of an FAA-designated "large hub" community, *or* each airport is in the same MSA or CMSA (*4*);
- The Herfindahl concentration index for the airports is less than 0.95.

Table 2 identifies the 14 MASs within the continental United States, based on the above definition. Enplanement and O&D passenger statistics for the MASs and their constituent airports are also presented. Most MASs have high traffic levels, with the majority exceeding 10 million enplanements per year. However, there are also some small MASs, three with traffic levels under 0.5 million. The MAS consists of two airports in eight cases, three airports in

TABLE 2 Existing Multiple Airport Systems

Region and MAS Airports	FAA Hub	Airport Code	1991 Scheduled Enplanements		1991 Domestic O&D Enplanements	
			Total	Index	Total	Index
1 CHICAGO, IL	L		29,040,932	0.818	12,644,170	0.783
O'Hare International		ORD	26,098,065		11,078,080	
Chicago Midway		MDW	2,935,166		1,564,190	
Meigs Field		CGX	7,701		1,900	
2 NEW YORK CITY, NY	L		27,918,360	0.313	19,806,200	0.329
Newark		EWR	9,645,295		7,197,470	
La Guardia		LGA	9,121,466		7,998,160	
John F. Kennedy International		JFK	8,207,264		3,601,360	
Islip/Macarthur		ISP	410,150		452,000	
Newburgh		SWF	355,822		350,340	
White Plains		HPN	178,363		206,870	
3 LOS ANGELES, CA	L		26,276,420	0.499	20,113,310	0.327
Los Angeles International		LAX	18,069,981		12,101,410	
Ontario/San Bernadino/Riverside		ONT	2,831,551		2,729,010	
Orange County/John Wayne		SNA	2,544,596		2,450,970	
Hollywood-Burbank		BUR	1,821,400		1,803,720	
Long Beach		LGB	648,541		636,130	
Indio/Palm Springs		PSP	330,741		334,150	
Oxnard/Ventura		OXR	20,643		39,390	
Palmdale/Lancaster		PMD	8,967		18,530	
4 DALLAS/FT. WORTH, TX	L		25,416,828	0.804	9,286,950	0.635
Dallas/Ft. Worth International		DFW	22,625,338		7,052,420	
Love Field		DAL	2,791,490		2,234,530	
5 SAN FRANCISCO, CA	L		20,149,914	0.529	14,464,640	0.465
San Francisco International		SFO	14,007,424		9,130,230	
San Jose Municipal		SJC	3,148,622		2,404,100	
Metropolitan Oakland		OAK	2,953,058		2,853,090	
Santa Rosa/Sonoma County		STS	35,675		65,690	
Concord/Buchanan Field		CCR	5,135		11,530	
6 WASHINGTON, D.C.	L		15,548,897	0.346	10,643,900	0.394
Washington National		DCA	6,602,686		5,692,600	
Dulles International		IAD	4,706,395		2,452,140	
Baltimore, MD		BWI	4,239,816		2,499,160	

three cases, and five, six, and eight airports in the remaining three cases. Enplanement distributions in the MASs are fairly concentrated, with half having HCI values over 0.8, and only two with HCIs under 0.5—the value for a two-airport MAS with evenly divided traffic. The concentration is also evident in the fact that in eight of the MASs, the busiest airport has more than five times as many enplanements as the second busiest. In no case, moreover, does a MAS include more than four airports with an enplanement level more than 10 percent that of the busiest airport in the MAS.

The MAS regions are compared to the FAA "hub" communities and the U.S. system as a whole in Table 3. The 14 MAS communities account for 43 percent of all U.S. passenger activity, even though they represent less than 3 percent of the communities receiving scheduled air service. All but two of the MASs lie in FAA-defined "hub" communities—those with at least 0.5 percent of total U.S. enplanements. Indeed, 32 percent of the "large hub" communities, which together account for 56 percent of "large hub" enplanements, are served by a MAS. In addition, 7 percent of the "medium hub" communities and 2 percent of the "small hub" communities have MASs.

The 14 MAS regions are diverse. In order to understand the different types of MASs that have developed in the United States, these systems were classified. The classification is based on Figure 1, in which the HCI and traffic of each MAS is plotted. For comparison "large hub" and "medium hub" SASs, all with HCIs of 1.0, are also plotted. From this figure, five clusters of MASs are identified. These are characterized in Table 4.

Cluster 1, consisting of New York and Washington, D.C., is unique in its lack of a dominant airport. Enplanements are shared almost equally among three or more airports, as indicated by its low airport concentration indices ranging from 0.31 to 0.39. In contrast to the other MAS regions, these two exhibit more concentration in their O&D traffic than their total enplanements. This reflects the fact that hubbing activity has focused on airports that are somewhat less competitive for the local market—Newark in the case of New York and Dulles and BWI in the case of Washington. Congestion at one or more airports in the MAS limits the market share of any one facility.

