Accessibility in the Deregulated Domestic Airline Network

MAHMOUD GHAFOURI AND TENNY N. LAM

Airline service to a sample of 27 airport hubs in the contiguous 48 states randomly selected from 145 hubs classified as large, medium, and small in 1977 was compared between 1977 and 1984. The purpose is to determine changes in accessibility by air travel since deregulation. The empirical analysis indicates that accessibility had become significantly better in 1984 when compared to 1977, the year before deregulation.

Since the deregulation of U.S. airlines in 1978, the industry has become more efficient and competitive *(1)*. Total revenue passenger-miles increased by nearly 50 percent between 1976 and 1983 *(1)*. Between 1978 and 1983, scheduled carriers supplied 36 percent more seat-miles *(2)*. As service becomes better over some parts of the air transportation system, some communities have lost a significant amount of their air service or have to adjust to smaller aircrafts, smaller carriers, and less direct routing *(3, 4)*. However, it is generally agreed that changes in schedule convenience, price and service options, and total supply have been positive *(1–4)*.

Given the goals of deregulation, changes in the level of air service are expected to be nonuniform. This study is an attempt to look at the changes that have occurred at a sample of individual airport hubs. A hub is either a single airport or a group of airports serving the same community. Emphasis is placed on the larger hubs: hubs that are classified as large, medium, and small. Each of these hubs generates at least 0.05 percent of the annual national total number of enplaned passengers. Nonhubs, those generating less than 0.05 percent of the national traffic, are not considered here because they have been extensively studied *(1, 3–9)*.

The question to be asked is what changes, if any, have taken place in the accessibility of air travel at the sampled hubs. Accessibility is an indication of the ability to travel between points in a network by using the service available in the system. It is a measure of systemwide travel convenience. It may be indicated by the number of places connected by airline service and the number of different types of flights per week between places. In this study, both connectivity and the weekly frequencies at 27 randomly selected airport hubs are examined for March 1977 (before deregulation) and March 1984 (after deregulation). These comparisons can show only the changes that have taken place, bearing in mind that the changes might not necessarily be caused by deregulation alone. In addition, some statistics of airline supply for March 1985 are also presented to show a continuation of the trends at the medium and small hubs in the study sample.

One major change after deregulation has been the restructuring of the route system. Many airlines reorganized their route structure to improve operational efficiency, market penetration, and service quality. The present supply pattern of scheduled airline service reflects the desire of the airlines to optimize equipment and labor utilization. Other factors, such as entries and exits of operators, the air traffic restrictions imposed after the controllers' strike, and the fluctuations in fuel prices, have given added impetus to the design of route structures that are flexible and responsive to dynamic changes in the operational environment. Of particular interest from a traveler's viewpoint are the collective effects resulting from all the route changes made by each individual airline.

The structure of a transport net incorporates both the existence of links and the frequency of service on the links. In addition, connectivity in space and time is also important. A dominant feature of the rationalized domestic route network is the hub-and-spoke pattern *(10)*. Gone was much of the so-called direct service that meandered through small hubs and intermediate stops. The separation of feeder and line haul functions within a hub-and-spoke network also intensifies the specialization by carriers. These measures improve not only the accessibility in the network but also the economies of operation. With well-coordinated timed transfers at the hubs, added flight frequencies can be offered between more origins and destinations without additional equipment or crew. Ideally, few trips need more than two transfers, except between very remote places.

To the travelers, route structuring affects their convenience and accessibility. Other aspects of service quality, such as travel time, scheduling, and fare, are also important, but they will not be addressed here. By using a simulation technique, Bailey, Graham, and Kaplan integrated many of the route and schedule factors in their study *(11, 12)*. However, it is not unreasonable to assume that in general, more frequent service means more convenient scheduling and the type of flights (nonstop, direct, or connection) is indicative of the travel time. Only convenient connection flights are generally listed in the Official Airline Guide *(13)*, which is the data source here. Moreover, a criterion of a maximum of two transfers is also imposed here in the tabulation of the connected flights. Capacity and equipment are also important issues, but they are not dealt with in this study. It is assumed that under deregulation, airlines will meet passenger demand and preferences with adequate capacity and appropriate equipment whenever it is profitable to do so.

SAMPLE AND DATA

Twenty-seven hubs were selected from the 145 hubs in the 48 contiguous states and classified as large, medium, and small in 1977. The sampling was carried out by a stratified random

Department of Civil Engineering, University of California, Davis, Davis, Calif. 95616.

