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Airline mergers and their effect on network structure

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The Airline Deregulation Act of 1978 introduced high-level competition into the US domestic industry. The resulting network changes have created a deluge of research, largely focused on the hub-and-spoke structure. Over 15 years have passed since deregulation, and the industry still appears somewhat unsettled. Recent concerns of domestic carriers include downsizing of some hubs, and discussions of further consolidation of operations. Mergers may be the answer for airlines with shrinking markets within the US transportation system. This study examines the effect on network structure created by the merger of two carriers from the perspective of hub structures, accessibility and geographic coverage.

Keywords: air transportation, hub, mergers

The widespread adoption and growth of the hub-and-spoke system in the United States was largely a response to the passage of the Airline Deregulation Act of 1978 (Bailey *et al*, 1985; Meyer *et al*, 1981). Relaxing the regulatory control of the government on domestic airline traffic forced carriers to strive for greater flow efficiency and cost reduction in order to remain competitive. Concentrating flights at one or more key nodes raised the seat-occupancy levels (load factor), thus allowing the usage of larger aircraft (scale economies), as well as maximizing the number of on-line (same carrier) origin–destination matchings available to passengers (Goetz and Dempsey, 1989; Lopuszynski, 1986).

The major carriers created hubs at strategic regional points in their air networks so travelers from numerous origins (spokes) could be routed through the hub cities and then connected with flights to their final destinations (Goetz and Dempsey, 1989). Initially, each airline focused its hub-and-spoke strategies on a few large-city airports where the carrier already controlled a sizeable share of the market (Lopuszynski, 1986). As new airlines formed and older airlines expanded their networks, several other (often medium-sized) cities were chosen as hub transfer points. Today, the largest carriers have as many as four or five major hubs (not all of them cost-effective) scattered throughout the nation. Hub saturation has become an issue for some of these carriers causing a downsizing at several hubs such as Northwest's Memphis and American's Raleigh/Durham and Nashville hubs (Glab, 1993).

The resulting network geography of air transportation routes in the USA has greatly altered network structures, connectivity, passenger flow patterns and general competitiveness within the industry (Ivy, 1993; Shaw, 1993). This has stimulated a deluge of research from many fields. Geographers have contributed to theoretical location models on hub spacing and interaction within the network (Chou, 1990; O'Kelly, 1986a; 1986b; 1987; O'Kelly and Lao, 1991). Others have looked at changes in market power and profitability of the major carriers and larger airports in the hub-and-spoke environment (Borenstein, 1989; Leigh, 1990; Toh and Higgins, 1985).

Although mergers were a common occurrence in the US airline industry during the mid- to late 1980s and some argue that such consolidation is likely to continue into the 1990s (Glab, 1993; Labich, 1990), the network geography of airline mergers has not been fully examined in the literature. Many aspects of mergers could be investigated, but the purpose of this study is to examine patterns of changes in network structure that can occur as two airlines consolidate their operations.

Mergers and acquisitions

One of the promises of deregulation was an increase in the number of domestic carriers which would in turn keep passenger fares at a reasonable level. Relaxing the entry/exit restrictions did initially foster the growth of a significant number of new airlines, but many of them were short-lived (Goetz and Dempsey, 1989). Larger carriers were able to drive many of them (as well as some other large national

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carriers) out of business through fare wars and/or eventual government-approved mergers.

During the latter half of the 1980s, many of the larger regional carriers were absorbed by financially stronger airlines. The mergers, which had to be approved by the US Department of Transportation (DOT), largely followed two themes: (1) merging to eliminate the competition at specific hubs or along many route pairs, or (2) merging to expand geographic coverage of the domestic market. Below is a look at some of the more publicized airline mergers in the USA during the 1980s. The statistics presented were calculated from the *Airport Activity Statistics of Certified Route Air Carriers*, 1982 and 1990 (USDOT, FAA, annual).

Some of the approved mergers were cases of buying out the competition. For example, the TWA acquisition of Ozark (1986) led to a strong TWA dominance along many routes out of St Louis which was a hub for both carriers. Prior to the merger, TWA controlled 42% of the domestic scheduled departures and 54% of the enplaned passengers at St Louis' Lambert Field while the figures for Ozark were 35% and 29%, respectively. At the end of the 1980s, TWA held 74% of the scheduled domestic departures and 79% of the enplaned passenger traffic. Because of the clear dominance of one carrier in St Louis (and other US cities), many debate the wisdom of the DOT's decision. Only Southwest Airlines has been able to build up a modest presence in St Louis since the merger largely due to a fare structure often below that of TWA along several city-pairs.

The Northwest merger with Republic created a similar situation at Minneapolis/St Paul International Airport. At the time when Northwest applied for permission to merge with Republic, both carriers had solid hub operations at Minneapolis/St Paul and were in direct competition on 45 different city-pairs (OECD, 1988). Northwest, the dominant carrier at the hub, controlled 43% of the enplaned passengers and 34% of the scheduled domestic departures in 1982. By the end of the decade, their enplaned passenger share rose to 80%, and domestic departure share to 75% largely due to the acquisition of Republic Airlines in 1986.

The second theme seems to have been guided by a perceived need to cover neglected regions of the nation. Delta's acquisition of Western and its Salt Lake City hub in 1986, for example, gave Delta a presence in the northwestern section of the country, a presence which was minimal before the merger. Delta now has hub facilities in every quadrant of the nation (Shaw, 1993).

USAir's acquisition of Piedmont Aviation created a strong market position for the carrier up and down the eastern coast of the USA. USAir already had a strong foothold in the northeast, while Piedmont had built up an impressive market in the southeast with its Charlotte hub. In addition, USAir now operates the lucrative east coast shuttle that offers frequent service (often hourly) between the largest cities in the northeast. This service was operated as the Trump Shuttle and the Eastern Shuttle previously.

Texas Air, operating as the parent company for Continental Airlines, proved to be the major aggressor in the merger activity. Texas International, Frontier, New York Air, People's Express, Britt Airways, Rocky Mountain Airways, PBA and Braniff's Latin America routes were all operated under the Continental system by the end of the 1980s (Goetz and Dempsey, 1989). The now-bankrupt Eastern was also acquired by Texas Air, but still operated under the Eastern logo. Texas Air quickly began to experience financial difficulties as its costly overexpansion proved to be inefficient and even ineffective in some markets (Glab, 1993).

