Houston Intercontinental Airport

Airport
and
Airspace

Capacity Enhancement Plan

Houston Intercontinental Airport

Airport and Airspace Capacity Enhancement Plan

September 1993

Prepared jointly by the U.S. Department of Transportation, Federal Aviation Administration, the City of Houston, Department of Aviation, and the airlines and general aviation serving the Greater Houston Metropolitan Area.

Summary

The Federal Aviation Administration (FAA), airport operators, and aviation industry groups have initiated joint Airport Capacity Design Teams at various major air carrier airports throughout the U.S. These Capacity Teams identify and evaluate alternative means to enhance existing airport and airspace capacity to handle future demand. A Capacity Team for Houston Intercontinental Airport (IAH) was formed in 1991.

Steady growth at IAH has made it one of the busiest airports in the country. Activity at the airport has increased from 6,460,000 passenger enplanements in calendar year 1983 to 9,245,000 in 1991, a 43 percent increase. In 1991, the airport handled 311,000 aircraft operations (either takeoffs or landings).

The IAH Capacity Team recommended that a modeling and analysis of the airspace in the Houston Metropolitan Area, including the impact of operations at William P. Hobby (HOU) and Ellington Field (EFD), be incorporated into the capacity enhancement study for IAH. The Capacity Team was concerned that their efforts to increase the capacity of the airport would do little good if the terminal airspace in the Houston area and the adjoining en route airspace could not adequately handle the increased traffic. For that reason, the airport capacity study and airspace modeling for Houston Intercontinental Airport were combined into a single project.

The Capacity Team identified and assessed various actions which, if implemented, would increase IAH's capacity, improve operational efficiency, and reduce aircraft delays. The purpose of the process was to determine the technical merits of each alternative action and its impact on capacity. Additional studies will be needed to assess environmental, socioeconomic, or political issues associated with these actions.

Selected alternatives identified by the Capacity Team were tested using computer models developed by the FAA to quantify the benefits provided. For the airport capacity enhancement study, different levels of activity were chosen to represent growth in aircraft operations in order to compare the merits of each action. These annual activity levels are referred to throughout this report as: Baseline – 334,000 operations; Future 1 – 450,000 operations; Future 2 – 650,000 operations; and Future 3 – 900,000 operations.

Figure 1 illustrates the capacity and delay curves for the current airfield configuration at IAH under instrument flight rules (IFR). These curves show that aircraft delays will begin to escalate rapidly as hourly demand exceeds 70 to 110 operations per hour. Figure 2 shows that, while hourly demand exceeds 70 operations during certain hours of the day at Baseline demand levels, 110 operations per hour is frequently exceeded at the demand levels forecast for Future 2.

Figure 3 illustrates how delay will continue to grow at a substantial rate as demand increases if there are no improvements made in airfield capacity, i.e., the Do Nothing scenario. Annual delay costs will increase from 55,400 hours or $96.4 million at the Baseline level of operations to 926,300 hours or $1.61 billion by Future 2.

Figure 3 also shows the major airport capacity enhancement recommendations resulting from Part 1 of the Capacity Team study at Houston Intercontinental Airport.

Major Airport Recommendations

Recommendation	Future 2 Annual Delay Savings: Hours	Future 2 Annual Delay Savings: Millions of 1992 $
• Construct air carrier Runway 8L/26R to support triple independent approaches	774,800	$1,348.1
• Construct both air carrier Runway 8L/26R and new air carrier Runway 9R/27L to support quadruple independent approaches	764,400	$1,335.4
• Construct both Runway 8L/26R and Runway 9C/27C	755,700	$1,314.8
• Construct both Runway 8C/26C and Runway 9C/27C	745,800	$1,297.6
• Extend, widen, and strengthen Runway 14R/32L for air carrier departures, with arrivals on Runways 26L and 27R and add high-speed exit off Runway 14R	313,600	$545.7

Figure 1. Airport Capacity Curve — Hourly Flow Rate Versus Average Delay — IFR Operations