TABLE 1 HUBS SELECTED FOR THE STUDY

	Hub Size		
Region	Large	Medium	Small
East	BOS, Boston[a]	MEM, Memphis[a]	CAE, Columbia, S.C.[a]
	WAS, Washington, D.C.[b]	BDL, Hartford, Conn.[b]	BTV, Burlington, Vt.[b]
	ATL, Atlanta[b]	RDU, Raleigh, N.C.[b]	ALB, Albany, N.Y.[b]
Central	DTT, Detroit[a]	ABQ, Albuquerque[a]	FWA, Fort Wayne[a]
	STL, St. Louis[b]	CVG, Cincinnati[b]	SGF, Springfield, Mo.[b]
	HOU, Houston[b]	DSM, Des Moines[b]	LIT, Little Rock[b]
West	DEN, Denver[a]	SAN, San Diego[a]	BOI, Boise[a]
	SFO, San Francisco[a]	SLC, Salt Lake City[b]	GTF, Great Falls, Mont.[b]
	SEA, Seattle[b]	PDX, Portland, Oreg.[b]	SMF, Sacramento[b]

[a]Full sample of 145 origins.
[b]Random sample of 40 origins.

procedure. Three large, three medium, and three small hubs were randomly sampled from the hubs located in each of three geographical regions. The three regions cover the east, central, and west of the 48 states. The distribution of the hubs in the sample are given in Table 1, and their locations are shown in Figure 1 in which the solid circles represent hubs studied with all origins and the open circles represent hubs studied with a random sample of 40 origins. The size of the symbol indicates the size of the base hub. In 1983, there were only 110 large, medium, and small hubs in the 48 contiguous states. The hub size distributions are given in Table 2. Of the 27 hubs in the sample, there were six hub classification changes between 1977 and 1983. The changes are given as follows. The 1983 classification is cited here because it is the latest available.

TABLE 2 HUB SIZE DISTRIBUTIONS

Hub Size	1977	1983
Large	24	25
Medium	34	33
Small	87	52
Total	145	110

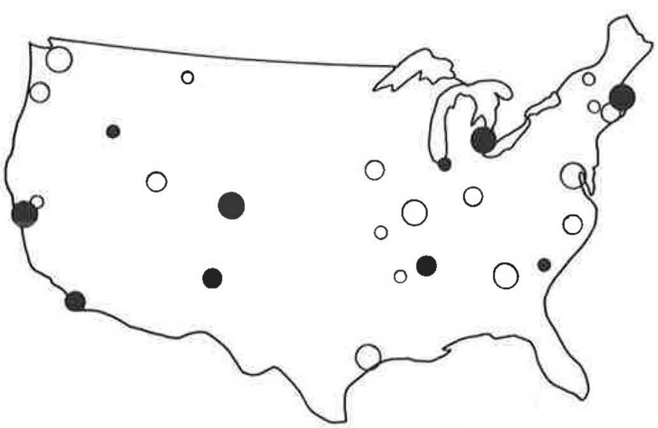

FIGURE 1 Geographical distribution of the base hubs in the study.

SAN, San Diego	M -> L
SLC, Salt Lake City	M -> L
SMF, Sacramento	S -> M
DSM, Des Moines	M -> S
SGF, Springfield, Mo.	S -> NH
GTF, Great Falls, Mont.	S -> NH

The sample represents approximately 37 percent of the large hubs, 26 percent of the medium hubs, and 10 percent of the small hubs. Of the 27 hubs in the sample, 10 were selected for a complete study, in which all the flights from the other 144 origin hubs to each of these base hubs were included in the analyses. A total of 1,440 city (hub) pairs are involved for these 10 base hubs. The remaining 17 base hubs in the sample were studied with respect to the service from a sample of 40 origin hubs randomly selected from the 144 in the population. Seventeen different samples of 40 were used for these 17 bases. This adds another 680 hub pairs to the study, for a total of 2,120 hub pairs. In the study by Bailey, Graham, and Kaplan *(11, 12)*, a sample of 200 markets (hub pairs) was used. For each hub pair, the weekly frequencies of nonstop, direct (same plane through service), and connection flights were tabulated from the Official Airline Guide *(13)* for March 1977 and March 1984, as well as March 1985 for three medium and three small base hubs in the sample. The data were then analyzed with respect to base hub size and region and with respect to origin hub size. Only the flights to the 27 selected bases (destinations) are analyzed.

SPATIAL ACCESSIBILITY

A well-connected transportation system offers travel opportunity to many places. Obviously, those places that generate and attract more travel will be better served. The average percentage of potential origin hubs in each hub size group that were connected to the base hubs in the sample by nonstop flights is given in Table 3. These are the basic links radiating from each base hub into the total network. Building on the nonstop links, the network is formed and the direct and connection flights are constituted. Across all groupings of base-origin hub sizes, the base hubs were connected by nonstop flights, on

TABLE 3 AVERAGE PERCENTAGE OF ORIGINS SERVING THE BASE WITHIN EACH ORIGIN/BASE HUB SIZE GROUPING

BASE HUB SIZE	ORIGIN HUB SIZE: LARGE(24) 1984	LARGE(24) 1977	MEDIUM(34) 1984	MEDIUM(34) 1977	SMALL(87) 1984	SMALL(87) 1977
NONSTOP SERVICE						
LARGE	89	84	50	37	16	12
MEDIUM	53	41	14	12	7	6
SMALL	18	16	7	7	3	3
DIRECT SERVICE						
LARGE	98	98	80	79	40	39
MEDIUM	80	77	44	39	17	12
SMALL	39	39	19	13	9	5

Note: Parentheses show number of flights involved.

average, to more origins in 1984 than in 1977. The largest increase was between large and medium hubs. Nonstop accessibility between hubs classified as medium and small was not significantly changed between 1984 and 1977. This was a continuation of the trend reported for 1981 in comparison with 1978 *(14)*.