Even though recent years have seen a few new carriers such as Reno Air, Ultrair and KIWI come on the scene, consolidation is clearly the future of US aviation (Glab, 1993; Labich, 1990). Competition from Delta, American and United, collectively referred to as 'the Big Three', may make the likelihood of long-term success questionable for these fledglings and the other larger, established carriers alike. Further merging within the US airline industry is certainly not out of the question as it may be vital for survival. Continental's interest in seeking a merger partner, for example, has been well publicized (Lollar, 1991). Those new smaller carriers that survive may do so by finding underserved niche markets within the US air transportation network.

Some problems of hubbing and mergers

The hub-and-spoke system has indeed spread out the air traffic flow around the USA. The top ten US airports (in terms of enplanements) carried 42% of domestic traffic in 1978 compared with 34% in 1990 (Ivy, 1993). However, hubbing combined with the overly permissive merger approvals by the DOT have created problems of market dominance in many large cities. Single-carrier dominance is often most severe, of course, at hub airports.

One such hub airport has received a lot of attention of late. Until early 1991, Atlanta's Hartsfield International Airport was a major transfer hub for both Eastern and Delta. After Eastern's demise, Delta was left the overwhelmingly dominant carrier at Atlanta and, therefore, along many city-pair matchings in the southeast. Bad feelings that have become quite public erupted between Delta and the city of Atlanta as government officials sought desperately to lure another carrier to Hartsfield in order to keep fares in check (Arendt, 1991; Glab, 1992). Atlanta was eventually able to lure the ailing TWA to set up a small hub-and-spoke operation using some of Eastern's old gates. To date the Atlanta experiment has proven successful for TWA. The airline's October 1993 schedule listed 59 daily

departures from Atlanta. Competition at the same hub is good for passengers, but air carriers may want to avoid it unless there exists an underserved (price and volume) or growing market.

Another serious issue has been the increasing dominance of a small number of carriers. In 1985, the top five airlines in the USA controlled 41% of the domestic traffic. Today, however, the top three (American, Delta and United) transport six out of every 10 US air passengers (*Frequent Flyer*, 1993). Between January 1992 and April 1993 the market share of American, Delta and United collectively rose from 55% to 60%, while many other carriers saw their market shares shrink slightly during the same period. Northwest's market share fell from 12.54% to 12.3%, Continental's from 9.7% to 9.37% and TWA's from 6.81% to 4.54%. Of the national carriers, only USAir increased its market from 7.17% to 8.09% (*Frequent Flyer*, 1993). This was largely due to its increasing focus on the eastern market which included the expansion of the USAir shuttle in the northeast and in Florida.

Merger evaluation

In order to compete with the 'Big Three', one possible alternative for the other carriers is to create a more competitive environment through further mergers. In practice, airline mergers can be evaluated from many aspects such as financial status, network coverage and structure, and corporate strategy, among others. This paper examines only one aspect: hub-and-spoke network structures. Specifically, this paper evaluates the impact on the hub-and-spoke structures of an air carrier's network owing to a proposed merger. While an analysis of actual mergers of the 1980s could certainly provide much useful insight, this study focuses on possible mergers of the remaining domestic carriers. It was decided that empirical data could also reflect the outcome of several decisions (such as competition, congestion and financial) that would make it difficult to isolate and evaluate the effect on network structures only. The proposed methodology could be used as a first-step analysis by an individual airline when contemplating a merger with another carrier.

Methodology

In a hub-and-spoke network, the 'level of hubbing' and the location of hubs are critical considerations to an airline. 'Level of hubbing' refers to the level of a node connected to other nodes in a network. When two airlines are merged, the relative hubbing level of a city could become stronger, weaker or unchanged depending on the configurations of the original network structures. This study measures the hubbing level of a city according to Equation (1).

$$S_i = \frac{\Sigma_{j=1,n} D_{ij}}{N-1} \qquad (1)$$

where D_{ij} represents the shortest topological distance between nodes i and j, and N is the total number of nodes in the network. If there exists a direct connection (ie, direct flight) between nodes i and j, the topological distance between the two nodes is 1. The topological distance between nodes i and j becomes 2 if it requires a transfer between the two nodes. If a node has direct flights to all other nodes in a network, the total shortest topological distance of that node is equal to $N-1$ and its S_i index value is 1. On the other hand, a node with an S index of 2 suggests that this node, on average, requires one transfer to reach another node in the network.

It should be noted that using the S index with topological distances has its limitations. In many cases a valued graph approach using actual distances or some other variables might be a more desirable method of measuring nodal accessibility. However, in terms of current hub-and-spoke operations, the number of transfers is a more important consideration than actual travel distances. Hub operations focus mainly on the number of cities that have direct flight connections with a specific hub. If there is no direct service between a particular pair of cities, it is desirable to minimize the number of transfers. Therefore, it is acceptable to measure hubbing levels using topology (ie direct and indirect linkages).

Aggregate connectivity is evaluated in this study largely on the basis of levels of duplicated cities and flight links served by the two merged carriers. However, the alpha (α) and gamma (γ) indices are used as supplementary measures to examine the effect of duplicated nodes and links on the aggregate network connectivity levels. These indices were calculated for each network using Equations (2) and (3) (Taaffe and Gauthier, 1973).

$$\gamma = \frac{e}{N\,(N-1)/2} \qquad (2)$$

$$\alpha = \frac{e-N+1}{[N\,(N-1)/2]-(N-1)} \qquad (3)$$

N and e are the total number of nodes and the total number of linkages in a network, respectively. The main difference between these two indices and the S_i index is that the first two measure the overall network connectivity level and the latter measures the accessibility level of individual nodes on a network. As the α and γ indices are not meaningful in measuring specific network connectivity patterns, they are not used to draw conclusions on the impact a merger has on hub-and-spoke operations. Nevertheless, the α and γ indices do reflect the levels of duplication on nodes and linkages of two networks (*Table 1*). This is especially true when a proposed merger results in increased values of the α and the γ indices (eg, Continental and TWA).

