U.S. Department
of Transportation

**Federal Aviation
Administration**

Report to Congress

A Case Study of Potential New Connecting Hub Airports

Report of the Federal Aviation Administration Pursuant to House Report 101-183 and Senate Report 101-121 Accompanying the Department of Transportation and Related Agencies Appropriations Act, 1990

Washington, D.C. 20591

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I — Introduction

This report has been prepared in response to language in House Report 101-183 and Senate Report 101-121 accompanying the Department of Transportation and Related Agencies Appropriations Bill for FY 1990.

The Federal Aviation Administration (FAA) was asked to examine potential new connecting hub airports as a means of capacity enhancement to relieve flight delays at major hub airports.

The Appropriations Committee requested that FAA study various alternatives that might help to expand the capacity of the National Airspace System, including new connecting hub airports, reliever airports, and expanded use of existing commercial service airports. The concept of using primary commercial airports that are currently underutilized as potential new, connecting-hub airports in order to relieve flight delay at existing major hubs is one such alternative.

The FAA is undertaking planning initiatives aimed at addressing these alternatives. Among these is a plan to explore the basis for developing an expanded system of reliever, alternate origination/destination, and potential new connecting-hub airports.

This report examines four airports as possible new connecting hubs and describes their potential to relieve congestion at major hubs.

Characteristics of a Hub

At a hubbing airport, an airline schedules a "bank" or concentration of flights to arrive within a given peak hour during the day and depart in as short a time as schedule permits, allowing passengers to change planes and be on their way with minimal inconvenience. The advantages are that the passenger has a much larger choice of destinations at cheaper fares from his/her origination city than would be possible if only non-stop flights existed that were economically viable to the airline. The airlines benefit because their planes fly with fuller loads and they are able to attract more passengers because of the increased number of city-pairs they serve. Both the passenger and the airlines gain something from the operation. For people who live close to the hub airport, hubbing is beneficial because many non-stop flights are available to many cities that would not otherwise be able to support such service. This convenience and air travel savings are possible only if the hub has enough airside capacity to allow a bank of flights to arrive and depart expeditiously during peak hours.

New Hubs

It is reasonable to assume that as flight delays grow at traditional connecting hub airports, airlines will develop new connecting hub airports. Recent examples include Raleigh–Durham and Nashville.

While airlines will choose a new hub based on their own particular market strategies[1], hub airports developed since deregulation have exhibited more than one of the following characteristics:

- Strong origin/destination (O&D) market
- Good geographic location
- Expandable airport facilities
- Multiple instrument weather arrival capability
- Strong economy and availability of balanced work force
- Ability to accommodate existing/planned scheduled service fleet

1. It should be noted that these strategies are treated by an airline as proprietary, and, in general, this information is not shared outside the company, much as pricing decisions on ticket fares are not shared prior to implementation.

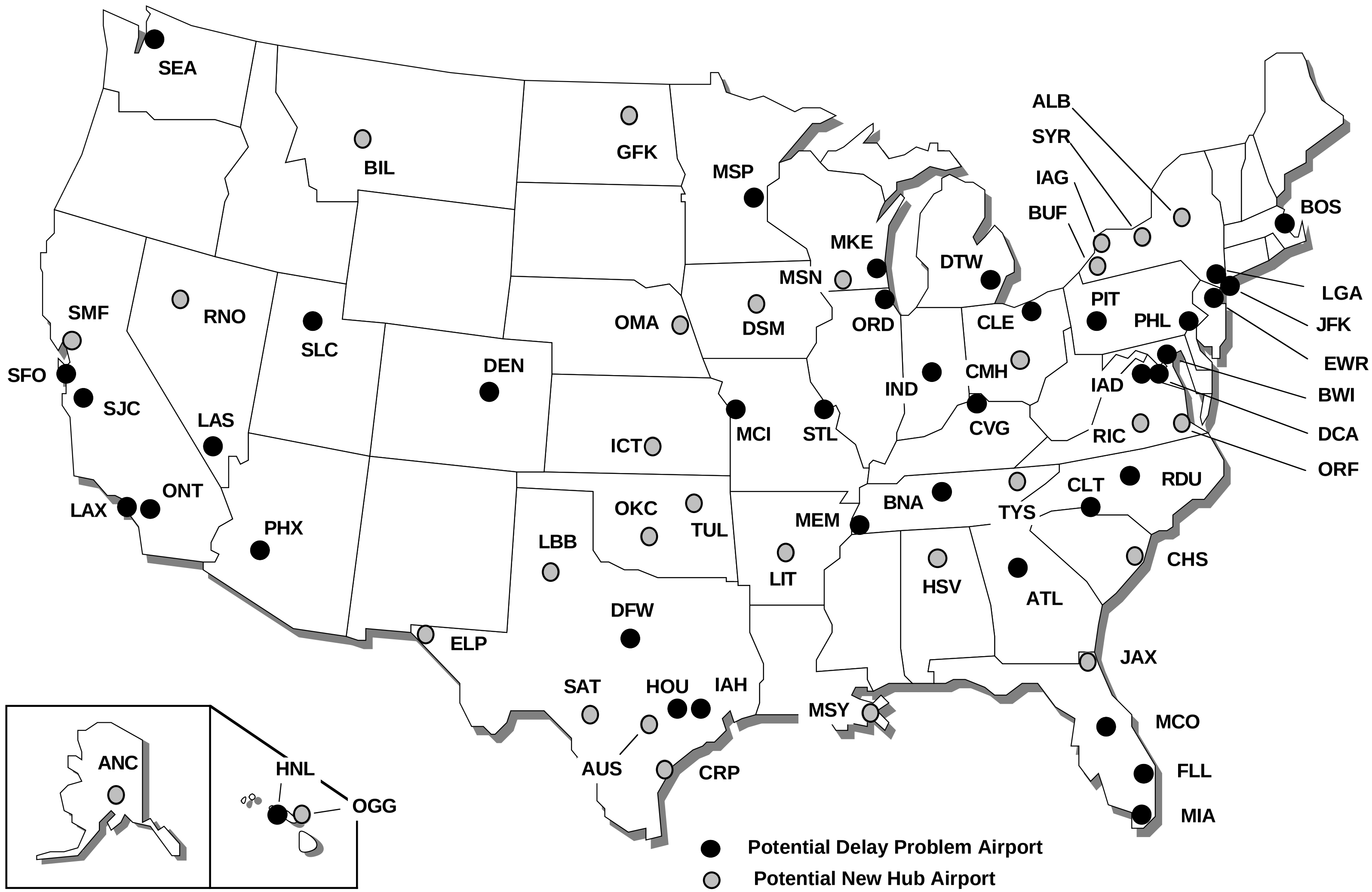

Figure I-A. Potential New Connecting Hub Airports Having Dual IFR Approaches
(more than 50 miles from 1998 potential delay problem airports)

More than two dozen airports have been identified by the Federal Aviation Administration as potential new connecting hubs. These potential hub airports, shown in Figure I-A, are more than 50 miles from forecast delay-problem airports, and each has sufficient potential runway capacity to accommodate significantly increased airport operations.

The potential new connecting hubs in Figure I-A were selected because they had the capability to permit multiple approach streams during instrument meteorological conditions, and they enplaned more than 400,000 passengers in fiscal year (FY) 1988. The actual development of new connecting hubs will be a function of airline, state, and local community decisions.[2]

The Raleigh-Durham Experience

Raleigh-Durham Airport (RDU), located in east central North Carolina, has been a major hub for American Airlines since 1987. At present American has claimed about 67% of air carrier departures and about 60% of air carrier passengers at Raleigh-Durham.

Prior to American Airlines' hub start in 1987, yearly operations at Raleigh-Durham were 190,000 to 210,000. After the start of the hub, airport operations increased steadily from 273,000 in 1988 to an estimated 290,000 in 1990. American now schedules 120 departures per day at RDU, and commuter aircraft, including American Eagle, schedule about 60 departures per day.

The basic reasons that American chose Raleigh-Durham as a hub are fourfold:

1. <u>Geography:</u> American had little or no operations in the Southeast, and RDU was about mid-point between passenger destinations in the North and South.
2. <u>Origin/Destination Traffic:</u> The Research Triangle Park, a complex of research and development, high-tech, and light industrial industries, is located adjacent to Raleigh–Durham with a high per capita income, and a highly educated work force. This work force together with local university travel provides a steady source of good passenger traffic.
3. <u>Airport Layout:</u> A new parallel runway was already under construction that would provide increased

2. 1990-91 DOT/FAA Aviation System Capacity Plan

capacity for a hub the size that American envisioned. In addition, a new terminal had been planned that airport officials would be willing to tailor to the tenant's needs.

4. Airport Authority: The management of the airport was able to react quickly and arrange the design of the airport in a timely manner. Planning and construction took about two years to complete.

The new hub has contributed definite benefits to the community in the form of increased employment. In 1986, RDU had approximately 1,800 airport employees. This figure has now grown to 4,200. Some American crews based at RDU live in the area. American also has part of the American Airlines reservation system nearby, employing 1,800 - 2,000 people.

Some organizations have moved to the Research Triangle in the last three years because of the increased service by American. Existing companies, such as IBM, have increased employment dramatically.

The Raleigh-Durham management continues to be active in promoting the airport and has co-sponsored with FAA an airport capacity design team, which has recommended options for future increased capacity and delay reductions for Raleigh-Durham. The airport already has plans for a third parallel air carrier runway, a separate general aviation runway, and numerous taxiway and exit improvements. American has indicated a desire to eventually increase departures from the present 120 daily departures to 300 per day.

Study Plan

This report will assess the impact of the development of connecting hubs by conducting four case studies of airports identified in the DOT/FAA 1990-91 Aviation System Capacity Plan that offer the possibility of reducing aircraft delays and increasing capacity at nearby major airports. The objective of these studies is to determine the effect on delay at nearby large delay problem airports, along with the effect on delay throughout the entire Air Traffic Control system as a result of the creation of a new connecting hub.

By design, the scope of this study has been limited to look only at the potential these four airports have to increase system capacity and reduce congestion and delay at major airports nearby. This study will not attempt to determine air carrier interest in selecting a particular new connecting hub. Airlines will move to develop a new hub when delays at an existing hub are no longer tolerable or when they expect to capture a significant share of the origin and destination (O&D) market at the new airport. Before an airline decides to open a new hub, it must make operational and economic sense, and the airlines treat these decisions in a proprietary, confidential manner. Marketing surveys and studies, which are beyond the scope of this study, would have to be conducted to verify the adequacy of the O&D market and determine the viability of an airline's investment in a new hub. Airports, local communities, airport authorities, and other interested members of the aviation industry can facilitate an airline's decision making process. But, in addition to conducting their own marketing surveys, they must advertise within the industry not only all the characteristics of their airport that would make it a good choice as a new hub, but also the willingness of their local community to absorb the increased traffic and noise that might result.

In addition, this study makes no attempt to determine the adequacy of the passenger terminal facilities or the air traffic control facilities, personnel, and equipment to support a new connecting hub at any of these airports. At some point relatively early in the airline's decision process, the FAA and the local airport authority need to be notified of the possibility that the airline may open a new connecting hub so that necessary preparations can be made to accommodate the rapid increase in passengers and aircraft operations.

Each of these four airports is capable of supporting an expansion in operations while decreasing delays at nearby airports. These airports will be described in terms of their existing physical facilities, operations, capability to support expanded operations, and forecast flight delay savings at other major hub airports.

The four potential new connecting hub airports are located at:

1) Huntsville, Alabama
2) Port Columbus, Ohio
3) Sacramento, California
4) Oklahoma City, Oklahoma

The four selected airports were chosen for their geographical diversity and are among the thirty identified as potential new hubs in Figure I-A. It is most likely that a study featuring the other airports identified as potential new connecting hubs would produce results similar to those found in the following pages.