The number of nonstop origin hubs deleted and added between 1977 and 1984 is tabulated in Table 4 for each of the 10 base hubs analyzed with a full sample of origin hubs. The data are separated for each origin hub size group. Also shown are the changes in weekly nonstop flight frequencies involved. Overall, there were more additions than deletions, both in terms

TABLE 4 ORIGIN HUBS DELETED AND ADDED TO NONSTOP SERVICE BETWEEN 1977 AND 1984

BASE HUB	ORIGIN: LARGE HUBS (24) DELETION	LARGE HUBS (24) ADDITION	MEDIUM HUBS(34) DELETION	MEDIUM HUBS(34) ADDITION	SMALL HUBS (87) DELETION	SMALL HUBS (87) ADDITION
LARGE BASE HUBS						
SFO	2 (19)	1 (14)	6 (62)	1 (7)	1 (3)	0 (0)
DEN	0 (0)	3 (109)	0 (0)	10 (136)	4 (35)	10 (136)
DTT	1 (20)	3 (82)	2 (14)	2 (47)	3 (21)	4 (57)
BOS	1 (7)	1 (20)	3 (27)	4 (65)	1 (13)	2 (25)
MEDIUM BASE HUBS						
SAN	1 (7)	4 (69)	1 (21)	2 (21)	1 (14)	0 (0)
ABQ	0 (0)	2 (34)	1 (7)	1 (14)	1 (7)	0 (0)
MEM	0 (0)	4 (68)	1 (14)	3 (46)	2 (14)	4 (42)
SMALL BASE HUBS						
BOI	1 (7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
FWA	0 (0)	1 (7)	1 (35)	2 (21)	0 (0)	1 (8)
CAE	2 (14)	0 (0)	0 (0)	2 (19)	0 (0)	1 (6)

Note: Parentheses show number of flights involved.

TABLE 5 DISTRIBUTION OF THE NUMBER OF BASE HUBS IN THE SAMPLE WITH SERVICE FROM VARYING ORIGINS BETWEEN 1977 AND 1984

BASE HUB SIZE	ORIGIN HUB SIZE: LARGE +	LARGE 0	LARGE -	MEDIUM +	MEDIUM 0	MEDIUM -	SMALL +	SMALL 0	SMALL -
NONSTOP SERVICE									
LARGE	5	2	2	5	3	1	6	1	2
MEDIUM	7	2	0	4	4	1	4	3	2
SMALL	3	3	3	2	7	0	4	4	1
DIRECT SERVICE									
LARGE	0	9	0	3	2	4	4	1	4
MEDIUM	5	0	4	3	3	3	6	3	0
SMALL	2	3	4	4	4	1	7	1	1

Note: + = more, o = same, and - = fewer.

of the number of hubs and the number of flights. Most changes occurred at Denver, Memphis, and San Francisco.

Realizing that an efficient network must also involve a large degree of passenger consolidation over lesser traffic routes, one may look at the extent of hubs connected by direct or through service that includes nonstop flights and flights involving one or more intermediate stops but without a change of plane. Such data for 1984 and 1977 are also given in Table 3. The average percentage of origin hubs serving the base was either about the same or slightly increased. With direct flights the accessibility of large and medium base hubs was greatly improved. However, small base hubs were not connected to too many other hubs even with direct flights.

A great deal of the service improvement since deregulation has been concentrated on a few of the markets. To a traveler, the specific individual airports are important. The distribution of the number of base hubs in the sample with service from more, the same, and fewer origins is given in Table 5. For nonstop service, the ratio is about two to one between base hubs with more origins and base hubs with fewer origins. The changes were minor for direct service, with the noticeable exceptions in the accessibility between medium and small hubs and between small hubs and small hubs.

The number of origin hubs not listed with any service with two or fewer transfers to the 10 base hubs analyzed with 144 origins is tabulated in Table 6. Again, the improvements of 1984 over 1977 are evident. The most dramatic improvements were for connections between small hubs and medium hubs. However, the accessibility between two small hubs remained poor in 1984, in spite of the significant systemwide improvements over 1977. Because nonstop or direct flights are available between all large hubs, it is theoretically possible to travel from one small hub to another small hub by involving only two transfers and three flight segments. The lack of listing in the Official Airline Guide for many small hubs and small hub connections may be a result of either the lack of travel demand or poor schedules.