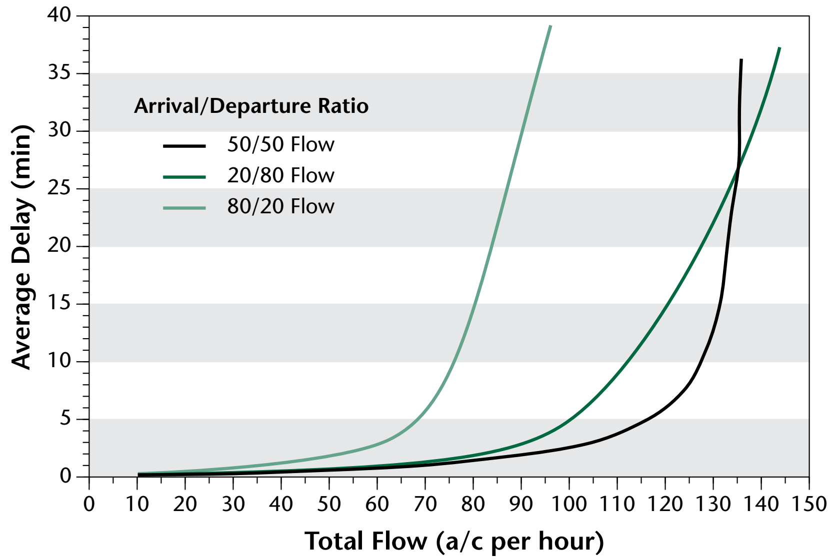


Figure 2. Profile of Daily Demand — Hourly Distribution

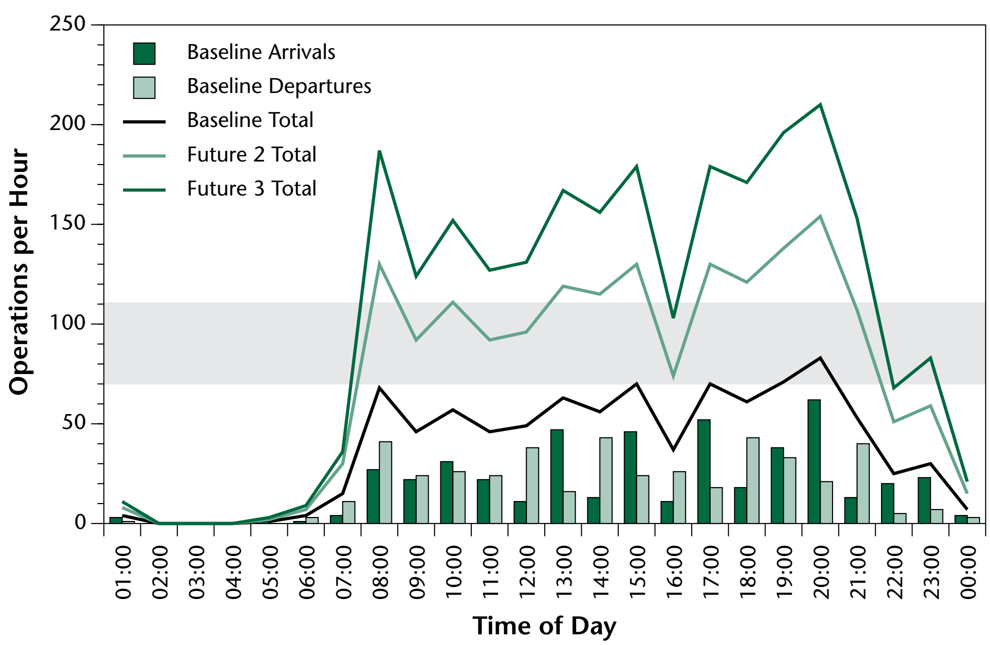
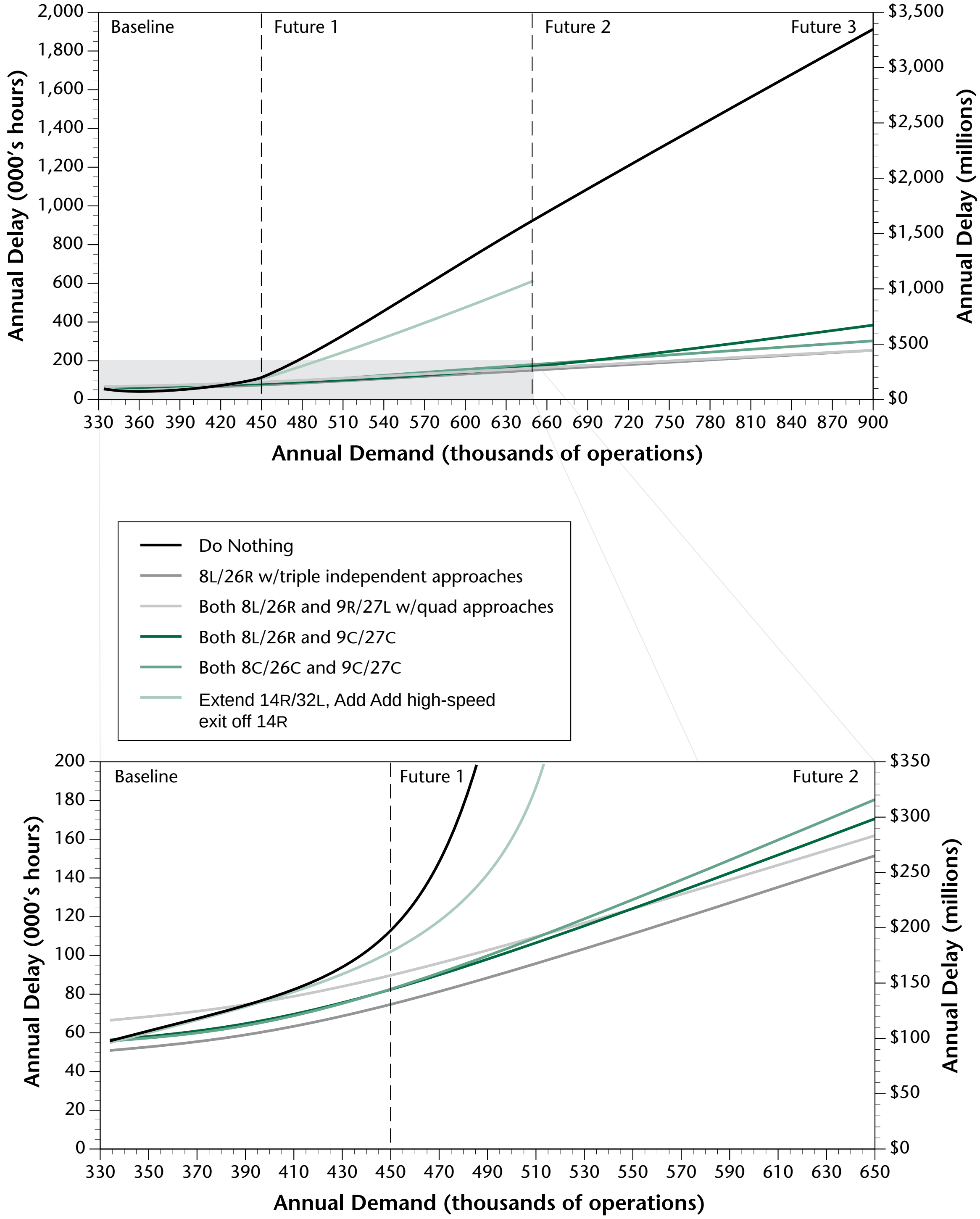


Figure 3. Annual Delay Costs — Capacity Enhancement Alternatives



The airspace capacity modeling study concentrated on the arrival and departure gates that are used to feed aircraft into and out of the Houston Terminal Radar Approach Control (TRACON). The Houston Center has established certain capacity levels for each of these arrival and departure gates. The results of the study indicate that the current Houston TRACON airspace can handle the traffic demand at the Baseline and Future 1 levels of activity. However, at the Future 2 and 3 demand levels, the number of arrival and departure gates reaching or exceeding their assigned capacity will increase. The annual delay costs that will result from these airspace restrictions will increase as the demand increases.