Table 1 Percentages of duplicate links and duplicate nodes, and aggregate network connectivity measures

Airline	No. of links	% dup. links	No. of nodes	% dup. nodes	α	γ
1. The 'big three:						
American (AAL)	475		89		0.1011	0.1213
Delta (DAL)	571		85		0.1397	0.1599
United (UAL)	390		81		0.0981	0.1204
2. Six selected airlines:						
America West (AWL)	101		29		0.1931	0.2488
Continental (CAL)	319		74		0.0936	0.1181
Northwest (NWA)	343		75		0.0996	0.1236
Southwest (SWL)	122		23		0.4329	0.4822
Trans World (TWA)	214		59		0.0944	0.1251
USAir (USA)	710		79		0.2105	0.2304
3. Fifteen possible mergers:						
CAL–AWL	406	3.45	77	33.77	0.1116	0.1388
CAL–NWA	640	3.44	87	71.26	0.1516	0.1711
CAL–SWL	411	7.30	77	25.97	0.1175	0.1405
CAL–TWA	478	11.51	84	58.33	0.1161	0.1371
CAL–USA	943	9.12	94	62.77	0.1987	0.2157
NWA–AWL	432	2.78	79	31.65	0.1179	0.1402
NWA–SWL	449	3.56	78	25.64	0.1271	0.1495
NWA–USA	996	5.72	92	67.39	0.2210	0.2379
TWA–AWL	309	1.94	63	39.68	0.1306	0.1582
TWA–NWA	527	5.69	81	65.43	0.1415	0.1627
TWA–SWL	314	7.01	61	34.43	0.1435	0.1716
TWA–USA	871	6.08	87	58.62	0.2148	0.2328
SWL–AWL	144	54.86	39	33.33	0.2290	0.2686
USA–AWL	795	2.01	84	28.57	0.2092	0.2281
USA–SWL	816	1.96	84	21.43	0.2154	0.2341

Data and implementation

A total of six US airlines were originally included in this study. Four of them are national air carriers: Continental (CAL), Northwest (NWA), Trans World (TWA) and USAir (USA). Another two are regional carriers: America West (AWL) and Southwest (SWL). These six carriers were selected because of the potential of strengthening their operations to compete with American, Delta and United to keep market shares from shrinking irreversibly at the hands of the top three carriers. Flights between the 100 most populous cities in the domestic United States for each of the six carriers were extracted from the published timetables for the fourth quarter of 1990.

The data were then loaded into a geographic information system (GIS) package, Arc/Info, to create network layers for each air carrier. The shortest-path algorithm in Arc/Info was used to find the shortest topological distances (D_{ij}s) between a selected node and all other nodes on each network. Equation (1) was then applied to the summation of D_{ij}s for each selected node which resulted in the hubbing index (S_i) value of that node. The γ and the α index values were computed using Equations (2) and (3) by a simple retrieval of the number of nodes and the number of direct links on a network.

The study then combined two networks at a time to create a merged network. When a city-pair was served by both air carriers, one of the linkages was dropped from the merged network to avoid duplication. Similar procedures were applied to the merged networks for computing the S_i, γ, and α index values.

The 15 possible merger cases were examined according to the degrees of duplication on the cities (nodes) and links served by the carrier pairs (*Table 1*). Then, the aggregate network connectivity measures (ie, γ and α indices) were examined. The merger of different networks is very likely to cause a drop in these two indices, particularly if the two networks are vastly different. However, in a few cases the α and γ indices for the merged network became higher than at least one of the individual networks. This is clearly a sign of improvement. It is important to acknowledge a relationship between the α and γ indices and the duplication of nodes and linkages.

The changes in the accessibility levels of individual nodes (S_is) were then compared to identify the impacts on the hub-and-spoke structures due to the proposed mergers. These nodal accessibility comparisons focus on three aspects: (1) the change of rankings among the cities before and after a merger; (2) the change of the magnitude of index values before and after a merger; and (3) the change in geographic coverage before and after a merger.

Aggregate connectivity

When two airline networks are merged, it is expected that there will be some duplication in terms of the cities and the routes served by the two carriers. The level of duplication has implications regarding the competition or the complementarity between the two carriers. These implications are discussed below.

(1) 'Low' duplication levels on both nodes and links. When duplication levels on both nodes and links are low, it implies that the two carriers are not engaged in direct competition. Examples include USA–SWL (21.43% and 1.96%), USA–AWL (28.57% and 2.01%), NWA–AWL (31.65% and 2.78%), NWA–SWL (25.64% and 3.56%), CAL–AWL (33.77% and 3.45%) and TWA–AWL (39.68% and 1.94%). All of the cases involve one major carrier merged with a regional carrier, which mainly serve different markets.

Although these cases suggest a favorable condition for possible mergers, additional considerations such as duplication of major hubs and geographic coverage should be taken into account. A later section will examine such considerations using nodal accessibility index values computed for individual as well as merged networks.

(2) 'Low' duplication on nodes and 'high' duplication on links. This implies that, although the two carriers do not serve many duplicate cities, they offer overlapping service on a number of routes. This usually happens when one carrier exhibits a 'point-to-point' network structure that competes with another carrier on selected links. CAL–SWL (25.97% and 7.30%), TWA–SWL (34.43% and 7.01%) and SWL–AWL (33.33% and 54.86%) are examples of this category. The extreme case of SWL–AWL (both regional carriers), for example, suggests that a merger can significantly expand the network coverage of cities served, but not the linkages among those cities.

(3) 'High' duplication on nodes and 'low' duplication on links. This suggests that the two carriers serve some common cities with quite different hub-and-spoke structures. That is, their flights are oriented around different hubs adopted by the two carriers. The cities shared by the two carriers are mainly spokes on each network. It could also suggest that a carrier's network follows basically a 'point-to-point' structure, and these links serve mainly those cities that are spokes on another carrier's network.

Examples of this group include CAL–NWA (71.26% and 3.44%), NWA–USA (67.39% and 5.72%), TWA–NWA (65.43% and 5.69%) and TWA–USA (58.62% and 6.08%). Again, the differences among these cases need to be examined by nodal accessibility index values in order to compare their hub structures.

(4) 'High' duplication levels on both nodes and links. The two examples are CAL–TWA (58.33% and 11.51%) and CAL–USA (62.77% and 9.12%). These numbers imply that such carriers engage in direct competition. However, the γ and α indices suggest that the two cases may be different. For example, the CAL–TWA merger results in a better aggregate network connectivity for both carriers, but the same does not apply to the CAL–USA merger (*Table 1*). Therefore, it was also necessary to examine their hub-and-spoke structures for a better understanding of the potential impacts of proposed mergers.