FREQUENCIES

Flight frequencies are as important as the number of hubs served. Many qualities of service important to air travelers are

TABLE 6 NUMBER OF ORIGIN HUBS NOT LISTED WITH ANY SERVICE IN THE OFFICIAL AIRLINE GUIDE IN MARCH 1977 AND 1984

BASE HUB	ORIGIN: LARGE HUBS (24) 1984	LARGE HUBS (24) 1977	MEDIUM HUBS(34) 1984	MEDIUM HUBS(34) 1977	SMALL HUBS (87) 1984	SMALL HUBS (87) 1977
LARGE BASE HUBS						
SFO					3	4
DEN					4	7
DTT					2	4
BOS					2	0
MEDIUM BASE HUBS						
SAN					8	14
ABQ				1	9	40
MEM					9	20
SMALL BASE HUBS						
BOI		2	12	21	58	71
FWA	1	1	9	13	57	73
CAE		2	1	9	44	68

Note: Parentheses show number of flights involved.

related to or affected by flight frequencies. When there are more flights, the departure times are more convenient, there are more seats available, and there is stronger competition among the carriers. In this section, the frequencies are compared between 1984 and 1977 for the hubs in the study. The distribution of changes in nonstop and direct frequencies is given in Table 7. Direct flights involve same plane through service and include nonstop flights. Only one large hub and one small hub among the 27 hubs studied had fewer total nonstop flights in 1984 than in 1977. On the other hand, six of the 27 hubs had

TABLE 7 DISTRIBUTION OF THE NUMBER OF BASE HUBS IN THE SAMPLE WITH VARYING FREQUENCIES BETWEEN 1977 AND 1984

BASE HUB SIZE	ORIGIN HUB SIZE: LARGE +	LARGE 0	LARGE -	MEDIUM +	MEDIUM 0	MEDIUM -	SMALL +	SMALL 0	SMALL -
NONSTOP SERVICE									
LARGE	8	0	1	9	0	0	7	1	1
MEDIUM	9	0	0	5	4	0	6	1	2
SMALL	6	2	1	3	5	1	3	5	1
DIRECT SERVICE									
LARGE	7	0	2	8	0	1	7	0	2
MEDIUM	8	0	1	7	0	2	8	0	1
SMALL	6	0	3	6	2	1	6	0	3

Note: + = more, 0 = same, and - = fewer.

fewer direct flights. A comparison of the average total frequency between a base hub of certain size classification and other hubs in each of the three hub size groups is shown in Figures 2–4. On the average, frequency increased across all base-origin hub size groupings for both nonstop and direct flights. There were considerably more direct flights in 1984 than in 1977. Because all airline flights are formed of nonstop stages, the frequencies of nonstop flights are the most important to network accessibility.

A graphical depiction shows that the distribution of the improvements is almost across the board for the four large hubs, the three medium hubs, and the three small hubs that were studied with a full sample of 144 origins. Figure 2 is a comparison of the nonstop and direct frequencies between each of the four large base hubs and the origins in each of the three hub size groups. Similar comparisons for the medium and small base hubs are shown, respectively, in Figures 3 and 4. Another look at frequencies is on the distribution of the increases. Were the increases across the board or between only a few selected origin hubs? The number of origin hubs with increased and decreased frequencies to each of the 10 bases studied with a full sample of origins is listed in Table 8 according to origin hub size grouping. As can be seen, there were generally far more origin hubs with increased nonstop frequencies than there were origin hubs with declines.

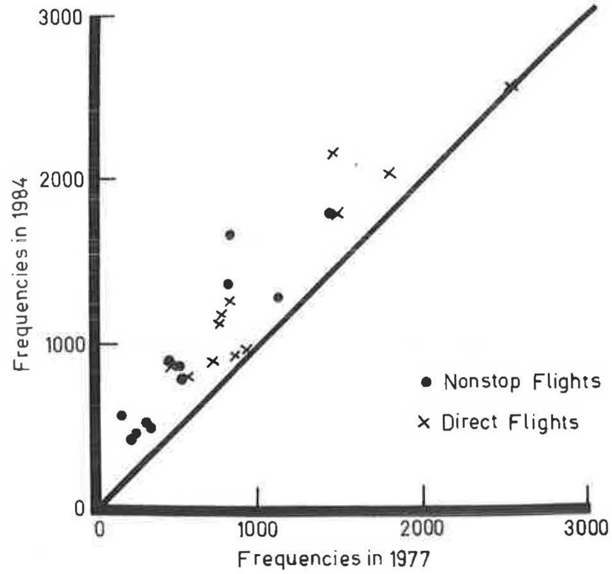

FIGURE 2 Comparison of the weekly frequencies in 1977 with those in 1984 for four large base hubs and each of three origin hub size groups.