Cluster 2 consists of five MAS regions, located in the South and West. These differ from the first group in that in each case one air-

TABLE 2 Existing Multiple Airport Systems (*continued*)

			1991 Scheduled Enplanements		1991 Domestic O&D Enplanements	
Region and MAS Airports	FAA Hub	Airport Code	Total	Index	Total	Index
7 MIAMI, FL	L		12,575,026	0.608	7,503,320	0.526
Miami International		MIA	9,212,517		4,609,900	
Ft. Lauderdale-Hollywood Int'l		FLL	3,362,509		2,893,420	
8 HOUSTON, TX	L		11,567,113	0.561	6,736,070	0.496
Houston Intercontinental		IAH	7,805,317		3,428,090	
W. Hobby		HOU	3,756,251		3,275,790	
Ellington Field		EFD	5,545		32,190	
9 DETROIT, MI	L		9,791,172	0.937	5,121,710	0.883
Wayne County		DTW	9,470,549		4,801,450	
Detroit City		DET	320,623		320,260	
10 CLEVELAND, OH	M		3,689,358	0.907	2,747,400	0.837
Hopkins International		CLE	3,508,196		2,502,300	
Akron/Canton		CAK	181,162		245,100	
11 NORFOLK, VA	M		1,222,110	0.911	1,196,100	0.837
Norfolk International		ORF	1,165,224		1,088,680	
Newport News/Patrick Henry Int'l		PHF	56,886		107,420	
12 PENSACOLA, FL	S		450,473	0.717	507,280	0.618
Pensacola Regional		PNS	373,688		376,770	
Ft. Walton Beach		VPS	76,785		130,510	
13 SANTA BARBARA, CA	---		207,892	0.929	263,890	0.798
Santa Barbara		SBA	200,269		233,820	
Santa Maria Public		SMX	7,623		30,070	
14 OSHKOSH/APPLETON, WI	---		135,199	0.830	173,720	0.820
Outagamie County/Appleton		ATW	122,515		156,310	
Wittman Field/Oshkosh		OSH	12,684		17,410	

Note: Index refers to Herfindahl index of airport concentration, the sum of the squared airport market shares of the given passenger type.

Sources: Enplanements - T3/T100 Report, ONBOARD Database, ODProducts Inc., 1991.
O&D - USDOT 10% Sample, Outbound Passengers, ODPLUS Database, ODProducts Inc., 1991.

port clearly dominates, resulting in a higher HCI, ranging from 0.50 to 0.61. However, secondary airports play a significant role in these MASs since the concentration indices are low compared to Clusters 3, 4, and 5. Indeed, the O&D traffic HCI for Los Angeles is very low, indicating the inability of any one airport to dominate the local market in such a far-flung urban landscape. Houston, although considerably smaller, is subject to much the same phenomenon. Although this group also contains higher density areas such as San Francisco and Miami, both of these have geographical features that encourage the dispersal of airport activity. In the case of the former, San Francisco Bay results in longer travel distances than the population density suggests, whereas the Miami region's location on a narrow coastal plain, and resulting elongated form, has a similar effect. As in the first cluster, airport capacity limitations may also reduce the concentration of enplanements.

The MAS regions in the third cluster, Dallas and Chicago, are distinguished by their role as major transfer points as the result of hub-and-spoke operations by air carriers. Because of the natural tendency for transfer activity to concentrate at a single airport, the enplanement HCI is higher: 0.64 to 0.82. The large number of transfer passengers at the primary airport results in a high service frequency which serves to attract most of the local traffic. However, the secondary airport in these regions is well located and attracts a reasonable share of the local passenger demand, decreasing the O&D HCI. These MASs are also subject to congestion, exacerbated by the traffic peaking due to connecting complex operations.

The fourth MAS cluster features a lower total enplanement level than the first three. The MASs in this group are also considerably more concentrated, with enplanement HCIs ranging from 0.91 to 0.94. All of these MASs consist of only two airports, with the dominant airport handling over 95 percent of the total passenger activity. This domination may be the result of the lower demand levels, higher densities, or less severe congestion problems.

The fifth and final cluster consists of MAS regions with very low traffic. These MASs are somewhat less concentrated than the fourth group, with enplanement HCIs ranging from 0.62 to 0.93. Two of the three result from unusual circumstances. Pensacola is dominated by military activity which has encouraged ancillary passenger service to develop at a second airport. Likewise, Appleton is the site of an airfield used by experimental aircraft. The Santa Barbara/Santa Maria MAS appears to be the result of these two formerly distinct regions growing together.

2. DETERMINANTS OF MAS CONCENTRATION

In this and the next section, we turn to statistical analysis of MASs in the United States. In this section, we analyze MAS concentration levels, whereas in Section 3 we investigate the determinants of MAS status.