The α and γ indices for the various single and combined networks are given in *Table 1*. The closer that the index value lies to 1, the stronger the connection of nodes within a network. It should be noted that if these mergers actually took place, there would no doubt be an adjustment of route structures which would affect these indices.

A perusal of the indices of the possible mergers shows that several of the two-carrier combinations yield higher α and γ values than at least one of the carriers on its own (e.g. Continental–TWA, Continental–America West and TWA–USAir). Those mergers involving USAir tend to show up quite strongly. USAir on its own has the highest α and γ values of the national carriers. This is due to its heavy concentration in the eastern half of the country and the tremendously high number of links in its network. The regional carriers (America West and Southwest) also have very high α and γ values due to the regionally compact nature of their networks. However, when merged with a national carrier, the results can be quite mixed. This issue is examined further with the inclusion of S_i index values as discussed below.

Merger classifications

When the networks of the 15 possible mergers were examined on the basis of duplication of nodes and links, and the α, γ and S_i index values, only 10 cases resulted in an improvement over at least one of the carriers' networks. The mergers of Continental and America West, Continental and Southwest, Northwest and America West, USAir and Southwest, and Southwest and America West did not yield any obvious competitive advantages over their respective single-carrier situations. As a result, they were dropped from further analysis. Three general classifications were identified according to the rankings of the top 15 most accessible cities based on the S_i index values in their respective merged and individual networks. These rankings are shown in *Tables 2* to *11*. The merged networks were classified as *single carrier dominant*, *overlapping* or *complementary*.

Table 2 Top 15 hubs of Continental, Northwest and their merged networks

CAL–NWA: Rank	City	S_i	CAL: Rank	S_i	NWA: Rank	S_i
1	Detroit	1.435	26	2.192	1	1.324
2	Houston	1.494	1	1.397	22	1.986
3	Memphis	1.518	—	—	2	1.419
4	New York	1.518	2	1.466	7	1.892
5	Minneapolis	1.529	20	2.096	3	1.432
6	Denver	1.624	3	1.548	26	1.986
7	Cleveland	1.671	4	1.548	33	2.189
8	Los Angeles	1.824	14	2.000	5	1.824
9	Boston	1.824	10	1.945	4	1.811
10	Seattle	1.894	6	1.932	8	1.905
11	San Francisco	1.894	9	1.932	9	1.919
12	Milwaukee	1.906	37	2.301	6	1.851
13	Washington DC	1.918	8	1.932	13	1.946
14	Philadephia	1.929	7	1.932	14	1.959
15	Orlando	1.929	12	1.945	11	1.946

Table 3 Top 15 hubs of Continental, Trans World and their merged networks

CAL–TWA: Rank	City	S_i	CAL: Rank	S_i	TWA: Rank	S_i
1	St Louis	1.383	46	2.384	1	1.069
2	New York	1.506	2	1.466	2	1.534
3	Houston	1.506	1	1.397	12	1.966
4	Cleveland	1.630	4	1.548	26	2.000
5	Denver	1.630	3	1.548	9	1.966
6	Washington DC	1.926	8	1.932	3	1.931
7	Boston	1.951	10	1.945	4	1.948
8	Phoenix	1.951	18	2.082	8	1.966
9	San Francisco	1.951	9	1.932	5	1.948
10	Kansas City	1.951	5	1.918	29	2.034
11	Indianapolis	1.963	19	2.082	15	1.983
12	Orlando	1.963	12	1.945	7	1.966
13	Seattle	1.963	6	1.932	10	1.966
14	Philadelphia	1.975	7	1.932	24	2.000
15	Dallas	1.975	20	2.096	22	1.983

Table 4 Top 15 hubs of Continental, USAir and their merged networks

CAL–USA: Rank	City	S_i	CAL: Rank	S_i	USA: Rank	S_i
1	Pittsburgh	1.376	23	2.137	1	1.256
2	Charlotte	1.430	—	—	2	1.321
3	Houston	1.495	1	1.397	22	2.013
4	New York	1.495	2	1.466	9	1.756
5	Philadelphia	1.559	7	1.932	4	1.513
6	Baltimore	1.559	37	2.301	3	1.500
7	Cleveland	1.570	4	1.548	6	1.705
8	Denver	1.613	3	1.548	46	2.103
9	Washington DC	1.720	8	1.932	10	1.769
10	Indianapolis	1.731	18	2.082	7	1.718
11	Los Angeles	1.742	14	2.000	8	1.756
12	Dayton	1.763	—	—	5	1.705
13	Boston	1.785	10	1.945	11	1.833
14	Kansas City	1.806	5	1.918	14	1.859
15	Orlando	1.817	12	1.945	13	1.846

Single carrier dominant

The *single carrier dominant* pattern results when the top 15 ranked cities of a merged network are overwhelmingly dominated by cities that were on the top 15 list for only one of the two carriers. The less dominant carrier often added only its major transfer hubs to the combined list. The USAir mergers with TWA and America West fall into this classification (*Tables 10* and *11*). USAir, with its strong east coast presence and an extraordinarily high number of linkages (710) compared with the other carriers (100–300), gains a few western cities to the top 15 hubs in each case. From USAir's perspective the mergers would mean a broader geographic coverage.

Table 5 Top 15 hubs of Northwest, Southwest and their merged networks

NWA–SWL: Rank	City	S_i	NWA: Rank	S_i	SWL: Rank	S_i
1	Detroit	1.351	1	1.324	18	2.318
2	Memphis	1.442	2	1.419	—	—
3	Minneapolis	1.455	3	1.432	—	—
4	Phoenix	1.779	10	1.932	2	1.500
5	Los Angeles	1.818	5	1.824	13	2.182
6	Houston	1.831	22	1.986	1	1.455
7	Boston	1.831	4	1.811	—	—
8	Dallas	1.870	27	1.986	4	1.727
9	Milwaukee	1.870	6	1.851	—	—
10	San Francisco	1.896	9	1.919	15	2.182
11	St Louis	1.909	25	1.986	9	1.909
12	Seattle	1.922	8	1.905	—	—
13	Nashville	1.922	19	1.973	7	1.818
14	Las Vegas	1.922	17	1.959	14	2.182
15	San Diego	1.935	12	1.946	17	2.273