DISTRIBUTIONAL PATTERNS

It is evident from the statistics presented up to this point that accessibility in 1984 was better than in 1977. For each of the hubs in the study, there were generally more flights to connect to more places. However, the improvements were not uniform across the whole system. There were gains and there were losses. However, the gains seem to outweigh the losses. A general observation was that extensive long-distance nonstop services of low demand were substituted with direct or connection flights. Also, the nonstop frequencies that were reduced

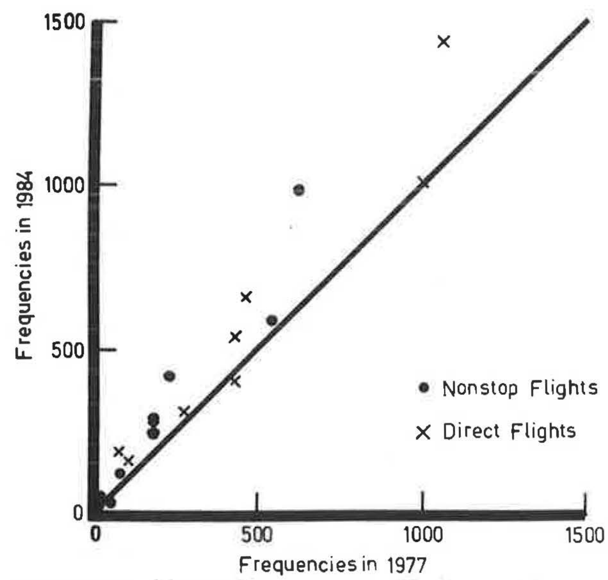

FIGURE 3 Comparison of the weekly frequencies in 1977 with those in 1984 for three medium base hubs and each of three origin hub size groups.

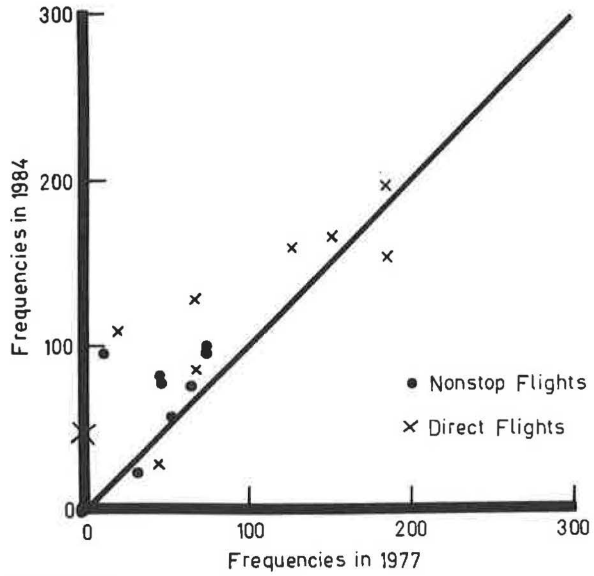

FIGURE 4 Comparison of the weekly frequencies in 1977 with those in 1984 for three small base hubs and each of three origin hub size groups.

were usually those that were either very high or very low in 1977.

There are two aspects of accessibility that may be subjected to biases in the reorganization of the airline network. One is the possibility of a reduction in supplies. The usual measure of supply is the plane-miles of nonstop flights, the backbone of the network. Another possible bias is that the accessibility gained may come at the expense of some segments of the market. This section examines the total plane-miles of nonstop flights; the average distances of nonstop, direct, and connection flights; and the average population of the origins weighted by nonstop, direct, and connection frequencies for the 10 base hubs studied with a full sample of 144 origins. The last item is an attempt to look at the direction of change in the frequency of flights with respect to the size of the markets served by the different levels of service.

The data for the nine base hubs show that supplies between small origin hubs and large base hubs enjoyed sizable increases. This is an indication that each large hub has become a major feeder point of small hubs within its market area. Looking at the small base hubs, the increase in nonstop plane-miles from large hubs was not as great. The asymmetric relationship implies that there were more small hubs feeding into each large hub, while the service to each small hub was not significantly changed from the level in 1977.

If the accessibility has improved, there would be more flights to more places, including places that are near and far. In transportation, demand generally decreases with distance when everything else is being equal. A trend towards better accessibility may imply more and better service to farther places. Comparisons in the average distance between each base hub and the hubs served within each origin hub size group are shown in Figures 5–7. Three average distances are shown. The average distances were obtained by using the frequencies of nonstop, direct, and all flights as weights. The direct flights include nonstop flights and all flights include nonstop, direct, and connection flights. From the figures, it can be seen that the average distances increase with a lower level of flight service.

TABLE 8 NUMBER OF HUBS WITH INCREASED AND DECLINED NONSTOP FREQUENCIES BETWEEN 1977 AND 1984

BASE HUB	ORIGIN: LARGE HUBS (24) INCREASED	LARGE HUBS (24) DECLINED	MEDIUM HUBS(34) INCREASED	MEDIUM HUBS(34) DECLINED	SMALL HUBS (87) INCREASED	SMALL HUBS (87) DECLINED
LARGE BASE HUBS						
SFO	12	6	5	8	9	3
DEN	22	1	24	0	24	6
DTT	18	2	12	6	9	5
BOS	7	9	11	3	7	1
MEDIUM BASE HUBS						
SAN	11	2	2	1	2	2
ABQ	6	4	2	1	2	1
MEM	12	5	6	4	8	4
SMALL BASE HUBS						
BOI	3	1	1	2	N/A	N/A
FWA	3	1	2	1	2	0
CAE	1	3	3	1	3	1

Note: Parentheses show number of flights involved.