II — Four Potential New Connecting Hub Airports

Huntsville, Alabama
Port Columbus, Ohio
Sacramento, California
Oklahoma City, Oklahoma

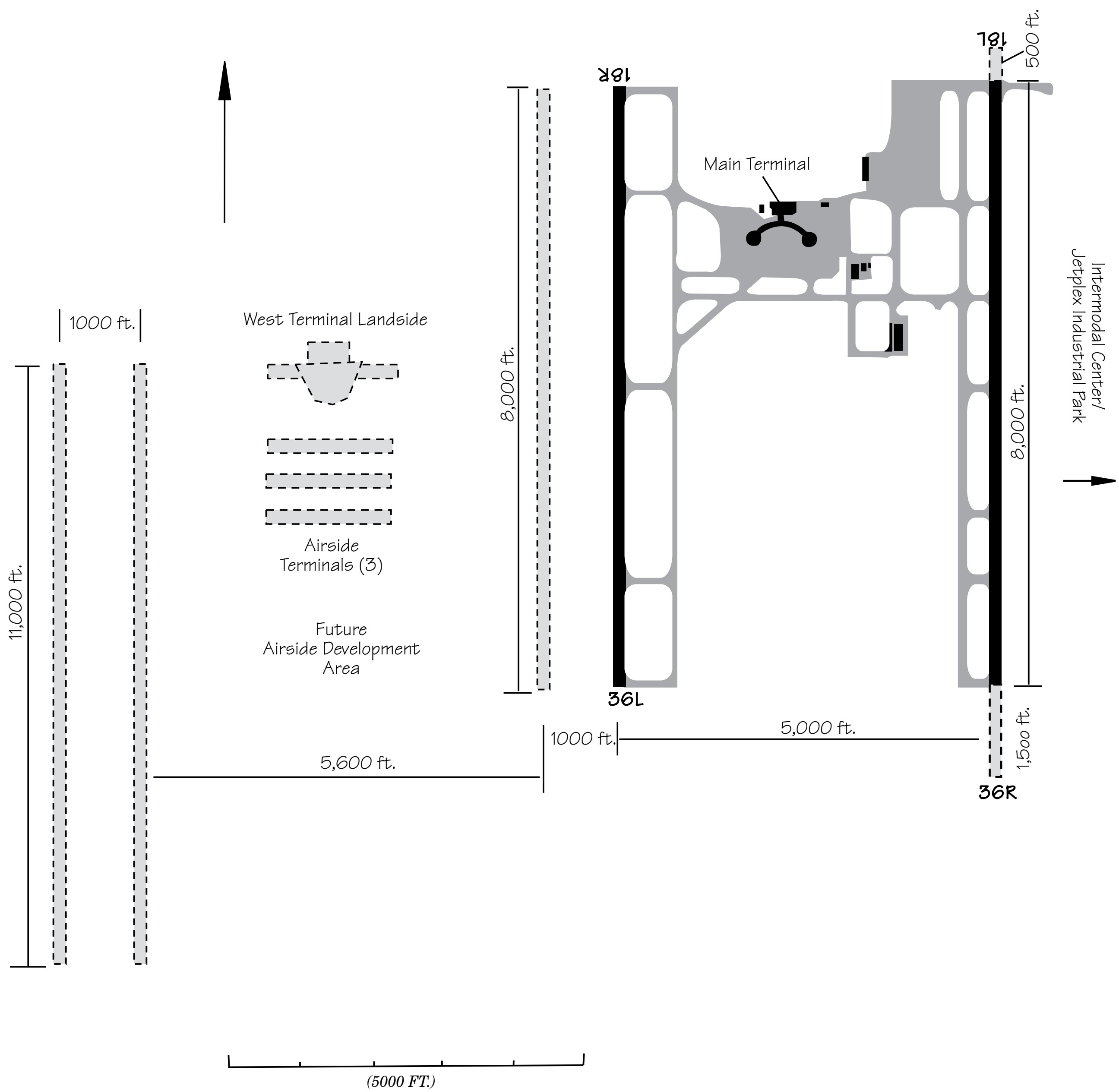

Figure A-1
Huntsville
International Airport

A. Huntsville International Airport

Huntsville International Airport — Carl T. Jones Field (HSV) has two 8,000-foot runways separated by 5,000 feet and a new airport surveillance radar (ASR-9). The weather conditions in the region are not extreme, and visual meterological conditions occur 85-90% of the time.

The airport, located on a site of 3,330 acres, is twelve miles southwest of downtown Huntsville, Alabama. Huntsville International is about 130 nautical miles northwest of Atlanta, making it an attractive transfer point for the southeastern United States and offering airlines and passengers the opportunity to avoid potential aircraft delays at Atlanta's Hartsfield International Airport.

Physical Facilities

Huntsville International arriving air traffic is handled by Memphis Air Route Traffic Control Center and handed off to the control of the Huntsville Airport Radar Service Area, which uses the new ASR-9 radar. The tower is an FAA Level 3 Radar Facility, based on total instrument operations, and is staffed from 6 a.m. to midnight daily. At other hours radar assistance is provided by the Memphis Center. Huntsville tower handled 116,853 instrument operations in fiscal year 1989, and ranks Number 154 nationally in total instrument operations.

The airport (Figure A-1) has two parallel north/south runways (18 Right/36 Left and 18 Left/36 Right) separated by 5,000 feet, which could allow simultaneous instrument landings. Huntsville has Category I (CAT I) ILS approaches to runways 18R, 18L, and 36L and both runways are equipped with high intensity runway lighting systems. No ILS approach procedure is currently available for runway 36R. (Category I instrument approaches allow an approach down to 200 feet above the ground with a runway visual range of not less than 1,800 feet, while Category II instrument approaches allow an approach down to 100 feet above the ground with a runway visual range of not less than 1,200 feet.) The airport is scheduled to add Category II (CAT II) approach capability to runway 18R/36L in 1991. There are no published noise restrictions for aircraft operations.

A southerly approach stream makes the best use of the airport layout.[3] Huntsville can handle 105 operations (takeoffs and landings) per hour under Instrument Flight Rules

3. As defined as: The highest suitable capacity consistent with current ATC rules and practices — FAA AC 150/5060-5

(IFR) and 159 under Visual Flight Rules (VFR).[4] Visual Flight Rules are applicable when the cloud ceiling (the distance between the ground and cloud cover), is 1,000 feet or more, and the visibility is not less than 3 statute miles. Instrument Flight Rules (IFR) are applicable when cloud cover is less than 1,000 feet and 3 statute miles.

Given the present IFR capability (CAT I ILS to runways 18R, 18L, and 36L) and the addition of an ILS approach to 36R, Huntsville could handle an additional 217,000 operations per year[5] with a variety of wind/weather conditions.

The terminal is located midway between the runways near the north end of the field. An extensive terminal, cargo, and facilities expansion is underway that will provide the capability to handle increased passenger, cargo, and aircraft traffic. The new 640-foot long, 90-foot wide concourse will feature second level boarding with jet loading bridges and a total of ten gates. Four commuter aircraft parking positions are also available at the concourse. This new terminal facility has approximately 161,000 square feet available.

Huntsville International is located near Interstate 65, and a newly opened Interstate 565 interchange has greatly increased access to the airport, as the interchange feeds traffic directly into and out of the airport facility.

Huntsville is home for the International Intermodal Center, which supports receiving, transferring, storing, and distributing containerized rail, truck, and air cargo. The Norfolk Southern Railroad mainline is approximately two miles from the Intermodal Center. A spur rail connects the mainline to the Center.

The International Air Cargo Center, located in the Intermodal Center, has 87,500 square feet of space for receiving and distributing cargo, a public use free-trade zone, and customs services. Huntsville is a U. S. Customs Port of Entry and has Foreign Trade Zone status. U. S. Customs, customs brokers, and freight forwarders are available at the airport. The east runway (18L/36R) is being extended to 10,000 feet to accommodate international wide-body cargo aircraft.

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4. FAA, Office of Planning and Programming
   This assumes current fleet mix. If Huntsville became a hub, fleet mix would change and capacity would probably be reduced to 100-110 operations per hour under VFR.
5. 1989 DOT/FAA Airport Capacity Enhancement Plan

Operations

Passenger growth and enplanements for the last five calendar years have been as follows:

Enplanements (000)
1985 - 342
1986 - 374
1987 - 443
1988 - 439
1989 - 452

Huntsville is ranked Number 110 in enplanements in the Air Carrier Activity Information System (ACAIS) data base for the calendar year 1988.

Air carriers account for about 26% of daily traffic at Huntsville, with a reported 329 air carrier operations a week.

The airport is served by five major carriers, three commuter airlines, and several air cargo carriers. Fleet mix is 1% heavy jet, 29% large jet, 33% large prop, and 47% small prop. Huntsville was ranked Number 107 in total operations for FY 1988.

Capability to Expand Capacity

The airport is in the midst of a $37 million expansion project which includes a new concourse, remodeling and expansion of the existing terminal, apron and parking expansion, 18L/36R runway extension and overlay, and construction of an international air cargo center. As a result of its Foreign Trade Zone status, industrial bond financing, and a number of unique tax benefits, the airport has managed to attract industrial development on and near the airport. A major hotel located on the airport plans to expand its facility.

The airport plans to expand its facilities and runways over the next ten years. Acquisition of more than 3,000 acres west of the airport is planned, with land appraisals underway. A Huntsville International Airport Development Project Summary indicates that a planned parallel runway 1,000 feet west of 18R/36L could expand present capacity, by allowing more arrival and departure capability under Visual Flight Rules. In addition, a third (as well as a possible fourth) parallel runway 11,000 feet long is planned, located 6,600 feet west of existing 18R/36L, that could permit triple independent IFR arrivals, when triple approaches are approved. The result would be a potential increase to 78 independent arrivals per hour (156 operations) at Huntsville, under instrument arrival procedures. Because of the advanced planning and zoning for industrial use at the airport, there is ample room for expansion of the facilities.

A new west terminal area site plan at Huntsville indicates an international arrival facility with eight gates and three airside terminals, each with 36 gates. This landside facility and three airside terminals, connected by an underground quick transit system, would have a future total of 116 gates.

Flight Delay Analysis

A new connecting hub at Huntsville could produce delay savings with a potential diversion of flights from Atlanta Hartsfield (ATL). The following figures illustrate the potential effect on delays at Atlanta if a new connecting hub were created at Huntsville.

The scenario consists of estimating demand and delay at Atlanta in some future period assuming no change in the role Huntsville presently plays relative to Atlanta. This situation is then compared to one in which Huntsville has become a new connecting hub airport and now handles some of the traffic growth that previously connected at Atlanta. Specifically, it assumes that 200 daily operations (100 arrivals and 100 departures) are relocated as a result of establishing a new connecting hub at Huntsville. That number of flights would be "diverted" from the future growth at Atlanta.

The analysis uses FAA forecasts for 1998[6] as the basis of "future" demand. The figures in this section refer to 1998 simply as "future" demand, allowing for the possibility that the 1998 forecasted demand levels will be reached at a time other than 1998. The methodology and inputs are found in Appendix A.

6. DOT/FAA, FAA Terminal Area Forecast, July 1989

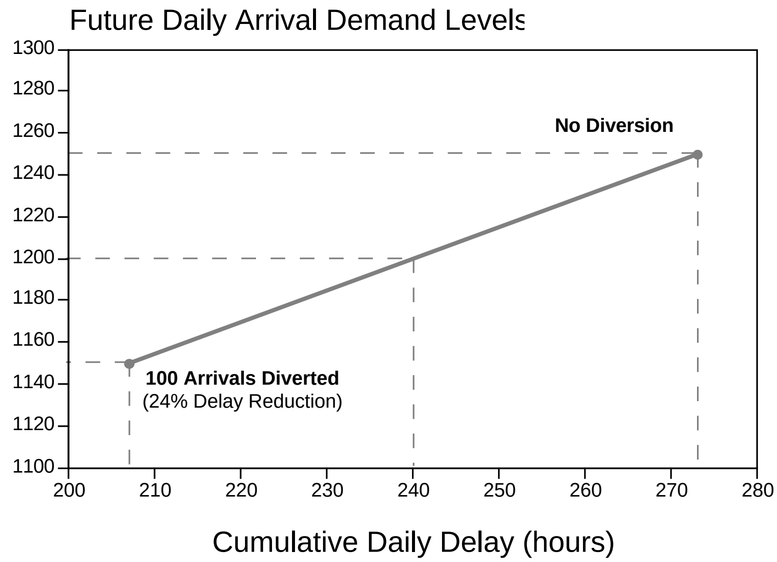

Figure A-2. Total Delay for Varying Arrival Demand Atlanta (ATL)

Atlanta's current baseline activity is 1,150 daily arrivals, while future demand is estimated at 1,249 daily arrivals. This future level of activity reflects a cumulative level of daily flight delay of 273 hours. This does not take into account Eastern Airlines' cessation of business in early 1991.