TABLE 3 Comparative Activity Statistics

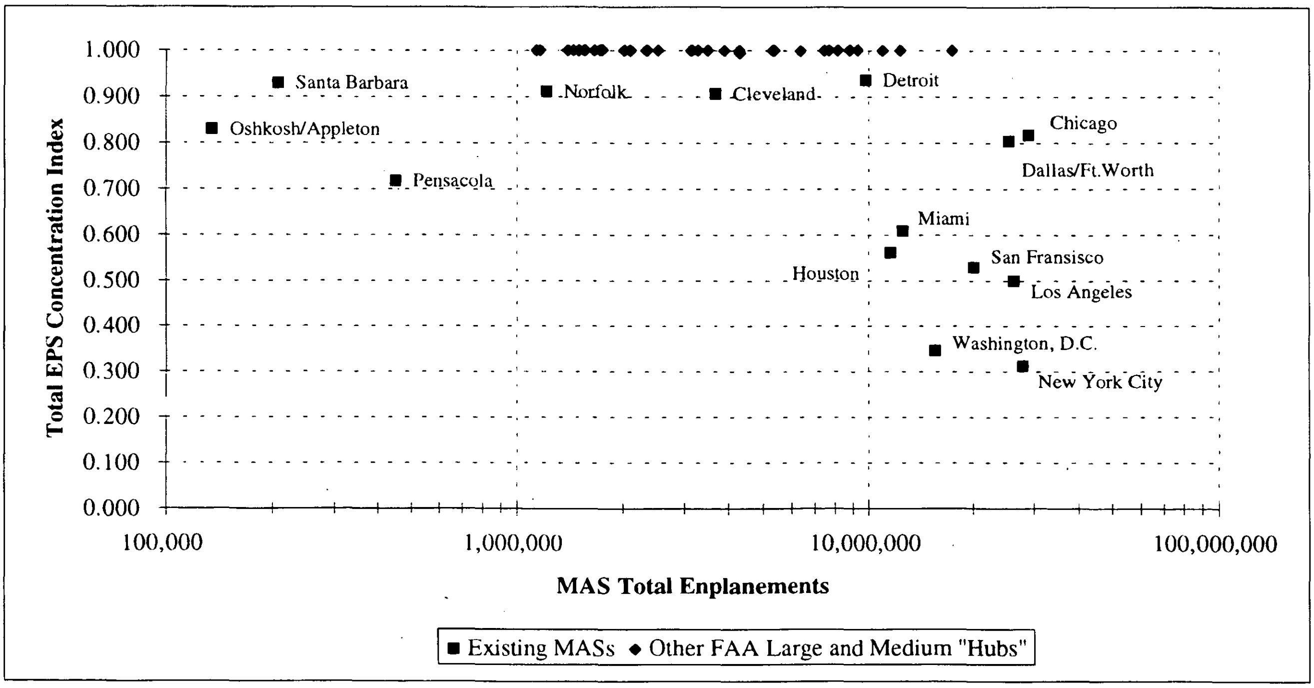
MASs as Percentage of:	Number of Communities	1991 Enplanements Total	Domestic	International	1991 Domestic O&D
Large Hub Communities	32.14%	56.39%	55.27%	75.23%	59.31%
Medium Hub Communities	7.41%	7.85%	7.91%	4.24%	7.93%
Small Hub Communities	1.82%	1.50%	1.54%	0.00%	2.03%
Non-Hub Communities	0.52%	2.06%	2.06%	0.00%	2.39%
Total Hub Airports	12.73%	45.00%	43.83%	68.36%	44.10%
Total All Airports	2.83%	43.24%	42.04%	68.26%	41.18%

Note: The definition of Multiple Airport System (MAS) communities consolidates several FAA "hub" communities.

We have already given considerable attention to the MAS concentration, as measured by the HCI. The concentration is important for several reasons. Since a SAS, by definition, has an HCI of 1, the HCI of a MAS measures how different it is from a SAS. The advantages and disadvantages of a MAS as compared with a SAS become more significant as the MAS concentration decreases. In a highly concentrated MAS, passengers from throughout the MAS region will use the primary airport, resulting in ground access costs comparable to a SAS. Likewise the primary airport of a highly concentrated MAS will be virtually as large as it would be in the case of a SAS. Also, for many destinations, the primary airport of a concentrated MAS is likely to be the only realistic alternative, depriving many or most air travelers of the choice that we have argued is one of the main benefits of a MAS. Finally, because a highly concentrated MAS is not very competitive, for most policy purposes it must be regulated as a monopoly. The potential gains from airport deregulation are therefore lost.

Having established that MAS concentration is important, we consider what factors may affect this variable. At a micro level, these factors will include anything that affects the distribution of traffic among MAS airports. These include a host of airport attributes, such as location and accessibility, capacity, use restrictions, traveler and travel agent awareness, and so on. These factors influence travelers' airport choices directly, and also indirectly through their effect on airline service supply decisions (*5*). Thus a complete representation of the processes determining MAS concentration would require a highly detailed analysis. There has been considerable work at this level (*6–9*), and more is ongoing, but here we want to paint with a broader brush.