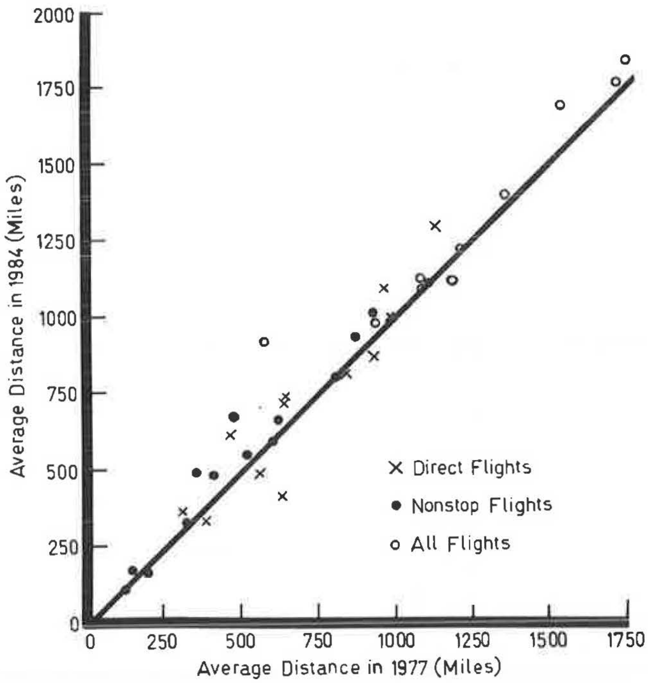

FIGURE 5 Comparison of the average distance between origin and destination for three types of flight service between 1977 and 1984 for four large base hubs and each of three origin hub size groups.

For example, farther places become more accessible with direct flights versus nonstop flights. The figures also show that there were more increases (above the 45 degree line) in the average distance in 1984 than there were decreases (below the 45 degree line) for large and medium base hubs (Figures 5 and 6).

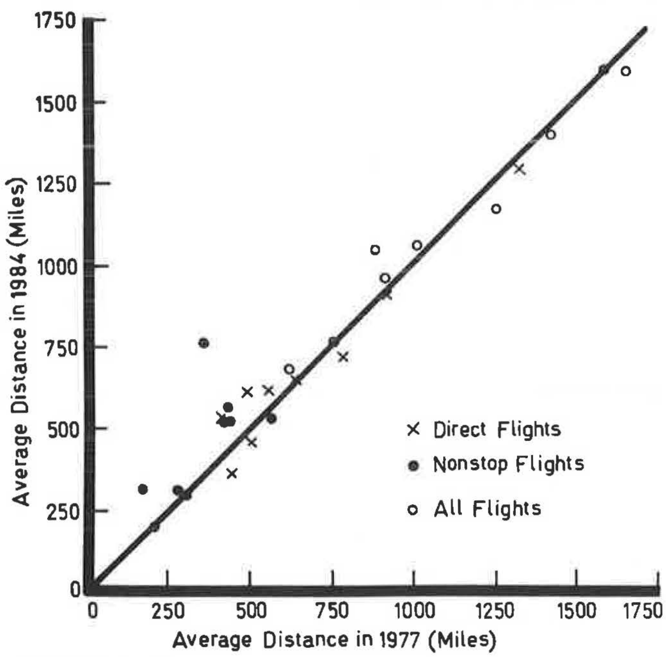

FIGURE 6 Comparison of the average distance between origin and destination for three types of flight service between 1977 and 1984 for three medium base hubs and each of three origin hub size groups.

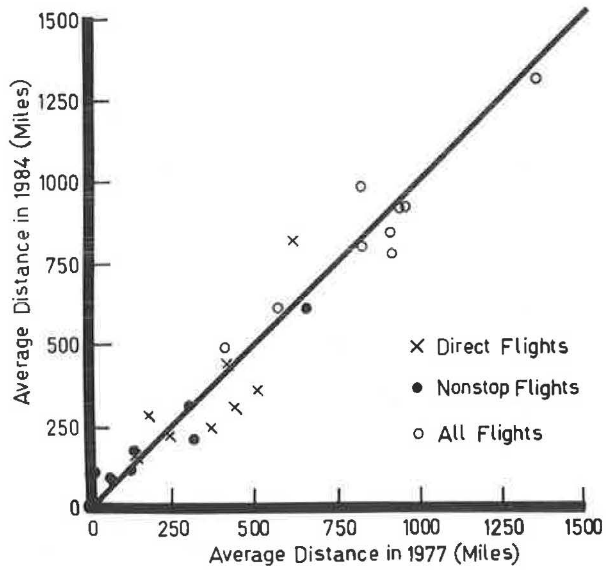

FIGURE 7 Comparison of the average distance between origin and destination for three types of flight service between 1977 and 1984 for three small base hubs and each of three origin hub size groups.