If, as a result of Huntsville's potential new hub status, 100 daily arrivals (200 operations) were shifted from future growth at Atlanta to Huntsville, the forecast daily delay at Hartsfield would be reduced 66 hours, a 24% delay reduction (Figure A-2). It can be shown by interpolation, a diversion of 50 daily arrivals (100 operations) would result in a reduction of 33 hours of forecast daily delay at Atlanta Hartsfield.

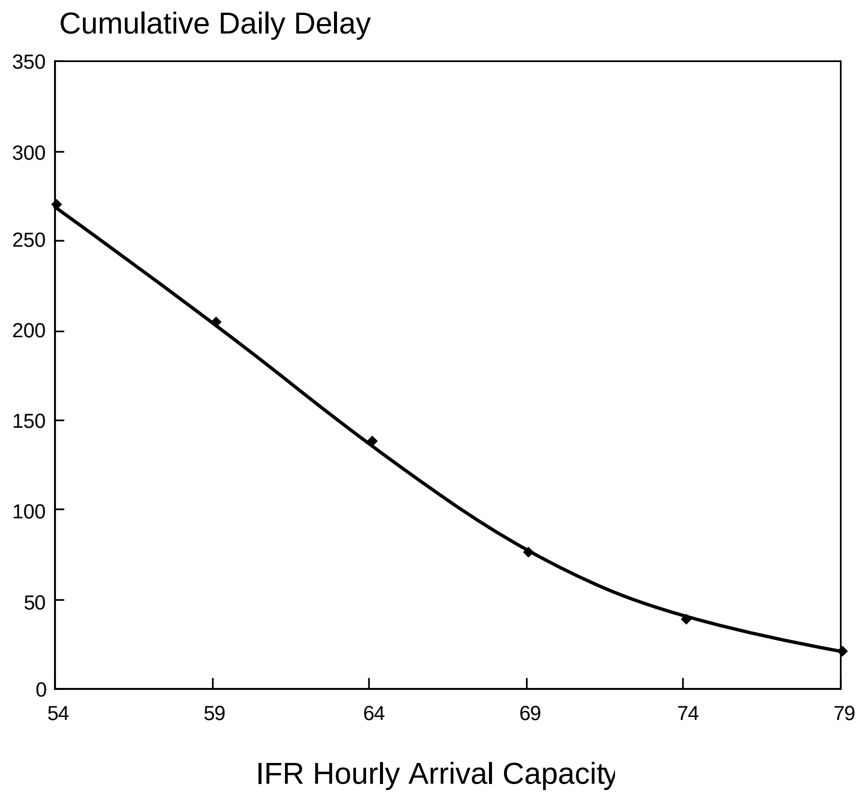

Figure A-3. Capacity Delay Curve for Atlanta (ATL) Assuming a New Connecting Hub at Huntsville

Figure A-2 assumes an hourly arrival capacity of 59 flights under Instrument Flight Rules (IFR) at Atlanta. Figure A-3 shows the relationship between capacity and delay at Atlanta Hartsfield at future demand levels, at various IFR capacities. The curve indicates a proportionate decrease in benefits if arrival capacity grows at Atlanta. For example, an IFR hourly arrival rate of 69 would result in a daily delay of 75 hours.

A separate study was conducted to measure the impacts throughout the National Airspace System’s network of airports of establishing a new connecting hub at Huntsville (HSV) which could relieve growth-induced flight delays at Atlanta (ATL). Four scenarios were assumed:

1. VFR weather conditions throughout the country, without the establishment of Huntsville as a hub (the "VFR Base" scenario).
2. The same as the VFR Base scenario, but with Huntsville established as a connecting hub (the "VFR New Hub" scenario).
3. IFR (Category I) weather conditions at Atlanta and Huntsville, without the establishment of Huntsville as a hub (the "IFR Base" scenario).
4. The same as the IFR Base scenario, but with Huntsville established as a hub (the "IFR New Hub" scenario).

All scenarios assume 1998 traffic growth, as projected in the FAA's Terminal Area Forecasts. All values are per day. The methodology and inputs are found in Appendix B.

Hubs	**Weather**		**Delay Hours U.S. Systemwide**
ATL/HSV	VFR	Base	2,060
		New Hub	2,053
		Diff.	(7)
		% Diff.	-0.34%
	IFR	Base	3,174
		New Hub	2,799
		Diff.	(375)
		% Diff.	-11.81%

Under VFR conditions on the sample day in 1998, 2,060 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from Atlanta to Huntsville, 2,053 delay hours occured systemwide.

Therefore, 7 fewer hours of delay occured in the VFR scenario with the establishment of Huntsville as a new hub. The 7 delay hours amount to a reduction of 0.34% total hourly system delay.

The table also indicates that under IFR conditions on the 1998 sample day, 3,174 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from Atlanta to Huntsville, 2,799 delay hours occured. This reduction of 375 hours amounts to a decrease of 11.81% total hourly system delay.

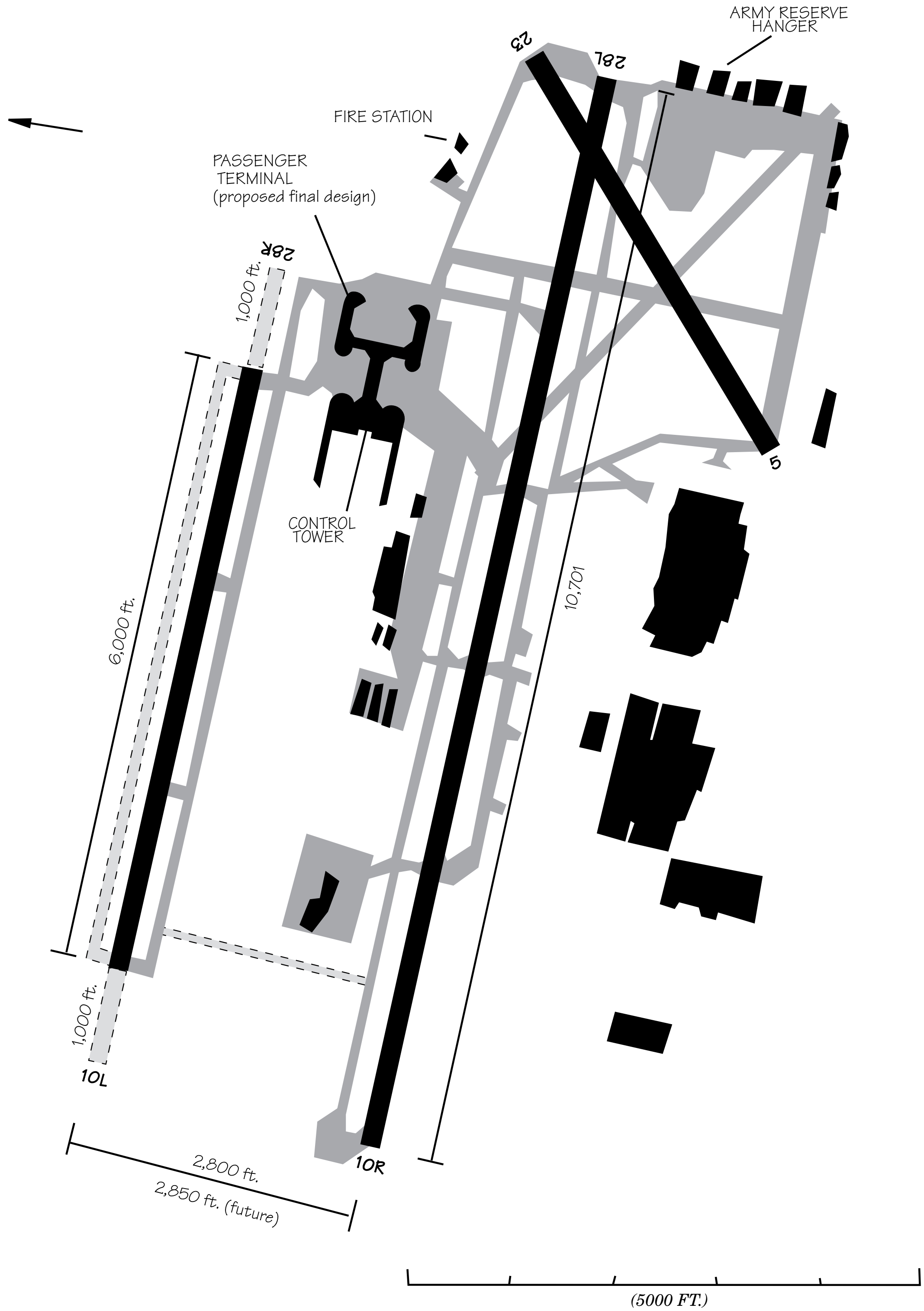

Figure B-1
Port Columbus
International Airport

B. Port Columbus International Airport

Port Columbus International Airport (CMH) is located within the City of Columbus, Ohio, on the east side. Port Columbus is located about 265 miles southeast of Chicago, one hour by air. As a new connecting hub airport, it could help reduce potential flight delays at Chicago O'Hare.

Winters are mild, and the airport has never been closed because of snow or ice storms. VFR conditions exist approximately 89% of the time.

Physical Facilities

Port Columbus arriving air traffic is handled by Columbus Radar Approach Control, located on the airport, and handed off to the Port Columbus Airport Tower Facility. The tower is an FAA Level 4 Radar Facility, based on total instrument operations, and is attended continuously. Port Columbus handled 330,651 instrument operations in fiscal year 1989, and ranks Number 57 nationally in total instrument operations.

In 1981, Port Columbus opened a newly renovated main terminal and in December, 1989, opened a new 102,000 square foot South Concourse with an additional seven gates resulting in a total of twenty-five. Three more gates are planned for a proposed total of twenty-eight. An upgrade of the international arrivals area is scheduled for 1991. U.S. Customs is located in the Port Columbus terminal.

Columbus is a major cargo destination center. The airport's geographic location allows air cargo to be delivered quickly, as nearly one-half of the Nation's population can be reached in one day's drive from Columbus. Interstates 70 and 71 are nearby, permitting rapid transportation of Port Columbus air freight. As a result, and in response to demand from shippers, work will begin shortly on a new 55,000 square foot cargo facility.

Port Columbus (Figure B-1) has two parallel runways (10R/28L and 10L/28R) separated by 2,800 feet and a third intersecting runway (5/23). Runway 10L/28R is 6,000 feet long (soon to be extended to 8,000 feet) and runway 10R/28L is 10,701 feet long. Runway 5/23 is a 4,483-foot runway intersecting the 10,701-foot runway near the approach end of 28L. There are Category I (CAT I) ILS approaches to runways 28L, 10R, 10L and a non-precision approach to 28R. As a result, multiple approaches are only available to the east on runways 10R and 10L. Noise restrictions consist of the closing of runway 10L/28R for turbine engine operations on a daily basis between the hours of 10 p.m. and 7 a.m.

Current airport capacity is 63 operations per hour in IFR and 152 operations per hour in VFR.[7] It should be noted that during IFR conditions, the airport operates with two dependent parallel IFR approach arrival streams to runways 10R and 10L. Parallel approach streams are dependent when aircraft in one stream must maintain separation standards with aircraft in the adjacent stream. Current standards require a diagonal separation of two nautical miles between aircraft on adjacent approaches, in addition to in-trail separation between aircraft in the same arrival stream. An FAA program is underway to allow independent parallel operations with runway separations less than the current standard 4,300 feet.[8] If new runway separation criteria are permitted to 2,800 feet, this potential new technology could allow independent approaches at Port Columbus, and the IFR capacity could be increased to about 104 operations per hour.[9] If the separation criteria are not reduced to 2,800 feet, this increased operation level under IFR conditions may not be achievable.