At the macro level, we hypothesize that the level of concentration in a MAS is affected by three factors. First, as local (or O&D) traffic increases, we expect concentration to decrease. More local traffic will result in more markets in which nonstop service can be supported from more than one airport. Since service quality gains from flight frequency are diminishing, high local demand results in a reduced frequency advantage for the primary airport. Also, the stronger the local traffic base, the more willing airlines will be to serve more than one airport in the region. Finally, the larger the pri-



Note: Index refers to Herfindahl index of airport concentration, the sum of the squared airport market share values of the given passenger activity type.

FIGURE 1 Total enplanements vs airport concentration

TABLE 4 Multiple Airport System Community Characteristics

		Passenger Activity (millions)				Land Area	Airport Capacity	
	Number of	1991 EPS		1991 Dom. O&D		1984	FAA Delays (1)	
	Airports	Total	Index	Total	Index	Area (sqkm)	1990	2000
CLUSTER 1								
New York City, NY	6	27.918	0.313	19.806	0.329	19,834	X	X
Washington, D.C.	3	15.549	0.346	10.644	0.394	17,032	X	X
CLUSTER 2								
Los Angeles, CA	8	26.276	0.499	20.113	0.327	88,081	X	X
San Francisco, CA	5	20.150	0.529	14.465	0.465	19,174	X	X
Miami, FL	2	12.575	0.608	7.503	0.526	8,200	X	X
Houston, TX	3	11.567	0.561	6.736	0.496	18,521	X	X
CLUSTER 3								
Chicago, IL	3	29.041	0.818	12.644	0.783	14,659	X	X
Dallas/Ft. Worth, TX	2	25.417	0.804	9.287	0.635	18,122	X	X
CLUSTER 4								
Detroit, MI	2	9.791	0.937	5.122	0.883	13,481	X	X
Cleveland, OH	2	3.689	0.907	2.747	0.837	7,563		X
Norfolk, VA	2	1.222	0.911	1.196	0.837	4,447		
CLUSTER 5								
Pensacola, FL	2	0.450	0.717	0.507	0.618	4,362		
Santa Barbara, CA	2	0.208	0.929	0.264	0.798	7,117		
Oshkosh/Appleton, WI	2	0.135	0.830	0.174	0.820	3,670		

Sources:

Passenger Activity - ODPlus (T3/T100) and ONBOARD (10% Ticket Survey) databases, ODProducts, Inc., 1991.
Index refers to Herfindahl index of airport concentration, the sum of the squared airport market share values of the given passenger activity type.
Land Area - U.S. Bureau of the Census for CMSA/MSA.
Delays - MAS contains airports to exceed 20,000 hours of delay in given year, Aviation System Capacity Plan, FAA, 1991/1992.

mary airport in the region gets, the more it is subject to diseconomies of scale such as longer walking distances or the need to build expensive parking structures.

Second, as connecting traffic increases, we expect concentration to increase. An airline with a connecting hub in a MAS will naturally consolidate this operation at one airport, since it is prohibitively costly and inconvenient to transport connecting passengers between airports. For similar reasons, interline connecting traffic is likely to concentrate at a single airport. If more than one airline operates a hub in a MAS, the situation is somewhat more complicated, since the advantages of being able to offer interline connections by using the same airport must be weighed against the traffic capture and product differentiation benefits from operating hubs at different airports. In many cases, however, the latter is not an option, since only one airport in the region has the capacity to handle the traffic surges resulting from connecting complexes.

Third, as the land area of the MAS region increases, we expect concentration to decrease. When the land area is greater, ceteris paribus, each airport will have a larger "captive" market area for whom it is by far the closest alternative. This will attract both passengers seeking convenience and airlines seeking a protected market niche.

To test these hypotheses, we estimated models of MAS concentration. The models are of the form:

$$\ln\left(\frac{\mathrm{HCI}}{1-\mathrm{HCI}}\right) = \alpha + \beta \cdot \ln(\mathrm{ODPAX}) + 5 \cdot \ln(\mathrm{ENP}) + \lambda \cdot \ln(\mathrm{AREA}) + \varepsilon \qquad (1)$$

where

HCI = Herfindahl concentration index;
ODPAX = total MAS O&D passengers in the year 1991 (millions);
ENP = total MAS enplaned passengers in the year 1991 (millions);
AREA = land area of the region, in square miles;
ε = a stochastic error term;
α, β, δ, and λ = coefficients to be estimated.

The transformation of HCI in the above equation is used to convert a 0-1 variable to one whose range is $-\infty$ to $+\infty$. According to our hypotheses, β is negative, δ is positive (since an increase in ENP, controlling for PAX, implies an increase in connecting traffic), and λ is negative.