However, it is the opposite for the small base hubs, as shown in Figure 7.

Similar to average distance, the average population of the origin hubs serving each of the base hubs was also calculated. The changes in the averages of population weighted by nonstop, direct and all frequencies were analyzed with data. If accessibility becomes more uniformly distributed, the averages should approach the unweighted average, which is the ratio of one. The results do not indicate any general trend and the differences between 1984 and 1977 are small. Since the averages were computed for different origin hub size groups, there does not seem to be any bias toward larger markets within each hub size category.

SOME 1985 DATA

Although the results of this study support the conclusions of many studies that the level of air transportation service had improved up to 1984, there is still a continuing concern over air service at smaller communities. For this reason, data from March 1985 were compiled for the three medium hubs and three small hubs that were studied with 144 origin hubs. In Table 9, the nonstop and direct weekly frequencies for 1977, 1984, and 1985 are compared for these six hubs. There were generally more flights in 1985, but the changes were uneven. The accessibility between these six hubs and the nonhubs for 1985 and 1977 is compared with the data in Table 10. Again, the changes varied from hub to hub. A general sense is that the improvements outweighed the declines.

CONCLUSIONS

This study compares airline service between 1984 and 1977. In 1978, the airline industry in the U.S. was deregulated from

TABLE 9 WEEKLY FREQUENCIES OF NONSTOP AND DIRECT FLIGHTS

DESTINATION HUB	ORIGIN: LARGE HUBS 1985	LARGE HUBS 1984	LARGE HUBS 1977	MEDIUM HUBS 1985	MEDIUM HUBS 1984	MEDIUM HUBS 1977	SMALL HUBS 1985	SMALL HUBS 1984	SMALL HUBS 1977
SAN	1093	993	619	27	21	21	108	38	53
	1662	1441	1068	226	260	193	299	310	280
ABQ	457	409	254	100	109	90	74	46	36
	817	665	460	223	166	119	255	197	90
MEM	687	586	547	253	224	194	281	292	178
	1162	1012	1000	411	400	426	474	548	436
BOI	126	80	49	92	99	77	13	0	0
	208	161	187	180	159	129	50	46	0
FWA	91	77	68	63	21	35	59	94	15
	185	167	152	108	28	48	78	108	22
CAE	95	95	77	58	78	49	40	58	56
	167	197	182	91	129	70	66	84	70

Note: Top entries show nonstop flights, and bottom entries show direct flights.

government control. Of particular interest to this study is the pattern of accessibility after the airlines had reorganized their route structure in order to become more competitive. The method used is one of selecting 27 hubs by stratified random sampling to represent large, medium, and small hubs in the eastern, central, and western regions. The nonstop, direct, and connection flight frequencies, either from all 145 hubs classified as large, medium, and small in 1977 in the contiguous 48 states or from 40 hubs randomly sampled from the 145, were analyzed with respect to measures related to accessibility. Because only the large, medium, and small hubs were studied, the emphasis of the study is placed on the major hubs. The nonhubs were not included in the study.

The statistics show that accessibility improved between 1977 and 1984 for hubs of all three sizes. In terms of the number of places serving the base hubs, there were more places accessible in 1984 by nonstop and direct flights. Large hubs served a much larger role in the reorganized network, especially as gateways for transferring to flights serving small hubs in the local market region. Medium hubs received improved nonstop services to and from large hubs. However, accessibility from small hubs to other small hubs improved only slightly. It appears that accessibility improved with the hub-and-spoke network. There is no identifiable geographical difference in the changes.

TABLE 10 NUMBER OF NONHUB ORIGINS CONNECTED TO THE BASE AND THE TOTAL WEEKLY FREQUENCY

DESTINATION HUB	NONSTOP FLIGHTS 1985	NONSTOP FLIGHTS 1977	DIRECT FLIGHTS 1985	DIRECT FLIGHTS 1977
SAN	1	3	5	8
	13	43	33	87
ABQ	11	12	15	20
	330	167	435	283
MEM	20	11	27	28
	353	169	551	394
BOI	8	6	11	9
	185	82	248	119
FWA	1	0	1	1
	7	0	7	7
CAE	3	1	5	1
	15	7	39	7

Note: Top entries show nonhub origins connected to the base, and bottom entries show total weekly frequency.

In addition to improvements in spatial connectivity, the frequencies and total supply in terms of plane-miles also increased significantly between 1977 and 1984. With the added frequencies, the quality of service undoubtedly has also become better. The only deterioration in service is the need to make transfers for some passengers. Some attitudinal survey may be needed to find out the trade-offs from the passengers' point of view. However, from a network's stand point, the changes do not appear to result in biases unfavorable to accessibility.