Operations

Port Columbus had 1,759,000 enplanements in calendar year (CY) 1988, an increase of 3.8% over CY 1987. Port Columbus passenger enplanements from 1985 to 1989 are as follows:

Enplanements (000)
1985 - 1,526
1986 - 1,573
1987 - 1,695
1988 - 1,759
1989 - 1,789

Port Columbus is ranked Number 58 in enplanements in the 1990-91 FAA Aviation System Capacity Plan.

On an average day, Port Columbus has about 130 air carrier departures. Currently Port Columbus is served by 17 airlines, and there is no dominant carrier. Nearly all major

7. FAA, Office of Planning and Programming
8. 1990-91 DOT/FAA Aviation System Capacity Plan
9. Ibid.

service markets of Columbus are served by two or more competing carriers. Fleet mix typically consists of 0.1% heavy jet, 73% large jet, 0.1% large prop, and 27% small prop.

Port Columbus was ranked Number 42 in total operations for FY 1988. Operations over the last five fiscal years were as follows:

Operations (000)

1985 - 224
1986 - 237
1987 - 233
1988 - 233
1989 - 233

Capability to Expand Capacity

The airport is beginning a five–year $80 million dollar expansion of facilities. Runway 10L/28R is to be extended 1,000 feet on each end for a total length of 8,000 feet. A Port Columbus Airport Layout Plan also calls for a new parallel taxiway located just north of runway 10L/28R, as well as a new cross -over taxiway between parallel runways 10L/10R located to the west of the terminal. The new taxiways will provide easier access between runways and to the terminal area. Other planned improvements include an upgrade of runway 10R/28L with a CAT II instrument landing system and various taxiway construction.

A proposed site plan indicates an expansion of the present terminal and concourses allowing for a total of 54 gates. This new dual concourse would be connected to the terminal just east of the existing terminal and concourses.

Flight Delay Analysis

A new connecting hub at Port Columbus could produce delay savings with a potential diversion of flights from Chicago O'Hare (ORD). It should be noted that growth at Chicago O'Hare is limited because of continued slot restrictions. In comparison to other nearby competing hubs, O'Hare experienced little growth in air carrier operations from 1978 to 1988. A review of air carrier operations over this eleven year period is indicated in the following table:

Air Carrier Operations at Selected U. S. Hub Airports for Fiscal Years 1978 and 1988

Hub Airport	Air Carrier Operations FY 1978	Air Carrier Operations FY 1988	Average Annual Percent Change
Chicago O'Hare	598,304	631,073	0.5%
Chicago Midway	1,946	112,213	50.0%
Denver	268,586	374,614	3.4%
Detroit	62,776	250,445	4.4%
Minneapolis/St. Paul	127,036	214,025	5.4%

Figures B-2 and B-3 illustrate the potential effect of creating a new connecting hub airport at Port Columbus by diverting potential demand at Chicago O'Hare International Airport.

The analysis uses FAA forecasts for 1998 as the basis of "future" demand. The figures in this section refer to 1998 simply as "future" demand, allowing for the possibility that the 1998 forecasted demand levels will be reached at a time other than 1998. The methodology and inputs are found in Appendix A.

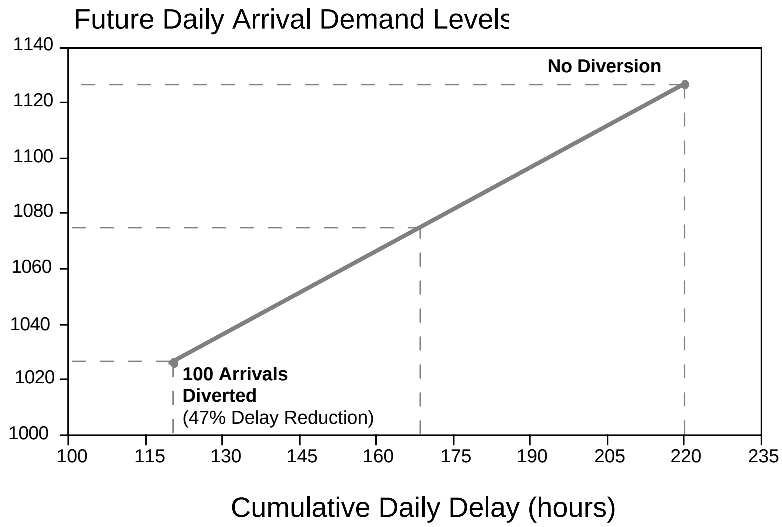

Figure B-2. Total Delay for Varying Arrival Demand Chicago (ORD)

The scenario consists of relocating 200 daily operations (100 arrivals and 100 departures) by establishing a new connecting hub at Port Columbus. That number of flights would be, therefore, “diverted” from future growth at Chicago O’Hare. The difference in flights at O’Hare is a daily average of 1026 flight arrivals versus 1126 arrivals, although intermediate levels are also considered.

This potential flight arrival diversion would result in an average flight delay savings of 102 hours per day at O’Hare Airport (Figure B-2). By interpolation, about 51 hours of forecast delay would be reduced at O’Hare by shifting 50 flights (100 operations) to Columbus.

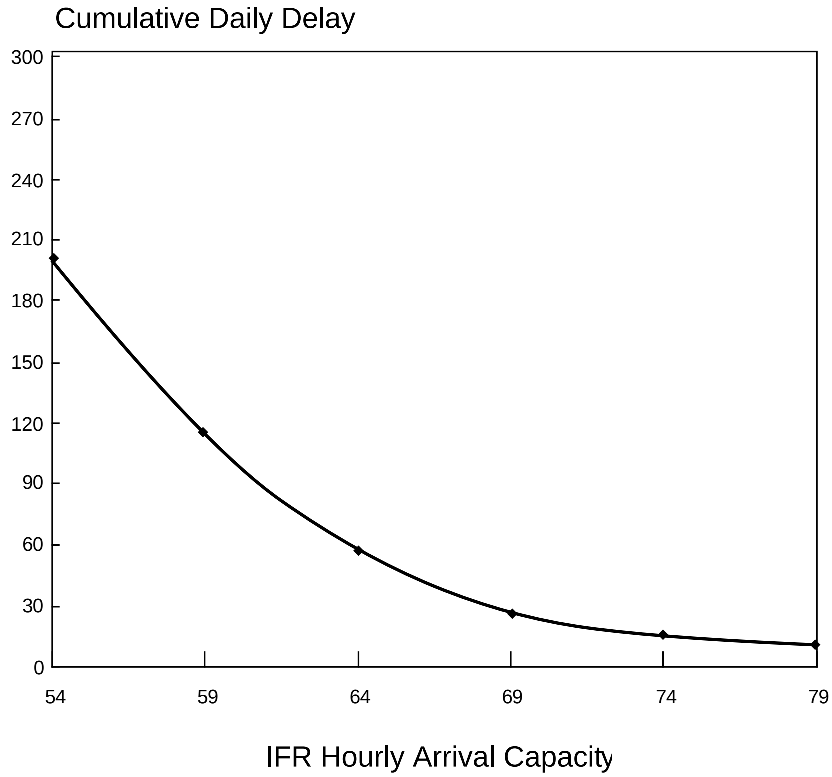

Figure B-3. Capacity Delay Curve for Chicago (ORD) Assuming a New Connecting Hub at Port Columbus

The level of delay savings, as depicted in Figure B-2, is based upon hourly arrival capacity at O'Hare of 59 flights during IFR. The above Figure B-3 shows the level of future delay savings if arrival capacity at Chicago O'Hare increases. For example, if hourly capacity at O'Hare were to increase from 59 arrivals to 64 arrivals, the cumulative daily delay would be reduced from 117 hours to 58 hours. Increased hourly capacity levels above 64 arrivals, however, would result in much smaller delay savings, and after 74 arrivals would result in negligible delay savings.

A separate study was conducted to measure the impacts throughout the National Airspace System's network of airports of establishing a new connecting hub at Port Columbus (CMH) to relieve growth-induced flight delays at Chicago O'Hare (ORD). Four scenarios were assumed:

1. VFR weather conditions throughout the country, without the establishment of Port Columbus as a hub (the "VFR Base" scenario).
2. The same as the VFR Base scenario, but with Port Columbus established as a connecting hub (the "VFR New Hub" scenario).
3. IFR (Category I) weather conditions at Chicago O'Hare and Port Columbus, without the establishment of Port Columbus as a hub (the "IFR Base" scenario).
4. The same as the IFR Base scenario, but with Port Columbus established as a hub (the "IFR New Hub" scenario).

All scenarios assume 1998 traffic growth, as projected in the FAA's Terminal Area Forecasts. The methodology and inputs are found in Appendix B.

The results (summarized in the following table) indicate the systemwide impacts under the assumed IFR and VFR conditions. All values are per day.

Hubs	**Weather**		**Delay Hours U.S. Systemwide**
ORD/CMH	VFR	Base	2,060
		New Hub	1,997
		Diff.	(63)
		% Diff.	-3.06%
	IFR	Base	2,541
		New Hub	2,291
		Diff.	(250)
		% Diff.	-9.84%

Under VFR conditions on the sample day in 1998, 2, 060 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from Chicago O'Hare to Port Columbus, 1,997 delay hours occured systemwide. Therefore, 63 fewer hours of delay occured in the VFR scenario with the establishment of Port Columbus as a new hub. The 63 delay hours amount to a reduction of 3.06% total hourly system delay.

The table also indicates that under IFR conditions on the 1998 sample day, 2,541 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from Chicago O'Hare to Port Columbus, 2,291 delay hours occured. This reduction of 250 delay hours amounts to a decrease of 9.84% total hourly system delay.

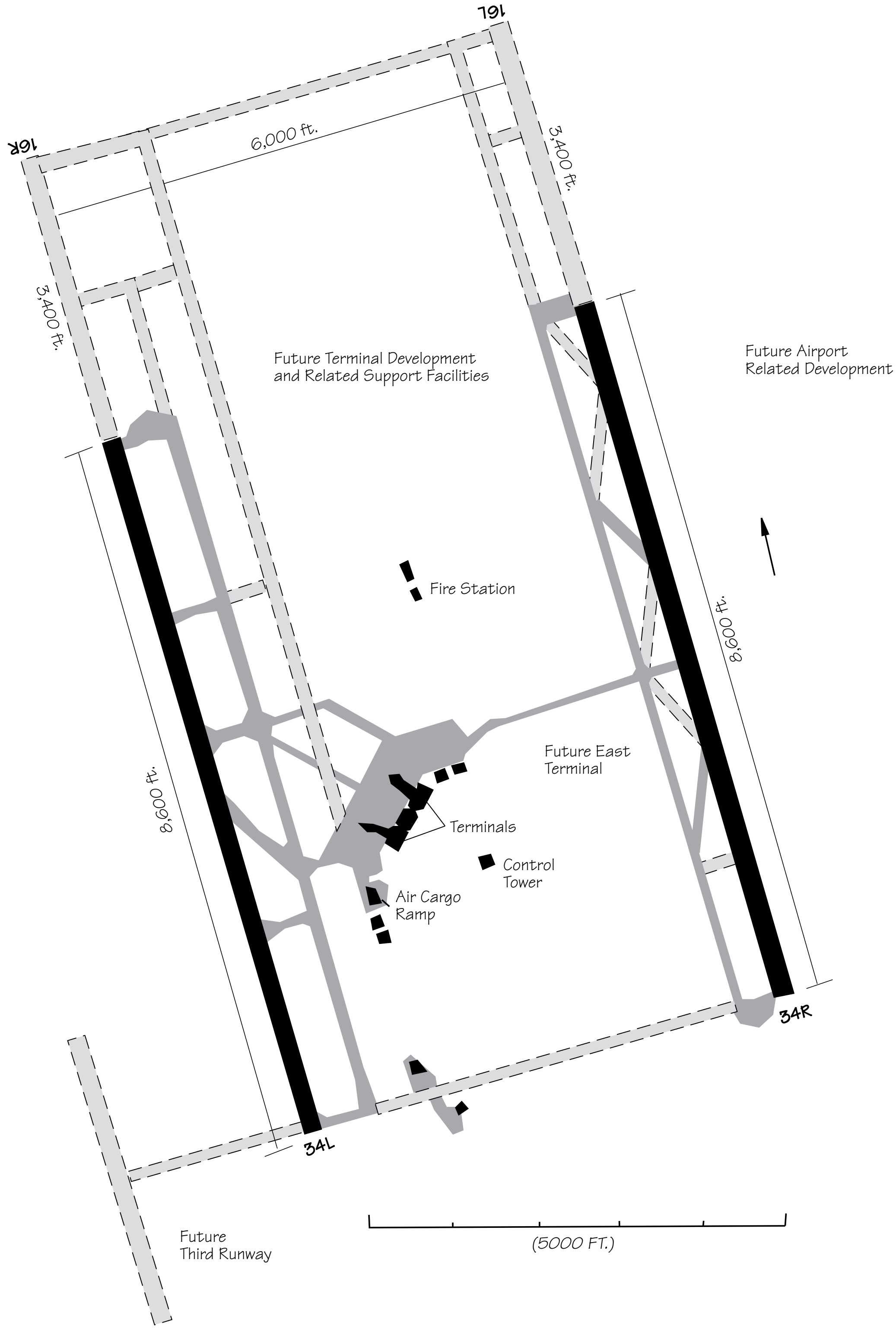

Figure C-1
Sacramento
Metropolitan Airport

C. Sacramento Metropolitan Airport

Sacramento Metropolitan Airport (SMF) is located approximately 70 miles east of San Francisco on a site of 5,500 acres, twelve miles northwest of downtown Sacramento. Arriving or departing passengers at Sacramento Metro have a short, direct highway link to Interstate 5. Interstate 80, a major west-east highway is nearby. The City of Sacramento is about a fifteen minute drive to the southeast. As a new connecting hub airport, Sacramento could offer airlines and passengers the opportunity to avoid potential delays at San Francisco International.