Table 6 Top 15 hubs of Northwest, USAir and their merged networks

NWA–USA: Rank	City	S_i	NWA: Rank	S_i	USA: Rank	S_i
1	Pittsburgh	1.363	35	2.189	1	1.256
2	Charlotte	1.418	—	—	2	1.321
3	Detroit	1.440	1	1.324	22	2.013
4	Memphis	1.505	2	1.419	50	2.115
5	Minneapolis	1.527	3	1.432	53	2.128
6	Philadelphia	1.527	14	1.959	4	1.513
7	Baltimore	1.626	34	2.189	3	1.500
8	Boston	1.670	4	1.811	11	1.833
9	New York	1.681	7	1.892	9	1.756
10	Washington DC	1.714	13	1.946	10	1.769
11	Indianapolis	1.714	18	1.973	7	1.718
12	Los Angeles	1.725	5	1.824	8	1.756
13	Tampa	1.791	15	1.959	12	1.833
14	Dayton	1.802	31	2.176	5	1.705
15	Kansas City	1.813	23	1.986	14	1.859

Table 7 Top 15 hubs of Trans World, America West and their merged networks

TWA–AWL: Rank	City	S_i	TWA: Rank	S_i	AWL: Rank	S_i
1	St Louis	1.129	1	1.069	—	—
2	New York	1.548	2	1.534	13	1.929
3	Phoenix	1.548	8	1.966	1	1.036
4	Las Vegas	1.597	38	2.034	2	1.143
5	San Francisco	1.887	5	1.948	4	1.929
6	Boston	1.887	4	1.948	12	1.929
7	Denver	1.903	9	1.966	8	1.929
8	Los Angeles	1.903	13	1.966	20	1.929
9	Houston	1.919	12	1.966	19	1.929
10	Seattle	1.919	10	1.966	9	1.929
11	Dallas	1.919	22	1.983	10	1.929
12	Minneapolis	1.935	25	2.000	7	1.929
13	Chicago	1.935	27	2.000	17	1.929
14	Colorado Springs	1.952	31	2.034	3	1.893
15	Salt Lake City	1.968	29	2.034	5	1.929

In addition, more of the S_i indices are at a higher level with less of a gap in values than for the USAir network alone. *Figure 1* shows the S_i indices for the individual carriers, while the values for the merged networks are given in *Figure 2*. The hubs at the higher accessibility levels have a wider geographic spread in the merged cases. This is particularly true for the USAir merger with TWA. Choosing an arbitrary threshold index of 1.6, for example, we find six hubs with S_i indices above 1.6 in the USA–TWA case compared with only four in the USAir network alone. The closer spacing of the values for

Table 8 Top 15 hubs of Trans World, Northwest and their merged networks

TWA–NWA: Rank	City	S_i	TWA: Rank	S_i	NWA: Rank	S_i
1	St Louis	1.325	1	1.069	25	1.986
2	Detroit	1.375	20	1.983	1	1.324
3	Memphis	1.463	43	2.052	2	1.419
4	Minneapolis	1.475	25	2.000	3	1.432
5	New York	1.638	2	1.534	7	1.892
6	Boston	1.788	4	1.948	4	1.811
7	Los Angeles	1.800	13	1.966	5	1.824
8	Milwaukee	1.850	36	2.034	6	1.851
9	Washington DC	1.863	3	1.931	13	1.946
10	San Francisco	1.863	5	1.948	9	1.919
11	Seattle	1.888	10	1.966	8	1.905
12	Phoenix	1.900	8	1.966	10	1.932
13	Tampa	1.913	6	1.966	15	1.959
14	Orlando	1.913	7	1.966	11	1.946
15	Denver	1.913	9	1.966	26	1.986

Table 9 Top 15 hubs of Trans World, Southwest and their merged networks

TWA–SWL: Rank	City	S_i	TWA: Rank	S_i	SWL: Rank	S_i
1	St Louis	1.100	1	1.069	9	1.909
2	New York	1.550	2	1.534	—	—
3	Phoenix	1.750	8	1.966	2	1.500
4	Houston	1.800	12	1.966	1	1.455
5	Dallas	1.833	22	1.983	4	1.727
6	San Francisco	1.833	5	1.948	15	2.182
7	Los Angeles	1.900	13	1.966	13	2.182
8	Albuquerque	1.917	43	2.052	8	1.864
9	New Orleans	1.917	17	1.983	16	2.227
10	San Antonio	1.933	34	2.034	10	1.955
11	Washington DC	1.950	3	1.931	—	—
12	Nashville	1.950	52	2.052	7	1.818
13	Oklahoma City	1.967	37	2.034	6	1.818
14	Tulsa	1.967	53	2.052	5	1.818
15	Las Vegas	1.967	38	2.034	14	2.182

Table 10 Top 15 hubs of Trans World, USAir and their merged networks

TWA–USA: Rank	City	S_i	TWA: Rank	S_i	USA: Rank	S_i
1	Pittsburgh	1.326	14	1.983	1	1.256
2	St Louis	1.372	1	1.069	48	2.103
3	Charlotte	1.384	45	2.052	2	1.321
4	New York	1.488	2	1.534	9	1.756
5	Baltimore	1.523	40	2.034	3	1.500
6	Philadelphia	1.535	24	2.000	4	1.513
7	Washington DC	1.674	3	1.931	10	1.769
8	Dayton	1.698	46	2.052	5	1.705
9	Cleveland	1.709	26	2.000	6	1.705
10	Indianapolis	1.733	15	1.983	7	1.718
11	Los Angeles	1.744	13	1.966	8	1.756
12	Boston	1.767	4	1.948	11	1.833
13	Tampa	1.814	6	1.966	12	1.833
14	Orlando	1.837	7	1.966	13	1.846
15	Kansas City	1.872	39	2.034	14	1.859

the merged case is readily observed (*Figure 2*). This may or may not be attractive to an airline as it could result in a less cost-effective hub network structure.