The model was estimated on the 11 MASs included in the first four clusters described above. The three MASs in the fifth cluster were excluded, since they are unusual cases whose behavior is unlikely to be captured by the same structural equation as the others. Also, data for these small MASs are suspect since reported O&D traffic exceeds reported enplanements, probably because the latter excludes commuter carriers. (We did estimate the model with all 14 MASs, obtaining similar coefficient estimates and significance levels, but with a slightly poorer fit.)

Estimation results appear in Table 5 which includes results for both the concentration of O&D traffic and enplanements. Both models have fairly good fits, with adjusted R^2 over 0.6. In both cases, the land area variable is statistically insignificant and of the wrong sign. This suggests that land area is a poor measure of the phenomenon it is intended to capture—the extent to which airports in the MAS have geographically protected market niches. The other variables have the expected signs. O&D traffic is statistically significant at the 5 percent level, whereas enplanements is significant at the 10 percent level (and, in three of the four models, almost significant at the 5 percent level). The O&D traffic coefficient has a larger magnitude than the enplanement coefficient. This is reasonable since an increase in O&D traffic implies an increase in enplanements, but according to the arguments above should nonetheless result in a net reduction in airport concentration. Finally, it is notable that connecting traffic is positively associated with O&D traffic as well as enplanement concentration. This implies that connecting traffic, itself tending to concentrate for reasons stated previously, pulls O&D traffic along with it.

3. DETERMINANTS OF MAS STATUS

Next we consider whether MAS status, like MAS concentration, can be explained at a macro level. Given a region, can we predict whether it is served by a MAS or a SAS? We already have some evidence on this question from Table 3, which shows a strong correlation between hub class and MAS status. Further evidence is obtained from categorizing "large" and "medium hubs" by enplanement level. Of the 51 regions (taking into account our consolidations) defined as "large" or "medium hubs" by the FAA (that is, with enplanements of 0.25 percent or more of the national total), all those with 20 million enplanements and 50 percent of the "hubs" with 10–20 million enplanements are MAS regions, whereas 90 percent with under 10 million enplanements are served by single airports.

In addition to total traffic, it is reasonable to suppose that other factors that affect MAS concentration also affect MAS status. Indeed, we have already argued that a SAS can be viewed as an extremely concentrated MAS. Therefore, in light of the findings from the last section, we expect regions with a higher proportion of O&D traffic to be more likely candidates for MAS status.

On the other hand, there is a qualitative difference between a SAS and even a highly concentrated MAS. In the latter case, a second commercial airport exists, and in the first it does not. The barriers to this transition (in either direction: opening a commercial airport, or closing it) are considerably higher than those to changing the distribution of activity among existing airports. Thus we expect that at any given time, the MAS status of a region will depend on past history as much or more than current conditions. This will introduce considerable noise into the analysis of a snapshot of the system at a given time.

Notwithstanding this problem, we used a binary choice model to analyze the MAS status of the 51 large and medium hub airports. The form of the model is:

$$P_i\,(MAS) = \frac{e^{\theta_k X_{ik}}}{1 + e^{\theta_k X_{ik}}} \tag{2}$$

where

P_i(MAS) = probability that region i is a MAS region;
X_{ik} = a vector of regional characteristics;
θ_k = a vector of coefficients to be estimated.

For the X_{ik} we tried various combinations of enplanements, O&D traffic, their ratios, and their logs. Estimation results for three of the better performing models are summarized in Table 6. The models have reasonable explanatory power, with ρ^2 (with respect of constants) approaching 0.5, and correct predictions for just over half of the MAS outcomes, and 90 percent of all outcomes. The models confirm the relationship between total traffic and MAS status already observed. They also lend some support to the hypothesis that MAS status is related to the O&D/connecting composition of traffic, although this effect is of marginal statistical significance.

TABLE 5 Estimation Results, Herfindahl Concentration Index Models

Independent Variable	Dependent Variable: O&D Traffic HCI (Transformed)		Dependent Variable: Enplanement HCI (Transformed)	
Constant	1.90	2.56	1.87	1.89
	(3.5)	(4.1)	(3.2)	(3.7)
ln(Enplanements)	2.12	1.94	1.57	1.57
	(2.4)	(2.2)	(2.0)	(2.2)
ln(O&D Traffic)	-3.75	-3.21	-2.63	-2.62
	(-3.2)	(-3.2)	(-2.6)	(-3.2)
ln(Land Area)	0.48	--	0.01	--
	(0.9)	--	(0.0)	--
R² (Adjusted)	.64	.65	.61	.66

Note: t-statistics in parentheses.
Land Area is in units of sqkm

TABLE 6 Estimation Results, MAS Status Model (Binary Logit)