VFR conditions (above CAT I) occur approximately 95-98% of the time at Sacramento Metropolitan.[10]

Physical Facilities

Sacramento Metropolitan arriving air traffic is handled by the Sacramento Terminal Radar Approach Control, located at nearby McClellan Air Force Base, and handed off to the control of the Sacramento Metropolitan Tower. The tower is an FAA Level 2 Facility, based on total airport operations, and is operated continuously. Sacramento Metropolitan handled 119,024 instrument operations in fiscal year 1989 and ranks Number 152 nationally in total instrument operations.

The airport has a two–unit terminal with thirteen second-level gates. A commuter terminal with ground boarding gates is located just east of the main terminal.

Two air cargo and freight terminals are located between the passenger terminals and the general aviation ramp. Thirty-four million pounds of freight and twenty-one million pounds of air mail are shipped annually to and from the airport.

Sacramento Metropolitan (Figure C-1) has two parallel runways, 16L/34R and 16R/34L. Each runway is 8,600 feet long separated by 6,000 feet. Runways 16R and 34L are equipped with ILS approaches and are Category I instrument approach runways. Runway 16R now has Category III ILS approach capability and is equipped with center line, touchdown zone, and high intensity runway lighting. (Category III approaches allow instrument approaches

10. The ability to conduct *visual approaches* would be closer to 80%, since visual approach criteria are greater than basic VFR conditions. Ground fog, dust, and smoke from agricultural burning may result in localized reduction of visibility.

without a decision height minimum, and runway visibility range down to 700 feet (or lower).) Non-precision approaches are available to 16L/34R. Runway 16L has high intensity runway lighting. A midfield taxiway provides direct and balanced aircraft taxi times from either runway. Although there are no published noise restrictions for the airport, there are informal noise abatement procedures, which might limit airport capacity.

Since Sacramento Metropolitan has ILS approaches in both directions to only one runway (16R/34L), the IFR airport capacity is limited to a one runway arrival stream to the north or to the south. This results in an hourly IFR capacity of 56 operations. Hourly VFR capacity is 149 operations.

If independent ILS approaches are made available to both 16L/34R and 16R/34L, the IFR capacity would increase to 111 operations per hour under IFR.[11] With independent ILS approaches to present runways, Sacramento Metropolitan has a potential unused capacity of 129,000 operations per year under IFR conditions.[12]

Operations

Sacramento Metropolitan has had a steady growth of enplanements since the early eighties. 1989 Sacramento Metropolitan Airport statistics indicate that 3,733,594 passengers were enplaned and deplaned. Sacramento Metropolitan is ranked Number 55 in enplanements in the 1990-91 FAA Aviation System Capacity Plan. Enplanements for the last five calendar years at Sacramento Metropolitan are:

Enplanements (000)

1985 - 1,350
1986 - 1,606
1987 - 1,750
1988 - 1,792
1989 - 1,800

On a typical day Sacramento Metropolitan has about 140 scheduled air carrier departures with a fleet mix of 34% large jet, 26% large prop, and 40% small prop. Currently the

11. FAA, Office of Planning and Programming
This assumes current fleet mix. If Sacramento Metropolitan became a hub, fleet mix would change and capacity would probably be reduced to 100-110 operations per hour under VFR.
12. 1989 DOT/FAA Airport Capacity Enhancement Plan

airport is served by seven major carriers, four commuter airlines, and a number of cargo carriers.

Sacramento Metropolitan is ranked Number 65 in total operations for FY 1988. Total operations for 1985 to 1988 were as follows:

<u>Operations (000)</u>

1985 - 135

1986 - 155

1987 - 163

1988 - 182

Capability to Expand Capacity

According to a current Sacramento Metropolitan Airport Layout Plan, existing runways 16R/34L and 16L/34R will ultimately be lengthened to the north to 12,000 feet and have Category III (CAT III) approach capability. Additional taxiways at the ends of the two runways will allow more airport flexibility and capacity. Property is zoned for future airport–related development to the east of the airport.

Land is available to the west, between the airport and the Sacramento River, that would allow for the potential development of an additional runway or other airport facilities. A third runway would allow for the separation of general aviation aircraft from air carrier traffic. This potential third runway could also allow for triple IFR approaches, if triple approaches are approved, thus increasing IFR airport capacity.

Space for a future east terminal and related support facilities is available east of the present Terminals 1 and 2. New construction expected to begin in 1992 will include a third unit terminal with a single concourse, initially, with up to twenty-two additional gates. The Sacramento Metropolitan Airport Layout Plan calls for an eventual total of as many as 64 gates.

A large area of land between runways has been reserved north of the terminal complex for future terminal development and airport support facilities. Planning studies have indicated that this area could accommodate an additional passenger terminal with a capacity of from 100 to 120 aircraft gates, if needed.

The Plan has also reserved space for a rapid transit right of way, should the system become available. Planned realignment of roads, other than Interstate 5, near Sacramento Metropolitan could allow for more efficient access to the airport for surface traffic coming from the north and south.

Flight Delay Analysis

A new connecting hub at Sacramento Metropolitan could produce delay savings with a potential diversion of flights from San Francisco International (SFO). The following figures illustrate the potential effect on delays at San Francisco if a new connecting hub were created at Sacramento Metropolitan.

The scenario consists of estimating demand and delay at San Francisco in some future period assuming no change in the role Sacramento Metropolitan presently plays in the system. This situation is then compared to one in which Sacramento Metropolitan has become a new connecting hub airport and now handles some of the traffic growth that previously connected at San Francisco. Specifically, it assumes that 200 daily operations (100 arrivals and 100 departures) are relocated as a result of establishing a new connecting hub at Sacramento Metropolitan. That number of flights would be "diverted" from the future growth at San Francisco.

The analysis uses FAA forecasts for 1998 as the basis of "future" demand. The figures in this section refer to 1998 simply as "future" demand, allowing for the possibility that the 1998 forecasted demand levels will be reached at a time other than 1998. The methodology and inputs are found in Appendix A.

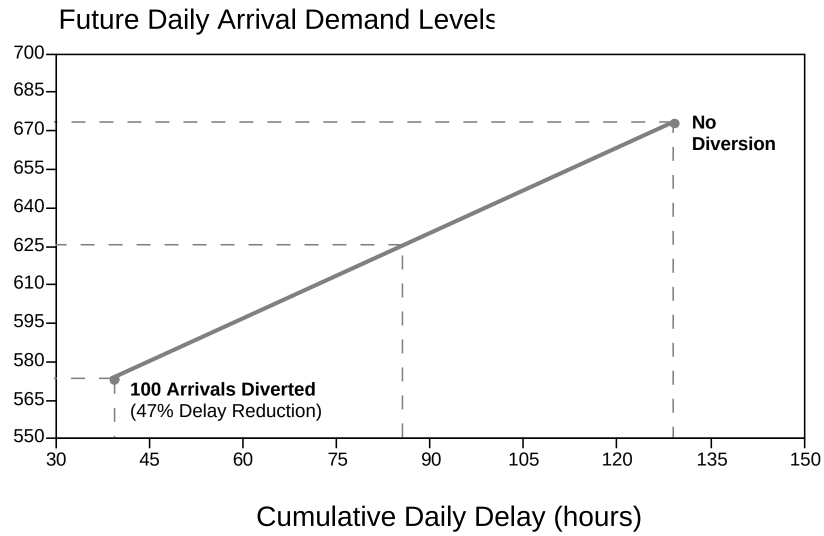

Figure C-2. Total Delay for Varying Arrival Demand San Francisco (SFO)

Future demand at San Francisco International is estimated at 673 daily arrivals. This level of activity reflects a cumulative level of daily flight delay of 129 hours.

If, as a result of Sacramento Metropolitan's potential new hub status, 100 daily arrivals (200 operations) were shifted from future growth at San Francisco to Sacramento Metropolitan, the forecast daily delay at San Francisco would be reduced 90 hours, a 47% delay reduction (Figure C-2). It can be shown by interpolation, a diversion of 50 daily arrivals (100 operations) would result in a reduction of 45 hours of forecast daily delay at San Francisco International.

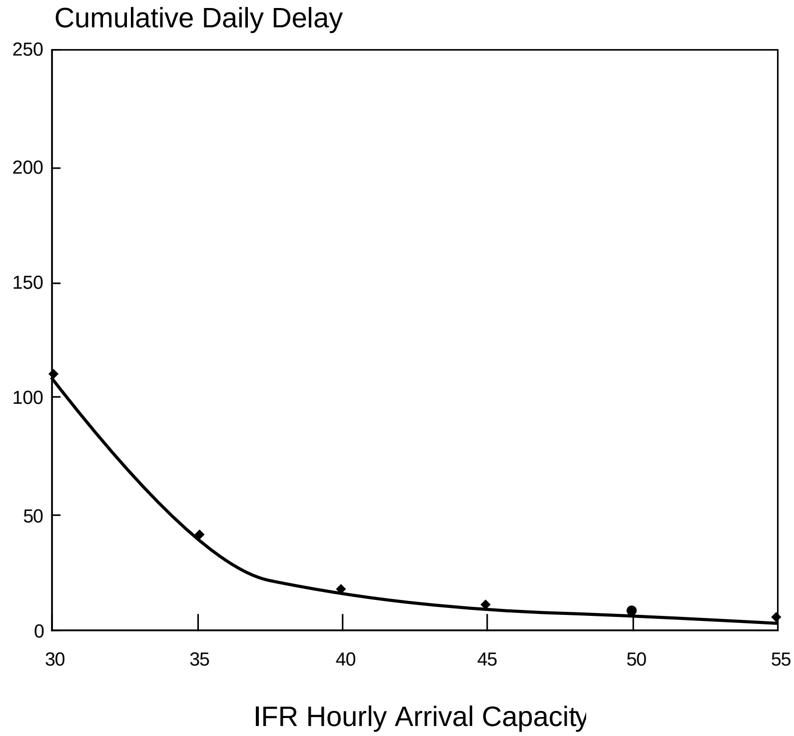

Figure C-3. Capacity Delay Curve for San Francisco (SFO) Assuming a New Connecting Hub at Sacramento Metropolitan

Figure C-2 assumes an hourly arrival capacity of 35 flights under Instrument Flight Rules (IFR). Figure C-3 shows the relationship between capacity and delay at San Francisco at future demand levels, at various IFR capacities. The curve indicates a proportionate decrease in benefits if arrival capacity grows at San Francisco. For example, an IFR hourly arrival rate of 40 would result in a daily delay of 15 hours, while an hourly arrival rate of 45 would result in a daily delay of 8 hours. It should be noted that at levels above 45 hourly arrivals the capacity-delay curve indicates only small improvements in daily delay.