Some of the Continental acquisitions from the mid- to late 1980s (discussed earlier) would be a likely example of this category (eg the mergers with New York Air, Britt Airways). Many of the carriers that ended up flying under the Continental logo (recall that Eastern was not incorporated into the Continental system) had much smaller networks and very different regional service from Continental's heavy western bias. Therefore, few of the hubs of

Table 11 Top 15 hubs of USAir, America West and their merged networks

USA–AWL: Rank	City	S_i	USA: Rank	S_i	AWL: Rank	S_i
1	Pittsburgh	1.301	1	1.256	—	—
2	Charlotte	1.361	2	1.321	—	—
3	Baltimore	1.494	3	1.500	24	1.929
4	Philadelphia	1.518	4	1.513	—	—
5	New York	1.675	9	1.756	13	1.929
6	Phoenix	1.675	19	1.987	1	1.036
7	Cleveland	1.699	6	1.705	—	—
8	Indianapolis	1.723	7	1.718	—	—
9	Las Vegas	1.735	28	2.038	2	1.143
10	Boston	1.735	11	1.833	12	1.929
11	Los Angeles	1.759	8	1.756	20	1.929
12	Dayton	1.783	5	1.705	—	—
13	Kansas City	1.831	14	1.859	23	1.929
14	Washington DC	1.843	10	1.769	—	—
15	San Francisco	1.904	15	1.923	4	1.929

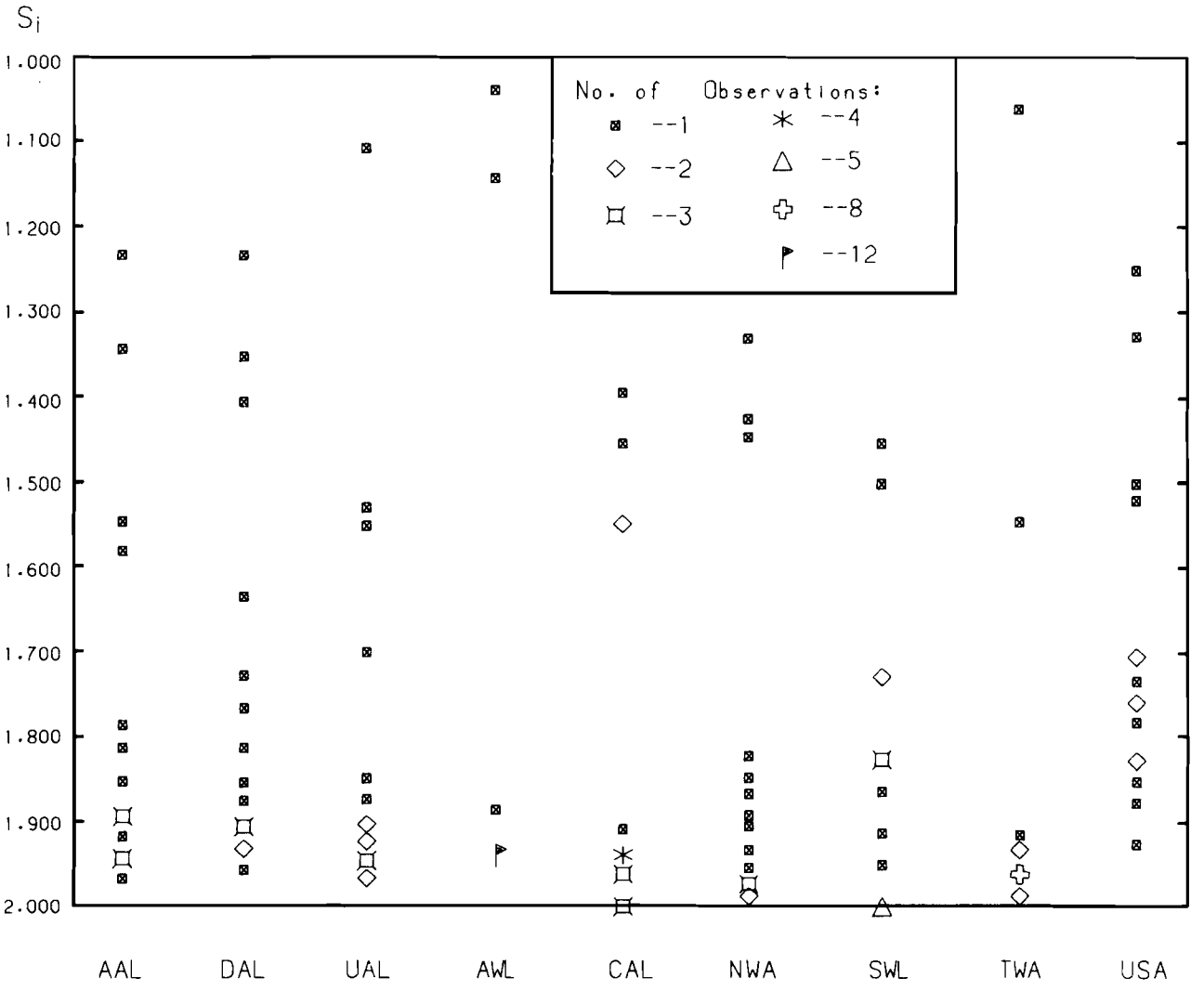

Figure 1 Distribution of the top 15 hubs, based on the S_i index values, by individual carrier