Independent Variable	Model 1	Model 2	Model 3
Constant	-3.66	-0.93	-8.04
	(-4.1)	(-0.5)	(-2.1)
Total Enplanements (Millions)	0.27	0.41	0.38
	(3.2)	(2.6)	(2.6)
O&D Traffic/Total Enplanements	--	--	5.15
	--	--	(1.3)
Total Enplanements/O&D Traffic	--	-2.41	--
	--	(-1.5)	--
ρ^2 (zero)	0.56	0.62	0.59
ρ^2 (constants)	0.41	0.49	0.46
Log Likelihood	-15.59	-13.60	-14.36
No. Correct MAS Predictions	6/11	7/11	6/11
No. Correct SAS Predictions	39/40	40/40	39/40
Total Correct Predictions	45/51	47/51	45/51

Note: t-statistics in parentheses.

The latter is not surprising if one considers the data. In 1990, the nation had five regions with over 10 million enplanements and an enplanement/O&D ratio over 2—Chicago, Dallas, Denver, Atlanta, and St. Louis. Of these, the first two are MAS regions and the others are served by a SAS. All the regions with less than 10 million enplanements in 1990 and a enplanement/O&D ratio over 2 have SASs but so do most other regions with traffic below this threshold. Thus, although the evidence that connecting traffic affects MAS concentration is quite strong, it is far less definitive in the case of MAS status.

4. POTENTIAL MULTIPLE AIRPORT SYSTEMS

The models developed in Sections 2 and 3 were used to investigate the potential for additional multiple airport systems development over the next two decades. To do this, we calculated the MAS probability of each of the 40 "large" and "medium hubs" currently served by a single airport. We did this both for 1990 and, using the FAA forecasts (*10*) for the year 2000. For purposes of comparison, the probabilities were also calculated for existing MASs.

Figure 2 shows the 1990 and 2000 results for all existing MASs and those SASs with a nontrivial MAS probability. The 1990 results show that, among the existing MASs, Detroit, Cleveland, and Nor-