A separate study was conducted to measure the impacts throughout the National Airspace System's network of airports of establishing a new connecting hub at Sacramento Metropolitan (SMF) to relieve growth-induced flight delays at San Francisco (SFO). Four scenarios were assumed:

1. VFR weather conditions throughout the country, without the establishment of Sacramento Metropolitan as a hub (the "VFR Base" scenario).
2. The same as the VFR Base scenario, but with Sacramento Metropolitan established as a connecting hub (the "VFR New Hub" scenario).
3. IFR (Category I) weather conditions at San Francisco and Sacramento Metropolitan, without the establishment of Sacramento Metropolitan as a hub (the "IFR Base" scenario).
4. The same as the IFR Base scenario, but with Sacramento Metropolitan established as a hub (the "IFR New Hub" scenario).

All scenarios assume 1998 traffic growth, as projected in the FAA's Terminal Area Forecasts. The methodology and inputs are found in Appendix B.

The results (summarized in the following table) indicate the systemwide impacts under the assumed IFR and VFR conditions. All values are per day.

Hubs	**Weather**		**Delay Hours U.S. Systemwide**
SFO/SMF	VFR	Base	2,060
		New Hub	2,003
		Diff.	(57)
		% Diff.	-2.77%
	IFR	Base	2,600
		New Hub	2,227
		Diff.	(373)
		% Diff.	-14.35%

Under VFR conditions on the sample day in 1998, 2,060 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from San Francisco to Sacramento Metropolitan, 2,003 delay hours occured systemwide. Therefore, 57 fewer hours of delay occured in the VFR scenario with the establishment of Sacramento Metropolitan as a new hub. The 57 delay hours amount to a reduction of 2.77% total hourly system delay.

The table also indicates that under IFR conditions on the 1998 sample day, 2,600 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from San Francisco to Sacramento Metropolitan, 2,227 delay hours occured. This decrease of 373 hours amounts to an decrease of 14.35% total hourly system delay.

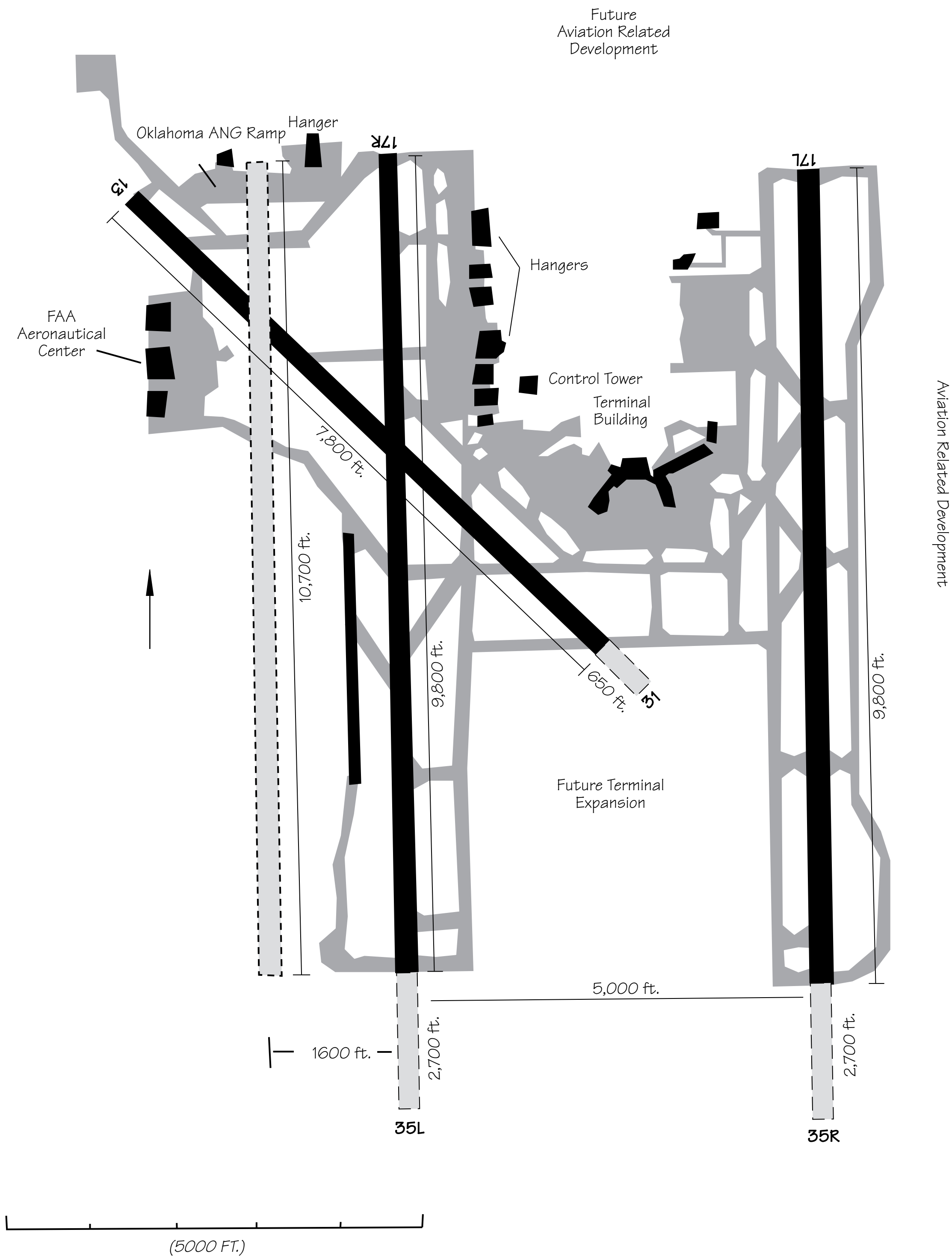

Figure D-1
Will Rogers World Airport
(Oklahoma City)

D. Oklahoma City

Oklahoma City Will Rogers Airport (OKC) is located in the center of Oklahoma on a site of 7,500 acres. The airport is located adjacent to three major interstate highways and is only 15 minutes from downtown Oklahoma City. Dallas–Fort Worth Airport is approximately 165 miles to the south.

VFR conditions (above CAT I) exist approximately 96% of the year at Oklahoma City.

Physical Facilities

Oklahoma City arriving air traffic is handled by the Oklahoma Terminal Radar Approach Control, located adjacent to the control tower, and handed off to the control of the Oklahoma City Airport Tower. The tower is an FAA Level 4 Control Facility, based on total instrument operations, and is operated continuously. Oklahoma City handled 286,212 instrument operations in fiscal year 1989 and ranks Number 74 nationally in total instrument operations.

In accordance with the Oklahoma City Master Plan, a $15 million terminal expansion was recently completed, resulting in a 72,000 square foot terminal consisting of three levels and two satellite concourses with a total of 16 gates serviced by jetways. The first level of the terminal building serves as a baggage claim and checking area. The second level is for departures and ticketing.

Oklahoma City is designated as a Port of Exportation for outbound air shipments. The airport is also designated as a "landing rights" airport, which allows commercial and private aircraft entry to U.S. Customs, with the required advance notice to Customs officials. In addition, there are four Foreign Trade Zones available on the airport that afford a considerable foreign tax saving for importers/exporters. A new 70,000 square foot air cargo facility has been completed just east of the main terminal. The facility can accommodate up to four 747 cargo carriers.

The airport (Figure D-1) is in the process of expanding its facilities to accommodate expected increases in traffic. Currently Oklahoma City has three runways. Runways 17L/35R and 17R/35L (each 9,800 feet) are over 4,300 feet apart which would permit independent IFR approaches. Crosswind runway 13/31 is 7,800 feet long. ILS approaches are available to 17R and 35R, with 35R having Cat II capability. (Category II instrument approaches allow an approach down to 100 feet above the ground with a visual range of not less than 1,200 feet.) Runway 17L/35R has newly installed centerline lights and in-pavement sensors monitor weather conditions that might require ice or snow removal. Runway 17L/35R is used almost exclusively by air carrier and air freight aircraft, because of the runway's proximity to the terminal and freight ramps. A 9,800–foot parallel taxiway, located east of runway 17L/35R, was completed in 1988.

Noise restrictions are minimal and consist of a voluntary runway use system between the hours of 10 p.m. and 7 a.m. daily. This involves shifting all VFR night traffic to the west runway, while using runways 17R and 17L for departures.

Oklahoma City is limited by having only one ILS approach to the south on runway 17R, and by one ILS approach to the north on runway 35R. There is no instrument approach procedure to runway 13/31. Current capacity for Oklahoma City, based on a typical fleet mix, would be 87 operations per hour under IFR, and 118 operations per hour under VFR.[13] Typically, with a southerly arrival stream, arriving aircraft will use runway 17R with its ILS approach, while departing aircraft will use runway 17L. Conversely, with a northerly arrival stream, arriving aircraft will use runway 35R with its ILS approach, while departing aircraft will use 35L (or to a lesser extent runway 31). As mentioned previously, runway 17L/35R is the runway of choice for most air carriers, because the runway is near the terminal and freight ramps.

An ILS to runway 17L is scheduled to be installed at Oklahoma City. With this additional ILS, the airport could handle 104 operations per hour in IFR, with a southerly arrival approach stream. With independent parallel ILS approaches to runways 17R/35L and 17L/35R, the airport could handle 163,000 additional operations per year.[14]

13. FAA, Office of Planning and Programming
14. 1989 DOT/FAA Airport Capacity Enhancement Plan

Operations

In 1989, seven airlines served 3,111,246 passengers, an increase of about 3% over 1988. Passenger enplanements over the last five calendar years have been as follows:

Enplanements (000)

1985 - 1,475
1986 - 1,475
1987 - 1,510
1988 - 1,510
1989 - 1,510

Oklahoma City is ranked Number 59 in enplanements in the FAA 1990-91 Aviation System Capacity Plan.

The airport reported 137,000 operations for FY 1989, an increase of 2.2% over FY 1988. Oklahoma City is ranked Number 86 in total operations for FY 1988. Total operations over the last five fiscal years have been as follows:

Operations (000)

1985 - 163
1986 - 160
1987 - 152
1988 - 133
1989 - 136

Over 55,000 air carrier operations were conducted in 1989. On an average day, Oklahoma City has about 79 air carrier departures with a fleet mix of 44% large jet, 15% large prop, and 41% small prop. Oklahoma City is served by seven airlines and nine air cargo carriers.

Capability to Expand Capacity

The Oklahoma City Airport Master Plan, scheduled to be updated 1992-1993, provides for an additional concourse with an increase of 12 gates. The apron is in place for this concourse allowing for rapid future construction. The Plan also provides for a fourth concourse as well as a second terminal for a total of 60 gates.

A new limited access road is to be constructed to the southwest of the airport permitting increased accessibility to the airport.

Simultaneous parallel ILS approaches to 17L/35R and 17R/35L, as well as an instrument approach to 13/31, would increase airport capacity when the airport is under IFR conditions. Airport Master Plans include a CAT I instrument landing system on 17L, a microwave landing system and a CAT II instrument landing system on 17R, installation of a new ASR-9 radar, and centerline and touchdown lighting on 17R.

A current Oklahoma City Airport Layout Plan indicates that extensions are planned for all runways. The north-south runways will be extended from 9,800 feet to 12,500 feet. The northwest-southeast runway will be extended from 7,800 feet to 8,450 feet.

The airport has sufficient land west of the existing runway layout for additional runway construction. Plans exist for a 10,700–foot long parallel runway 1,600 feet west of 17R/35L. This runway is planned to be a commuter/general aviation runway, which would allow greater use of the existing runways by large jet aircraft. As a result, Oklahoma City will then have three parallel runways for the most prevailing wind conditions.

Flight Delay Analysis

A new connecting hub at Oklahoma City could produce delay savings with a potential diversion of flights from Dallas–Fort Worth (DFW). The following figures illustrate the potential effect on delays at Dallas–Fort Worth if a new connecting hub were created at Oklahoma City.