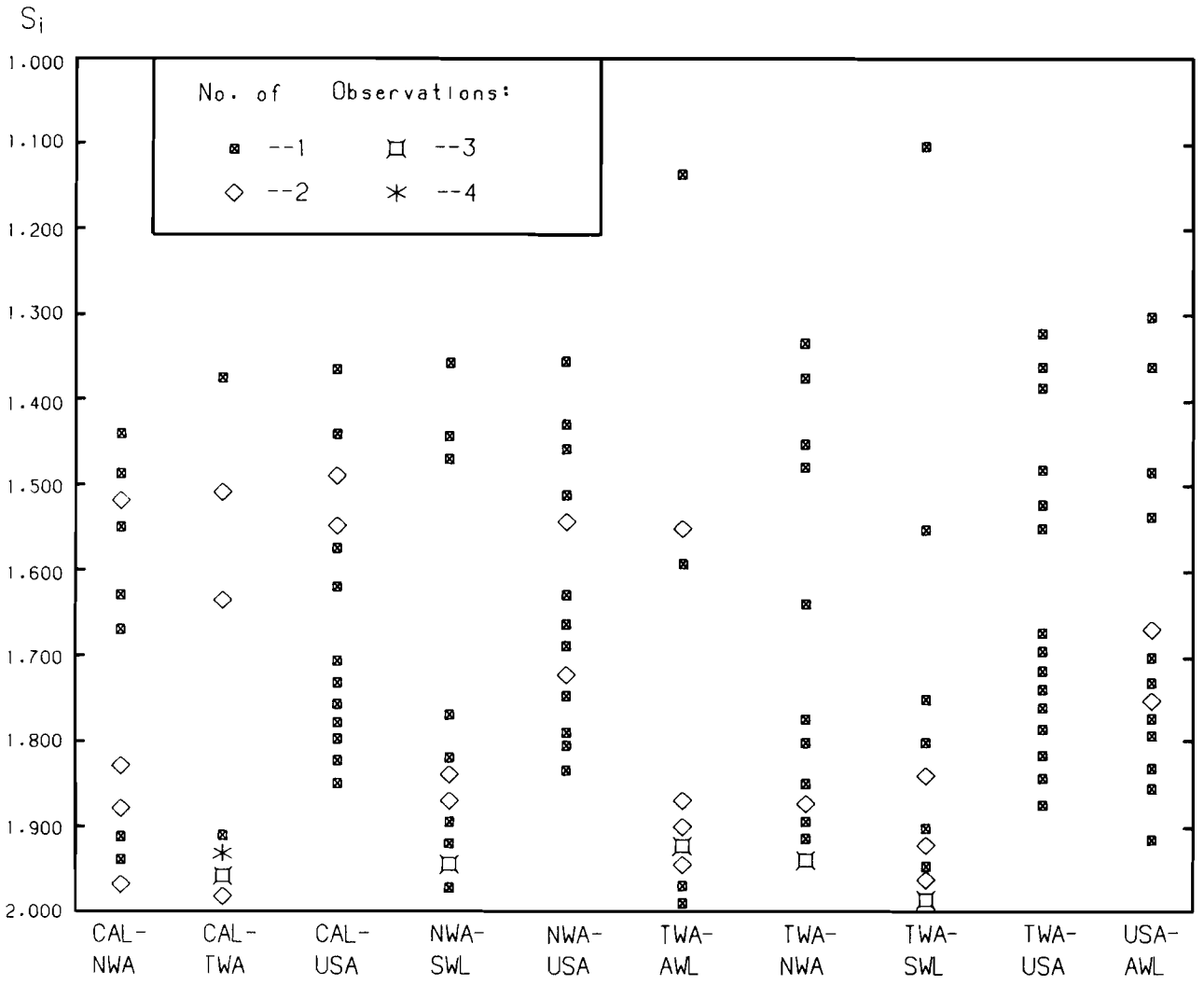

Figure 2 Distribution of the top 15 hubs, based on the S_i index values, by possible mergers

the smaller carriers were likely to rank high in S_i indices of the merged network.

Overlapping

When the top 15 hubs for the individual carriers were somewhat similar, often there appeared to be little change in the top 15 rankings for the merged network. This situation was classified as *overlapping*. The possible mergers of TWA with Continental and Northwest, as well as the USAir–Continental and Northwest–Southwest mergers all fall into this category (*Tables 3, 8, 4, 5*). The case involving the regional carrier is a situation where many of the nodes served by the national carrier were not served by the regional. However, some nodes highly served by the regional are also highly served by the national carrier, thus elevating their importance in the rankings.

Both mergers involving TWA exhibit a lower number of hubs with S_i indices above the 1.6 level, but the TWA–NWA case does show the same rather even spacing of the indices as discussed previously (*Figure 2*). The other TWA case has clear gaps in the rankings such as in the single case of TWA between its top two hubs and the rest of the list. Geographic changes in the top hubs from the single to the merged networks were rather slight except in the NWA–SWL merger which showed a good western pull. However, the appearance of a noticeable gap in S_i indices between the few highest ranked hubs and the remainder of the list is evident (*Figure 2*).

The 1986 merger of TWA and Ozark would be a good example of this category. Both airlines focused the bulk of their operations out of St Louis and served largely the same markets.

Complementary

Merged networks were classified as *complementary* when the top 15 rankings of the individual carriers contributed fairly equally to the top 15 list for the merged network. Often this yielded a complementary hub structure in terms of geographic spacing and a better geographic coverage in general for the network

as a whole. Cities that were served fairly well by each of the individual carriers generally have a much stronger showing on the rankings of the merged network.

The best example is probably the merged network of Continental and Northwest. The major hubs of both carriers prove to be truly complementary with differences (high for one carrier and lower for the other) in rankings and geographic location, while the secondary hubs often are very similar on both individual lists (*Table 2*). A much more uniform spacing of the S_i indices exists in the combined rankings, with five indices above the 1.6 threshold (*Figure 2*). In terms of geographic coverage a limited presence in the east is compensated by a strong saturation in the west and particularly upper mid-west regions of the nation.

The TWA mergers with the regional carriers (America West and Southwest) fall into this category (*Tables 7* and *9*). The latter combination is a special complementary case, as it involves a single hub structure (TWA) with the point-to-point network of Southwest. The Southwest top 15 cities (some not served by TWA) show up high on the combined list due to the favorable accessibility change via St Louis, which is well served by both carriers (*Table 9*). This gives the merged network a rather equal geographic coverage or regional pull. The single-hub structure of TWA combined with the point-to-point structure of Southwest creates a multiple gap situation in the S_i indices for the higher ranked hubs (*Figure 2*), but a clustering of the indices at lower levels in the top 15. Notice the strong index value for St Louis (1.1) which is an important city within both carriers' individual networks.

Another interesting case is the combination of USAir and Northwest. In terms of hub rankings, these two carriers largely indicate a 'complementary' pattern with USAir showing a slight dominance on the merged hub list (*Table 6*). However, the geographic locations of hubs of the two carriers suggest a concentration in the eastern half of the nation. Six of the S_i indices for this combined network lie above the 1.6 threshold as opposed to only four and three for USAir and NWA respectively as single carriers.

The DOT approved merger of Northwest and Republic in 1986 would be a decent example of this category. Whereas there was a lot of duplicate or overlapping service out of the Minneapolis hub (operated as a hub by both), the inclusion of Republic's Detroit and Memphis hubs no doubt added more eastern and southern cities to the upper rankings of the merged network.