The conclusions of this study agree with other studies on the same aspects of air transportation. The results indicate that accessibility did not deteriorate after deregulation. However, even for the larger hubs that were studied here, there were winners and losers. Overall, the losses were minor and for only a few of the hubs. There were large improvements for some of the hubs. For most of the hubs studied, the changes were generally positive. It is not possible within the scope of this study to relate the changes to deregulation. It is quite possible that the changes came naturally with growth and the maturity of the industry, independent of deregulation.

REFERENCES

1. *Report to Congress: Implementation of the Provisions of the Airline Deregulation Act of 1978.* Civil Aeronautics Board, Washington, D.C., Jan. 31, 1984.
2. M. A. Brenner, J. O. Leet, and E. Schott. *Airline Deregulation.* Eno Foundation for Transportation, Inc., Westport, Conn., 1985.
3. U.S. Congress. *Hearings before the Subcommittee on Aviation,*

Committee on Commerce, Science, and Transportation, Serial No. 98–15. Government Printing Office, Washington, D.C., 1983.
4. U.S. Congress. *Hearings before the Subcommittee on Aviation, Committee on Commerce, Science, and Transportation, Serial No. 98–38.* Government Printing Office, Washington, D.C., 1983.
5. Y. Chan. Airline Deregulation and Service to Small Communities. In *Transportation Research Record 851*, TRB, National Research Council, Washington, D.C., 1984, pp. 29–37.
6. T. R. Jones and S. I. Cocke. Deregulation and Non-hub Airports: Discriminant Analysis of Economic, Demographic and Geographic Factors. In *Proceedings, Transportation Research Forum*, Vol. XXVI, pp. 251–257, 1984.
7. D. Ming, D. Tolliver, and D. Zink. Effects of Airline Deregulation on North Dakota Fares and Service. In *Proceedings, Transportation Research Forum*, Vol. XXVI, 1984, pp. 265–274.
8. F. J. Stephenson and F. J. Beier. The Effects of Airline Deregulation on Air Service to Small Communities. *Transportation Journal*, 1981, pp. 54–61.
9. J. F. Molloy, Jr., *The U.S. Commuter Airline Industry.* Lexington Books, Lexington, Mass., 1985.
10. A. Kanafani and A. Ghobrial. Airline Hubbing, Some Implications for Airport Economics. *Transportation Research*, Vol. 9, No. 2, 1985, pp. 109–114.
11. D. R. Graham and D. P. Kaplan. *Competition and the Airlines: An Evaluation of Deregulation.* Staff Report, Office of Economic Analysis, Civil Aeronautics Board, Dec. 1982.
12. E. E. Bailey, D. R. Graham, and D. P. Kaplan. *Deregulating the Airlines.* M.I.T. Press, Cambridge, Mass., 1985.
13. *Official Airline Guide.* North American ed., 2 vols., Reuben H. Donnelley Corp., New York, N.Y., March 1977 and March 1984.
14. *A Staff Report on Airline Service, Fares, Traffic, Load Factors and Market Shares.* Civil Aeronautics Board, Aug. 1981.

Publication of this paper sponsored by Committee on Aviation Economics.

Air Transport Deregulation and Airport Congestion: The Search for Efficient Solutions

J. R. G. BRANDER AND B. A. COOK

Two broad approaches to the congestion problem exist. It is possible to expand slot availability. This analysis suggests the futility of such action. The other solution is to use price to ration capacity. Peak load pricing reduces social cost, shifts traffic to less congested periods, and improves the overall utilization of the airports. An auction mechanism would be the most efficient alternative. Under this approach, each slot would be awarded to the highest bidder. In addition to controlling congestion, the approach maximizes the return that could be generated by each slot and, hence, airport revenues.

A deregulated air transportation system is an open access commons. This is a system characterized by unrestricted (or open) access to everyone. This results in some form of adverse interaction among system users, which generates external costs such as congestion or, in the case of natural resource systems, depletion. The common property nature of the air passengers, the absence of entry barriers, and the ease with which productive capacity can be reallocated among the various air travel markets all establish the parallel. Economic rents will be totally exhausted if there are no constraints on landing slots. The available passenger stock will be over exploited and excess capacity will emerge. Congestion will develop exacerbated by the inherent tendency toward service scheduling. The congestion generates social costs due to overcrowding. Note that, strictly speaking, economic rent is the return to a resource with a supply that is absolutely fixed and nonaugmentable. However, when some inputs are fixed only in a short-run sense, this return may be called a quasi-rent.

Department of Economics, University of New Brunswick, P.O. Box 4400, Fredericton, New Brunswick, Canada E3B 5A3.

A brief review of the applicability of the common property framework to the industry is given at the beginning of the paper. Industry equilibrium is then discussed. Next, the tendency toward service scheduling and the resultant traffic peaks are reviewed. A variety of proposed solutions, both supply side and demand side, are reviewed in light of the analysis. In conclusion, demand management policies are required to increase the social surplus and control congestion.

THE AIRLINES AND COMMON PROPERTY EQUILIBRIUM

The theoretical structure, which was developed in the original paper *(1)* and on which this policy analysis is based, utilized a