The scenario consists of estimating demand and delay at Dallas–Fort Worth in some future period assuming no change in the role Oklahoma City presently plays in the system. This situation is then compared to one in which Oklahoma City has become a new connecting hub airport and now handles some of the traffic growth that previously connected at Dallas–Fort Worth. Specifically, it assumes that 200 daily operations (100 arrivals and 100 departures) are relocated as a result of establishing a new connecting hub at Oklahoma City. That number of flights would be “diverted” from the future growth at Dallas–Fort Worth.

The analysis uses FAA forecasts for 1998 as the basis of “future” demand. The figures in this section refer to 1998 simply as “future” demand, allowing for the possibility that the 1998 forecasted demand levels will be reached at a time other than 1998. The methodology and inputs are found in Appendix A.

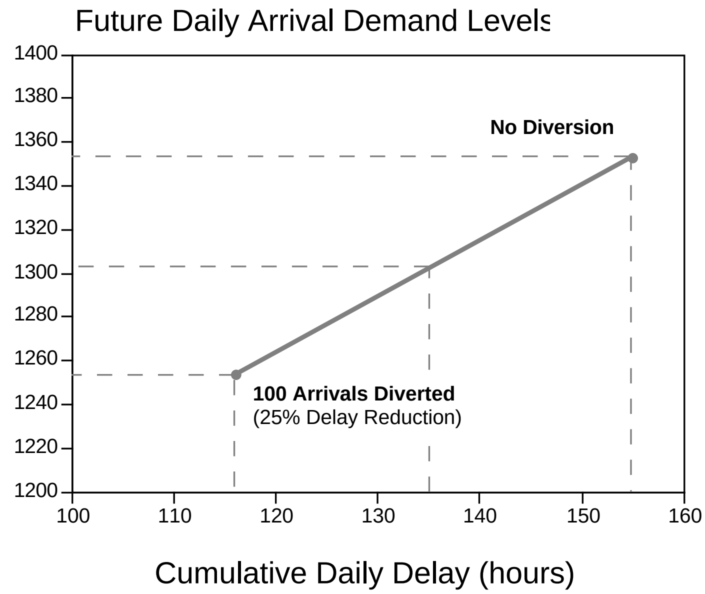

Figure D-2. Total Delay for Varying Arrival Demand Dallas-Fort Worth (DFW)

Future demand at Dallas–Fort Worth International is estimated at 1353 daily arrivals. This level of activity reflects a cumulative level of daily flight delay of 155 hours.

If, as a result of Oklahoma City's potential new hub status, 100 daily arrivals (200 operations) were shifted from future growth at Dallas–Fort Worth to Oklahoma City, the forecast daily delay at Dallas–Fort Worth would be reduced 39 hours, a 25% delay reduction (Figure D-2). It can be shown by interpolation, a diversion of 50 daily arrivals (100 operations) would result in a reduction of 20 hours of forecast daily delay at Dallas–Fort Worth.

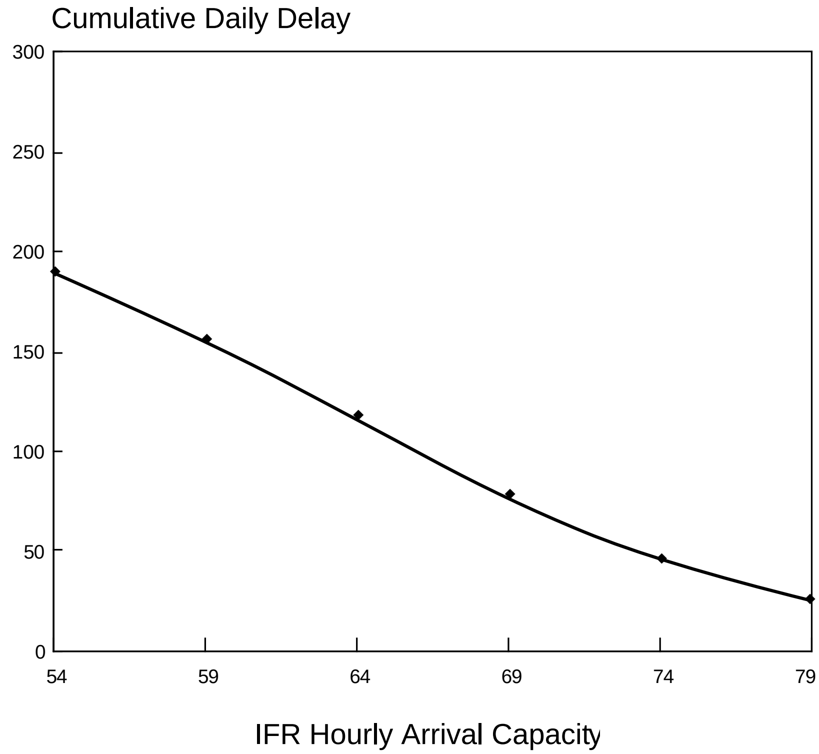

Figure D-3. Capacity Delay Curve for Dallas–Fort Worth (DFW) Assuming a New Connecting Hub at Oklahoma City

Figure D-2 assumes an hourly arrival capacity of 64 flights under Instrument Flight Rules (IFR). Figure D-3 shows the relationship between capacity and delay at Dallas–Fort Worth at future demand levels, at various IFR capacities. The curve indicates a proportionate decrease in benefits if arrival capacity grows at Dallas–Fort Worth. For example, an IFR hourly arrival rate of 69 would result in a daily delay of 77 hours, while an hourly arrival rate of 74 would result in a daily delay of 44 hours. It should be noted that, at levels above 74 hourly arrivals the capacity-delay curve indicates only small improvements in daily delay.

A separate study was conducted to measure the impacts throughout the National Airspace System's network of airports of establishing a new connecting hub at Oklahoma City (OKC) to relieve growth-induced flight delays at Dallas-Fort Worth (DFW). Four scenarios were assumed:

1. VFR weather conditions throughout the country, without the establishment of Oklahoma City as a hub (the "VFR Base" scenario).
2. The same as the VFR Base scenario, but with Oklahoma City established as a connecting hub (the "VFR New Hub" scenario).
3. IFR (Category I) weather conditions at Dallas–Fort Worth and Oklahoma City, without the establishment of Oklahoma City as a hub (the "IFR Base" scenario).
4. The same as the IFR Base scenario, but with Oklahoma City established as a hub (the "IFR New Hub" scenario).

All scenarios assume 1998 traffic growth, as projected in the FAA's Terminal Area Forecasts. The methodology and inputs are found in Appendix B.

The results (summarized in the following table) indicate the systemwide impacts under the assumed IFR and VFR conditions. All values are per day.

Hubs	**Weather**		**Delay Hours U.S. Systemwide**
DFW/OKC	VFR	Base	2,060
		New Hub	1,989
		Diff.	(71)
		% Diff.	-3.45%
	IFR	Base	3,638
		New Hub	3,073
		Diff.	(565)
		% Diff.	-15.53%

Under VFR conditions on the sample day in 1998, 2,060 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from Dallas–Fort Worth to Oklahoma City, 1,989 delay hours occured systemwide. Therefore, 71 fewer hours of delay occured in the VFR scenario with the establishment of Oklahoma City as a new hub. The 71 delay hours amount to a reduction of 3.45% total hourly system delay.

The table also indicates that under IFR conditions on the 1998 sample day, 3,638 delay hours occured systemwide. Following the diversion of 100 flights (200 operations) from Dallas–Fort Worth to Oklahoma City, 3,073 delay hours occured. This decrease of 565 hours amounts to a decrease of 15.53% total hourly system delay.

III — Conclusion

According to the DOT/FAA 1990-91 Aviation System Capacity Plan, up to 41 airports could each exceed 20,000 hours of flight delay by 1998 in the absence of capacity improvements. Potential new connecting hubs such as Huntsville International, Port Columbus, Sacramento Metropolitan, and Oklahoma City Will Rogers could significantly reduce this flight delay by diverting connecting air passengers from forecast delay-problem airports. Each of the four potential new hub airports in this report is capable of increasing operations substantially, while relieving major nearby airports of forecast flight delays.

These potential new hubs can expand current terminal facilities to handle larger passenger and baggage flow, while existing or planned runways can accommodate new increases in air traffic. This increased growth would result in economic benefits to the community in the form of additional employment and increased cash flow that would be generated by airport-related operations.

The four airports in this study, if developed as connecting hubs, could offer a partial solution to flight delay. The study has shown that the utilization of these airports could result in substantial reductions in hourly delay systemwide, especially under IFR conditions. These reductions in hourly delay will result in savings for both airlines and passengers.

As flight delays grow at traditional hub airports, it is reasonable to assume that airlines will consider these or other presently underutilized airports as potential new connecting hubs. Success as a new connecting hub could be realized by any one or more of the four case study airports, or other U. S. airports, but this success will depend on decisions of the airlines, airport management, and state and local governments.

This study is not intended to indicate a preference for the case study airports in becoming new connecting hub airports, as opposed to other candidate airports. As mentioned previously, it is most likely that a study featuring the other airports identified in the Aviation System Capacity Plan as potential new connecting hubs would produce results similar to those found in this report.

Appendix A *Notes on the Methodology and Inputs Used to Estimate Flight Diversion Benefits*

Methodology

The IFR capacity estimates resulted from a combined use of the FAA Airfield Capacity Model, airport surveys, and runway layout inspection. The capacity estimates apply to current layouts only. Future runway improvements are not considered.

The delay estimates were obtained through use of the M.I.T. Delay Model. This is a mainframe-based, analytical model that calculates delay by solving a number of time-dependent queuing equations.

Inputs

Arrival hourly demand was obtained through the NASPAC (National Airspace System Performance Analysis Capability) program, which, in turn, obtained it from the *Official Airline Guide* and general aviation estimates. The hourly arrival distribution of February 14, 1989, was used. It corresponds to a Tuesday, a relatively "average" weekday, and it precedes the schedule-disrupting Eastern Airlines strike. This distribution was then used to estimate a "1998" distribution, using FAA forecasted levels of demand, by assuming that only the total demand levels will change, not the distribution. The daily delay results were annualized by multiplying them by 365.

Weather information (annual IFR time averages), needed to assume IFR capacity levels, was obtained from FAA weather surveys performed in 1975. Accordingly, ATL is under IFR 12.9% of the time, ORD 15.2%, Dallas–Fort Worth 7.8%, and SFO 14.8%.

Airport layouts were obtained from the U.S. Department of Commerce. Noise considerations were not taken into consideration.

Appendix B *Systemwide Impact Analysis of Four New Hub Airports*

Introduction to AIRNET and Its Application in This Study

The Airport Network Policy Simulation Model (AIRNET) was developed for FAA by ATAC, Inc., as a policy analysis tool for analyzing the nationwide operational and economic impacts of airport noise abatement access restrictions, of airport capacity constraints, and of options for relieving those constraints. Since actions taken at one airport have impacts elsewhere in the system (because of aircraft itineraries), the core of AIRNET is a discrete-event simulation of the flow of traffic and the propagation of delays through the network of airports in the U.S. during a 24-hour period. Traffic delays result from runway queues, which are in turn a result of runway configurations, weather conditions, runway interactions, and air traffic control (ATC) aircraft separation times. Also simulated is airline construction of aircraft itineraries and flight schedules, including adjusments made in response to the imposition of airport access restrictions.

For noise policy analysis, AIRNET can be used to:

- Specify restrictions by (i) type of aircraft; i.e., by noise stage, noise level, weight or engine class, user-defined group of types, or any combination of these attributes; (ii) type of operation; i.e., landing, takeoff, or both; and (iii) degree of restriction; i.e., time of day, certain runways or whole airport, percent of target operations to be restricted, or number of target operations to be allowed.
- Identify which airports gain and which lose as a result of restrictions imposed at any airport or group of airports. Such gains and losses are in terms of numbers of Stage 2 and Stage 3 operations, enplanements, and population within the 65 dB LDN contour.
- Examine which airlines' schedules (and which aircraft types) are affected and how schedules are modified to comply with the restrictions.
- Measure the impacts on passengers in terms of costs of schedule changes (e.g., reduced or increased flight frequency and seat availability) on specific flight

segments, and the consequent changes in overall trip costs, travel demand, and consumer surplus.