Promising mergers

The mergers of Continental with Northwest (complementary) and TWA with Northwest (overlapping) yield higher α and γ indices than every national carrier except USAir (*Table 1*). The former case has actually been discussed by management at Continental and Northwest (Lollar, 1991). Both of the mergers are certainly quite competitive with 'the Big Three' not only from the perspective of α and γ indices, but also in that both mergers create more of a multiple-hub system with a better geographic spread (*Figure 3*). A multiple-hub system implies a greater number of cities with higher accessibility indices in a merged network over the single networks as can be seen in a comparison of *Figures 1* and *2*. This is, of course, good from the passenger's perspective, but could create a lower load factor for the airline. The CAL–NWA merger creates less of a gap between the higher and lower ranking hubs on the top 15 list (*Table 2*), resembling a hierarchical structure with more than two levels. This is less true of the TWA–NWA merger, probably because of TWA's very severe gap between the airline's top two hubs (St Louis and New York City) and the rest of the list. In addition, the number of links created by these two mergers and the number of nodes served are highly comparable to and competitive with those of American, Delta and United (*Table 1*). Indeed, the number of links is surpassed only by USAir's network already discussed as a unique case.

Conclusion

Airline mergers have become a product of deregulation. Since the Airline Deregulation Act of 1978, the nature of the industry has changed significantly, and merging has been a strategy opted for by some carriers in order to remain competitive. This paper examines the outcomes of possible airline mergers from the aspect of network structure. When two airline networks are merged, the resultant network can exhibit a quite different form from the original networks in terms of geographic coverage of cities and routes, overall network connectivity and hub-and-spoke pattern.

It is important to reiterate that the main purpose of this study is to develop a method of evaluating the effects of airline mergers on network structures. It is believed that one of the first evaluations of possible mergers is to examine the complementarity, level of overlapping or the level of dominance of the carriers involved. Subsequent decisions on the adjustments of hubs and linkages then come into play by taking into consideration other factors such as financial position, congestion, employee relations, etc.

This study incorporates several indices in a geographic information system to analyze the impacts on network structure caused by possible mergers. These indices provide useful information for evaluating the potential network improvements, and help to identify merger patterns. Three patterns (single carrier dominant, overlapping and complementary) are identified in the study. The proposed mergers in this study suggest that there is no one merger pattern that is clearly best under all circumstances. Every proposed merger should be evaluated individually

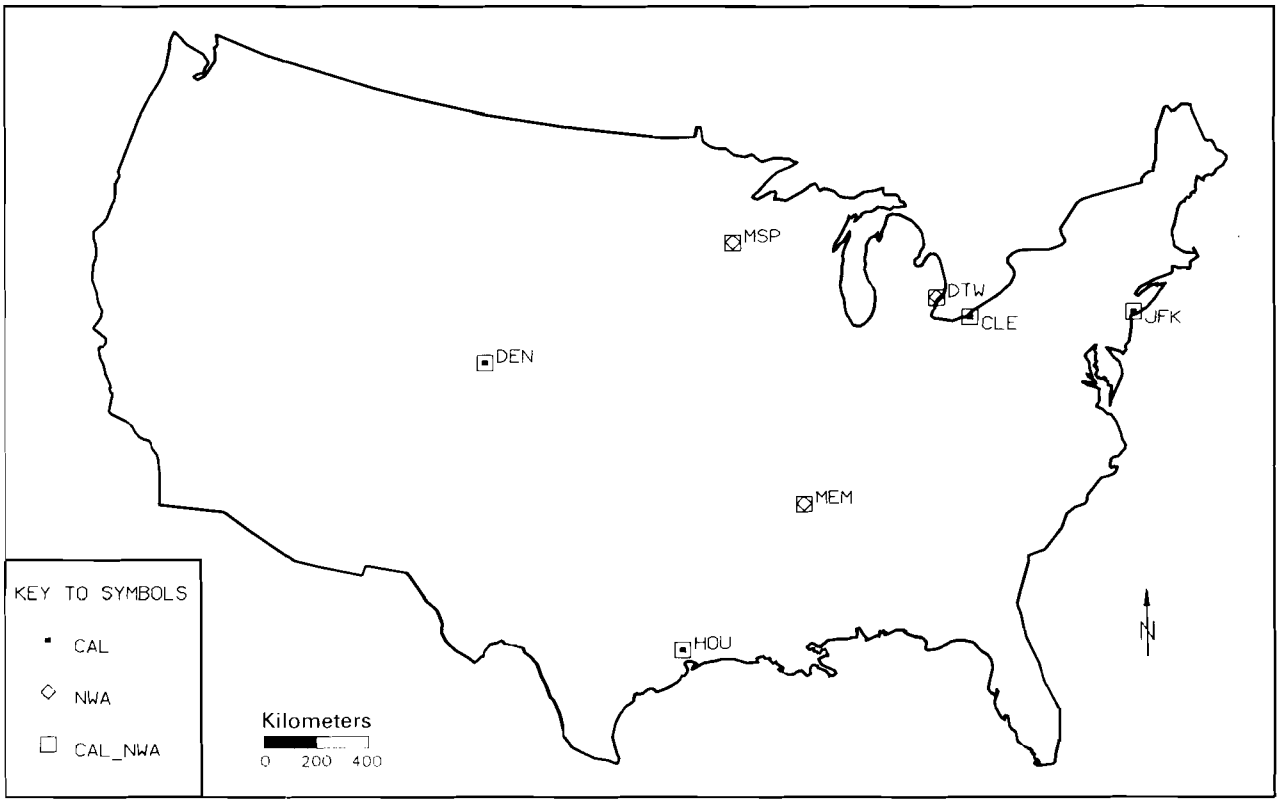

Figure 3 Geographic distributions of hubs, with $S_i < 1.7$, for Continental, Northwest and their merger

using all of the indices discussed earlier. The merger decision, of course, is also related to the strategy of the carriers involved. For example, USAir could merge with America West to gain a better coverage of the southwest quadrant of the nation, or it could merge with Northwest to expand its coverage of the middle section of the nation. Such decisions could naturally have direct implications for the success and level of competition that the newly merged carrier could engage in. The methodology and analysis presented in this study could be used by carriers to evaluate specific impacts on their network structure from a proposed merger. Such analyses could also be useful to the US Department of Transportation in evaluating the impacts that a proposed merger could have on the national market.

It is also evident from this study that the traditional aggregate network connectivity and nodal accessibility indices have their limitations on the analysis of hub network structures. One obvious limitation is their inability to compare networks in terms of geographic spacing of hubs and efficiency of hub operations. Although hub location models can help answer some of these questions, more effective indices that allow direct comparisons between hub network operations need to be developed in transport geography.

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