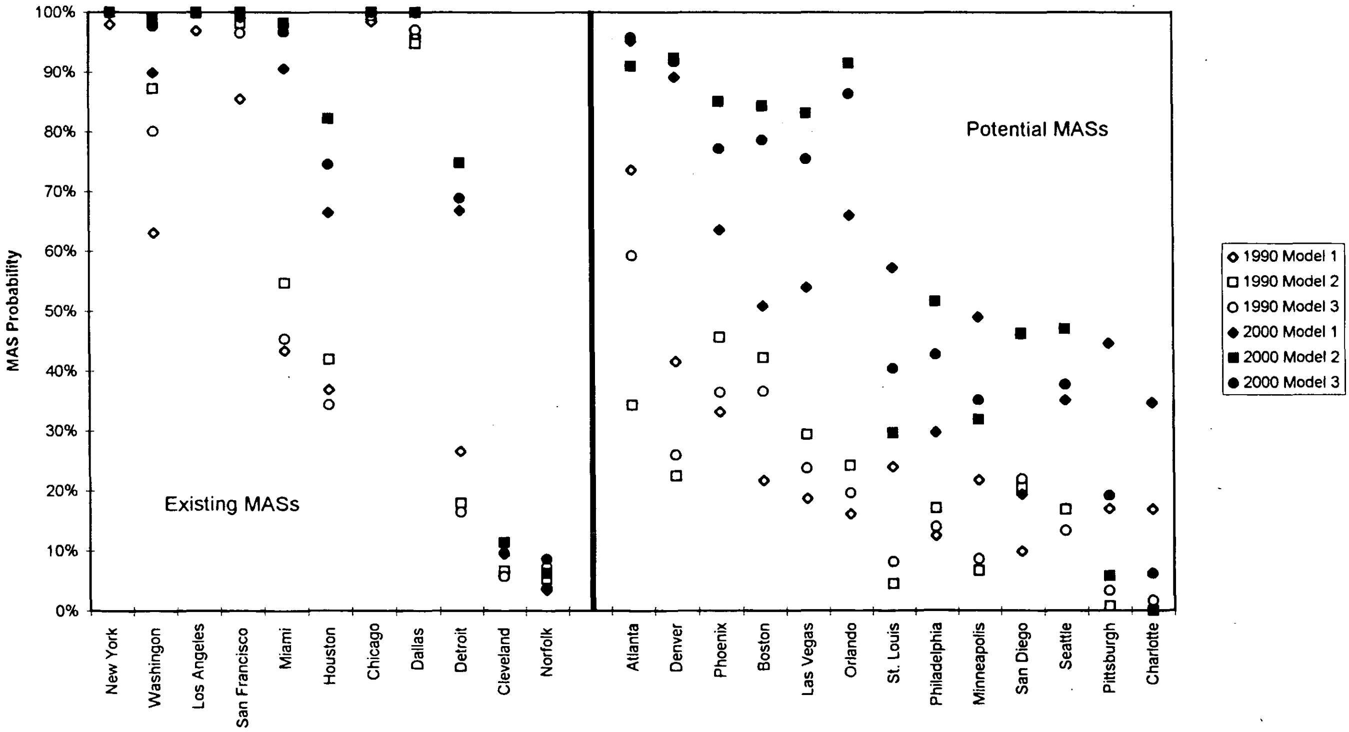


FIGURE 2 1990 and 2000 range of logit model predictions

folk are the least probable ones, based on their low traffic levels. These are all highly concentrated MASs. Both Cleveland and Norfolk are also cases in which the airports operate under separate local jurisdictions between which there is significant rivalry. This may help to explain why activity has not been consolidated at one airport in these regions. Among the SASs, Atlanta is the most likely candidate to be a MAS, based on 1990 data. Denver, Phoenix, Boston, and Las Vegas also have a fairly high MAS probability, although it is under 50 percent in all cases.

Figure 2 also shows MAS probability estimates for the year 2000, based on traffic growth projected by the FAA and assuming a ratio of enplanements to O&D traffic equal to that in 1990. The contrast with the 1990 results is striking. Six regions—Atlanta, Denver, Phoenix, Boston, Las Vegas, and Orlando—are forecast to realize traffic growth that would give them a MAS probability of over 50 percent based on two of the three models. Two others—St. Louis and Philadelphia—surpass the 50 percent threshold according to one of the models, whereas three other regions approach it. These results form the basis of the assertion made at the outset—conditions appear to be ripe for substantial increase in the number of multiple airport systems in the United States.

Figure 2 shows considerable variability in the MAS probabilities predicted by the different models. The major uncertainty behind this variability is whether the distribution of traffic between connecting and O&D passengers affects the probability of being a MAS. Regions with unusually high or low proportions of connecting traffic—St. Louis and Boston, for example—thus show the highest variability. Predictably, Model 1, which is based on enplanements only, yields the highest MAS probability for St. Louis, whereas the models that incorporate a connecting traffic effect yield the higher MAS probabilities for Boston.

Table 7 provides further indications of the potential for MAS development in the SAS regions included in Figure 2. It identifies those that are, or are forecast to be, subject to significant amounts of aircraft delay, and, using the concentration models discussed in Section 2, predicts what the enplanement and O&D traffic concentration levels would be if a MAS developed. (In applying the concentration models, we again assumed a ratio of enplanements to O&D traffic equal to that in 1990). With the exception of Las Vegas, airports in all these regions had significant amounts of aircraft delay in 1990. Consequently, additional capacity is likely to be needed. The predicted enplanement concentration gives an indication of how much traffic might be diverted from the existing airport if additional capacity were supplied in the form of a new airport (assuming the existing airport continued operating). Phoenix, Boston, Orlando, Las Vegas, Philadelphia, and San Diego have the lowest concentrations. In all of these cases, our model predicts a sizable (30 percent or more) diversion of enplanements from the existing airport under the MAS scenario. On the other hand, Atlanta, St. Louis, Minneapolis, Pittsburgh and Charlotte would be expected to have such a highly concentrated MAS that building an additional airport would hardly be worthwhile. Denver and Seattle are intermediate cases, in which MAS development would disperse traffic to some degree, although the primary airport would continue to be dominant. (Denver, of course, has elected to build a new airport but close the existing one.)

TABLE 7 Potential MAS Regions

Region	FAA Forecast Enplanements, 2000	Projected O&D Traffic, 2000	Over 20,000 Hours of Delay		Range of Predicted MAS Statust Probabilities		Predicted Concentration (HCI) if Region were MAS	
			1990	2000	Min 2000	Max 2000	EPS	O&D Traffic
Atlanta, GA	24.6	8.7	X	X	90.7%	95.6%	0.86	0.78
Denver, CO	21.4	9.6	X		88.5%	92.1%	0.77	0.68
Phoenix, AZ	15.6	10.1	X	X	62.4%	84.7%	0.62	0.54
Boston, MA	13.7	11.0	X	X	49.6%	84.0%	0.48	0.43
Las Vegas, NV	14.1	10.4		X	52.8%	82.7%	0.55	0.48
Orlando, FL	13.9	9.9	X	X	48.0%	78.3%	0.56	0.49
St. Louis, MO	14.6	5.9	X	X	29.4%	56.0%	0.89	0.81
Philadelphia, PA	10.4	7.7	X	X	29.0%	51.2%	0.64	0.56
Minneapolis/St. Paul, MN	13.4	6.1	X	X	31.6%	47.9%	0.86	0.78
San Diego, CA	8.3	7.6	X	X	19.0%	46.0%	0.54	0.47
Seattle, WA	11.3	7.1	X	X	34.2%	46.7%	0.72	0.63
Pittsburgh, PA	12.8	4.3	X	X	5.8%	43.6%	0.94	0.89
Charlotte, NC	11.2	2.3	X	X	0.0%	33.8%	0.99	0.97

Source: Forecast EPS - Terminal Area Forecasts, FAA, CY1993.
Delays - Aviation System Capacity Plan, FAA, 1991/1992.