- Incorporate fleet forecast assumptions — including introducing new or retrofitted aircraft types with alternative noise attributes.

For capacity congestion analysis, AIRNET can be used to:

- Estimate airport capacity and at what times of day congestion is likely to occur for given runway configurations and weather conditions.
- Assess the effect on capacity of such development options as new or upgraded runways, or new ATC equipment or procedural changes that allow modifications of arrival and departure aircraft separation times.
- Measure the impacts of capacity constraints in terms of departure and arrival delays, by airport and airline, and associated airline operating costs and passenger time costs and demand changes.
- Incorporate fleet forecast assumptions, including introducing new aircraft types, to examine the effect on airport delays, throughput, and other operational measures.

ATAC completed a small study for FAA that demonstrated the feasibility of including en route sectors in AIRNET. Implementation of such an enhancement would enable the user to designate certain sectors to be "focus" sectors, for which he would specify workload capacity values in terms of maximum instantaneous aircraft counts and maximum sector entry flow rates. Traffic management flow restrictions could also be specified. Impacts on delays and sector-specific statistics would then be generated through the simulation.

For the present study, AIRNET is used to provide a rough, first approximation to the systemwide impacts of establishing new connecting hubs to relieve existing congested connecting hubs. The current version of AIRNET is limited to "a rough first approximation" because of its reliance on the *Official Airline Guide* (OAG) for flight frequency distributions on routes, by airline and aircraft type, and on the FAA's Terminal Area Forecasts (TAF) for airport-specific growth multipliers. That is, airline route structures as reflected in the OAG are scaled up (or down) based on TAF growth from the base year to the target year (e.g., 1990 to 1998 in the present study).

The new connecting hubs are "implemented" in the scenarios described in the following section by changing the TAF forecasts for the associated airports. For example, operations forecasts are increased for OKC and decreased for DFW by a percentage amount that approximates the target 200 operations to be shifted to the new hub. The target number of operations for each airport is then distributed, by the AIRNET algorithm, to departure destinations, arrival origins, airlines, aircraft types, and time of day according to the distributions in the OAG day schedule being used.

Adherence to the OAG is deemed critical because it reflects the underlying complexity of market objectives and constraints — e.g., with respect to markets, routes, fleet, maintenance facilities, crew stations, etc. — that airlines face when making flight frequency and routing decisions. An enhancement to AIRNET has been proposed that would enable the user to input assumptions regarding new hubs, new airports, and passenger demand changes and that would then generate flight frequencies and aircraft itineraries on appropriate routes that are internally consistent. The implementation of such an enhancement would enable refinements to be made in the systemwide and airport-specific impacts of the new hub assumptions of this study.

Scenario Assumptions

Eleven scenarios, or simulation runs, have been specified and analyzed for this study. They are (the names shown are those appearing in the tabulated simulation results provided in this report):

1) **B90HUBS3**. A base run with today's traffic levels, using an OAG flight schedule for March 23, 1990. Airport capacity and, hence, delays depend heavily on assumptions about weather conditions, runway configurations used, and air traffic control separation standards. The model contains data tables on aircraft separation, based on runway interactions (e.g., crossing or parallel), sequence of operations (e.g., departure following arrival), sequence of weight classes (e.g., small following heavy), and weather conditions (IFR or

VFR). This scenario assumes VFR conditions throughout the country on the simulated day and that all airports use their highest capacity VFR runway configuration (as indicated in FAA's EPS data) throughout the day. Those data, assumed for the four subject major airports in this and all other VFR scenarios, are:

ATL	Rwys 26R and 27L for arrivals; 26L and 27R for departures
ORD	Rwys 14R, 22R, and 22L for arrivals; 27L and 22L for departures
SFO	Rwys 28R and 28L for arrivals; 1L and 1R for departures
DFW	Rwys 17L, 18R, and 13R for arrivals; 17R, 18L, and 13L for departures

EPS runway configuration data were not available on this study's four subject new hub airports. Therefore, the following VFR configurations were assumed for these airports in this and all other VFR scenarios:

HSV	Rwys 36L and 36R for both arrivals and departures
CMH	Rwys 28L and 28R for both arrivals and departures
SMF	Rwys 16R and 16L for both arrivals and departures
OKC	Rwys 35R, 35L, and 36 for both arrivals and departures (rwy 36 for general aviation aircraft)

Data on runways and runway interactions at the four subject new hub airports, as for the all AIRNET focus airports, were obtained from published airport diagrams.

2) **HUBS98BV**. The forecast simulation year was chosen to be 1998. AIRNET automatically uses FAA's Terminal Area Forecasts (TAF) of operations to scale the OAG to the selected future year. TAF enplanements forecasts are also used in the calculation of enplanements and passengers carried. The following table presents the 1990 and 1998 TAF forecasts for the eight airports of this study and the projected percent increase, based on the 1989 TAF forecasts (1990 TAF data are not yet installed in AIRNET).

	Operations/Day			Enplanements/Day		
	1990	1998	%Chg	1990	1998	%Chg
ATL	2148	2432	13.2	68,488	81,959	19.7
HSV	86	120	39.5	1,312	1,850	41.0
ORD	2106	2182	3.6	82,958	110,073	32.7
CMH	352	592	68.2	7,656	17,566	129.4
SFO	1216	1270	4.4	40,957	49,611	21.1
SMF	304	346	13.8	6,077	8,428	38.7
DFW	2076	2528	21.8	65,498	89,787	37.1
OKC	194	228	17.5	4,666	7,076	51.7

Source: FAA, Terminal Area Forecasts, 1989.

This scenario represents the 1998 VFR reference point for the four VFR hub scenarios described below. It is also used to show the delay impacts of doing nothing; that is, of the 1990-to-1998 projected traffic growth without the new hubs to relieve SFO, ATL, ORD, and DFW.

3) **HUBS98BI**. The potential benefits of the reliever hubs may be more (or less) pronounced under IFR weather conditions than under VFR conditions. This scenario represents the 1998 IFR reference point for the four IFR hub scenarios described below. It is also used to show the delay impacts of IFR conditions in 1998, when compared with the HUBS98BV scenario.

For this scenario, IFR (Category I) weather conditions are assumed to be in effect from 1300 to 2100 hours local time at all four of the major hubs and their respective reliever hubs. We want to assume the reliever and relieved hubs have the same weather conditions for the same period of time. Because of time zone differences between HSV and ATL and between CMH and ORD, the IFR conditions are imposed at HSV from 1200 to 2000 and at CMH from 1400 to 2200. VFR conditions and configurations (as shown above) are assumed at all other times. The IFR configurations assumed to be in effect during IFR weather conditions are:

ATL	Rwys 8L and 9R for arrivals; 8R and 9L for departures
ORD	Rwys 14R and 14L for arrivals; 9R and 9L for departures
SFO	Rwys 28R for arrivals; 1L and 1R for departures
DFW	Rwys 35R and 36L for arrivals; 35L and 36R for departures

HSV	Rwys 36L for both arrivals and departures
CMH	Rwys 10L and 10R for both arrivals and departures
SMF	Rwys 16R for both arrivals and departures
OKC	Rwys 35R for both arrivals and departures

IFR configurations for ATL, ORD, SFO, and DFW are from EPS data. IFR configurations at HSV, CMH, SMF, and OKC are based on the ILS runways at those airports as designated in the Airport/Facility Directory.

4) **HUBS98OV**. This scenario expands operations at Oklahoma City's Will Rogers World Airport as a hub to relieve Dallas–Fort Worth International. VFR conditions are assumed.

It is also assumed that OKC gets 200 additional daily operations, on average, in 1998 as a result of its new hub status and that DFW has correspondingly 200 fewer operations on average. Based on the TAF data shown above, these 200 operations are translated into 89 percent more operations at OKC and 8 percent fewer operations at DFW than in the 1998 base run. Since the TAF data (specifically, the 1990-to-1998 growth forecast) are used to scale the OAG day being simulated, the actual number of increased/decreased operations will not necessarily be 200, unless the OAG day happens to be an average day. The simulation results show how operations change based on these percentage changes.

Enplanements are assumed to change at DFW by the same percentage (-8) as operations, the implicit assumption being that the average number of enplanements per flight stays the same. These eight percent of DFW passengers amount to an increase of 100 percent in OKC enplanements.

For passenger demand calculations, it is assumed that all passenger changes are in connecting passengers, that originating passengers are not affected. Thus, the percentage of enplanements that originate at OKC and DFW are calculated to change from 100 percent to 50 percent and from 48 percent to 52 percent, respectively. (That is, 100/(100+100) = 50, and 48/(100-8) = 52.) For all airports, the base percentage of enplanements that originate there (e.g., 100 and 48 for OKC and DFW) is derived from 1988 Passenger Origin and Destination Survey data.

5) **HUBS98OI**. This scenario is the same as HUBS98OV, except it assumes the IFR conditions and configurations described in HUBS98BI.

6) **HUBS98SV**. This scenario expands operations at Sacramento Metropolitan Airport as a hub to relieve San Francisco International. VFR conditions are assumed.

It is also assumed that SMF gets 200 additional daily operations, on average, in 1998 as a result of its new hub status and that SFO has correspondingly 200 fewer operations on average. Based on the TAF data shown above, these 200 operations are translated into 59 percent more operations at SMF and 16 percent fewer operations at SFO than in the 1998 base run. Enplanements at SFO are assumed to change by the same percentage (-16) as operations, which corresponds to a 94 percent increase in enplanements at SMF. The percentage of enplanements that originate at the two airports is assumed to change from 99 percent to 73 percent at SMF and from 88 percent to 94 percent at SFO.

7) **HUBS98SI**. This scenario is the same as HUBS98SV, except it assumes the IFR conditions and configurations described in HUBS98BI.

8) **HUBS98HV**. This scenario expands operations at Huntsville International Airport as a hub to relieve Atlanta's Hartsfield International. VFR conditions are assumed.

It is also assumed that HSV gets 200 additional daily operations, on average, in 1998 as a result of its new hub status and that ATL has correspondingly 200 fewer operations on average. Based on the TAF data shown above, these 200 operations are translated into 162 percent more operations at HSV and 8 percent fewer operations at ATL than in the 1998 base run. Enplanements at ATL are assumed to change by the same percentage (-8) as operations, which corresponds to a 353 percent increase in enplanements at HSV. The percentage of enplanements that originate at the two airports is assumed to change from 99 percent to 22 percent at HSV and from 42 percent to 46 percent at ATL.

9) **HUBS98HI**. This scenario is the same as HUBS98HV, except it assumes the IFR conditions and configurations described in HUBS98BI.

10) **HUBS98CV**. This scenario expands operations at Port Columbus International Airport as a hub to relieve Chicago's O'Hare International. VFR conditions are assumed.

It is also assumed that CMH gets 200 additional daily operations, on average, in 1998 as a result of its new hub status and that ORD has correspondingly 200 fewer operations on average. Based on the TAF data shown above, these 200 operations are translated into 33 percent more operations at CMH and 9 percent fewer operations at ORD than in the 1998 base run. Enplanements at ORD are assumed to change by the same percentage (-9) as operations, which corresponds to a 56 percent increase in enplanements at CMH. The percentage of enplanements that originate at the two airports is assumed to change from 99 percent to 63 percent at CMH and from 58 percent to 64 percent at ORD.

11) **HUBS98CI**. This scenario is the same as HUBS98CV, except it assumes the IFR conditions and configurations described in HUBS98BI.

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4) *FAA Air Traffic Activity*, Fiscal Years 1984-1989.
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11) *Sacramento Metro Master Plan*, Reinard W. Brandley, Landrum & Brown, 1974.
12) *Sacramento Metro Master Plan Update*, Peat Marwick, Mitchell & Co., 1986.

Interviews

1) September 27, 1990, Interview with John Brantley, Director of Airport, Raleigh–Durham Airport.

Credits

1) Demand/Delay Curves, Mitre Inc.
2) Hub Study, Report Design, MiTech Inc.
3) System Impact Study, ATAC Inc.