The predicted O&D traffic concentration measures the extent to which passengers originating in each hypothetical MAS region would have a real choice among airports, and also the degree to which having multiple airports would reduce the private and social costs of ground access. It is consistently lower than the enplanement concentration, suggesting that a MAS can yield sizable consumer choice and ground access benefits even when the overall traffic remains highly concentrated.

5. CONCLUSIONS

Our results suggest that the potential exists for multiple airport systems to play a significantly expanded role in the U.S. commercial airport system. We have identified 13 SAS regions whose traffic growth and traffic composition make them potential candidates for MAS development. Of these, roughly half could benefit substantially from such development in terms of traffic diversion, consumer choice, and ground access cost. All of these regions have commercial airports that have or are expected to soon have significant aircraft delay. Serious consideration should be given to expanding airport capacity in these regions by adding a second airport.

Deciding whether to build a second airport is bound to be controversial. Political conflict appears in the present era to be an inevitable concomitant of any major addition to airport capacity. Savas (*11*) has observed that decisions involving urban systems frequently involve the search for a *single* politically feasible solution instead of choosing the best from a set of feasible alternatives. This clearly applies to airport planning. Our findings help establish the conditions under which a MAS may be viable, and thus when alternatives involving more than one airport can be added to the list of candidate solutions to be subjected to the political feasibility test. For example, it may be possible to build a more modest airport and keep the existing one operating instead of constructing a huge new airport and close the existing one, or avoid a major expansion of an existing airport in favor of adding capacity by means of a new airport. By no means will these MAS alternatives be the preferred ones in all situations, but in some cases they may allow capacity expansion to go forward when otherwise it would be politically infeasible.

If the near term benefit of MAS development is capacity expansion, in the long term there is also the potential of creating a competitive, entrepreneurial airport sector. In addition to permitting the obvious locational choices, this would encourage greater experimentation with services and prices, and thus increase the range of air travel options available to consumers. Put another way, airport deregulation is desirable for many of the same reasons that airline deregulation was. MASs, by curtailing the ability of airports to engage in monopolistic abuses, improve the prospects for such deregulation.

As Garrison and Gifford (*1*) point out, the air transportation system is in many respects mature, with highly standardized products and relatively little innovation. As air transport demand increases, the tendency is to respond by growth instead of development, by adding capacity to SASs instead of creating MASs. It is important to realize that this is not the only option, and that the MAS alternative could ultimately lead to a more innovative and dynamic air transportation system. We see an opportunity, and a challenge, in cultivating a competitive airport sector from monopolistic roots.

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REFERENCES

1. Garrison, W. L., and J. L. Gifford. Airports and the Air Transportation Systems: Functional Refinements and Functional Discovery. In *Technological Forecasting and Social Change*, Vol. 43, 1993, pp. 103–123.
2. Creager, S. Airline Deregulation and Airport Regulation. In *The Yale Law Journal*, Vol. 93, 1983, pp. 319–339.
3. *Airport Activity Statistics of Certificated Route Air Carriers, CY1991*. Series: FAA-APO-92. Federal Aviation Administration, Research & Special Programs Administration, 1992.
4. *Statistical Abstract of the United States*. U.S. Department of Congress, Bureau of the Census, 1990 and 1991.
5. Hansen, M., and Q. Du. *Modeling Multiple Airport Systems: A Positive Feedback Approach*. Research Report 93-12. Institute of Transportation Studies, University of California at Berkeley, 1993.
6. Gelerman, W., and R. De Neufville. Planning for Satellite Airports. In *Transportation Engineering Journal*, Vol. 3, 1973, pp. 537–551.
7. Harvey, G. Airport Choice in a Multiple Airport Region. In *Transportation Research*, Vol. 21, No. 6, 1987, pp. 439–449.
8. Innes, J. D., and D. Doucet. Effects of Access Distance and Level of Service on Airport Choice. In *Journal of Transportation Engineering*, Vol. 116, 1993, pp. 507–516.
9. *Multiple Airport Demand Allocation Model (MADAM) Calibration and Sensitivity Analysis*. National Capital Region Transportation Board, 1985.
10. *Terminal Area Forecasts FY 1993–2005*. Series: FAA-APO-93-9, U.S. Department of Transportation, FAA, Office of Aviation Policy, July 1993.
11. Savas, E.S. Systems Analysis and Urban Policy. In *Systems Analysis in Urban Policy-Making and Planning* (M. Batty and B. Hutchinson, eds.), Plenum Press, New York, 1983.

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