Based on the analysis performed in this airspace modeling study, future analysis of air traffic operations in the Houston area should investigate the effects of restructuring terminal area airspace to provide additional arrival and departure gates and of implementing updated air traffic control procedures.

	Annual Delay Costs	
	Hours	**Millions of 1992 $**
Baseline	0	$0
Future 1	24	$0.04
Future 2	7,545	$13.13
Future 3	34,840	$60.62

Taken together, the results of the two study efforts suggest the following conclusions:

- Operation of the existing airfield at IAH will result in unacceptable levels of delay shortly after aircraft operations exceed the Future 1 demand level of 450,000 per year.
- Several alternatives have been identified and evaluated and found to be capable of providing sufficient airfield capacity to accommodate the Future 3 demand level of 900,000 operations per year. The final selection of a preferred long-term plan for airfield development should be determined through additional study in the Airport Master Plan update process for IAH.
- The combined airspace capacity of all departure and arrival gates in the Houston TRACON is sufficient to handle aircraft demands beyond the Future 3 scenario. However, if current operational practices remain in place, several individual gates will experience demand loadings that exceed their capacity. Procedural changes will need to be examined as aircraft demand approaches the Future 3 scenario. These changes should seek to reallocate expected peak demand loadings to achieve a more even distribution among the various gates.

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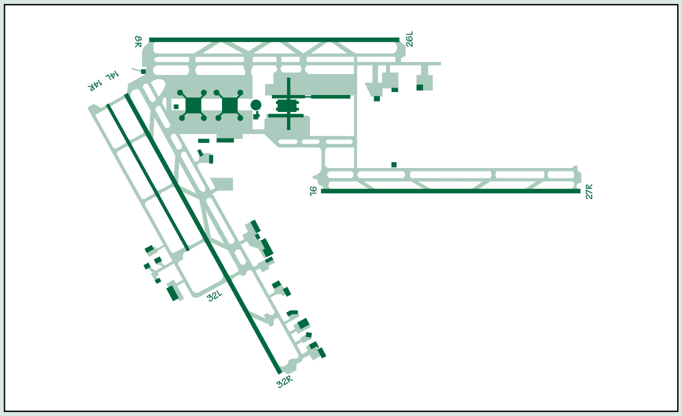
Part One

Airport Capacity Enhancement



Section 1 Introduction

Background

The national air transportation system is being called on to handle unprecedented growth and ever increasing activities. The challenge for the air transportation industry in the nineties is to enhance existing airport and airspace capacity and to develop new facilities to handle future demand. As environmental, financial, and other constraints continue to restrict the development of new airport facilities in the U.S., an increased emphasis has been placed on the redevelopment and expansion of existing airport facilities.

To begin to meet this challenge, the FAA, along with airport operators and aviation industry groups throughout the country, have initiated joint Airport Capacity Design Teams to study airport capacity enhancement at the major air carrier airports in the U.S. The objectives of these studies are to identify various alternatives for increasing capacity and to evaluate their potential for reducing delays.

In the past decade, Houston Intercontinental Airport (IAH) has been one of the nation's busiest airports. Enplanements at IAH rose from 6,460,000 in 1983 to 9,245,000 in 1991, a 43 percent increase. IAH's total aircraft operations reached 311,000 in 1991.

This report has established benchmarks for development based upon traffic levels and not upon any definitive time schedule, since actual growth can vary year to year from projections. As a result, the report should retain its validity until the highest traffic level is attained regardless of the actual dates paralleling the development.

A Baseline benchmark of 334,000 aircraft operations was established based on the estimated annual traffic level for 1992, the base year of the study. Three future traffic levels, Future 1, Future 2, and Future 3, were established at 450,000, 650,000, and 900,000 annual aircraft operations respectively, based on Capacity Team consensus of potential traffic growth at IAH. If no improvements are made at IAH, annual delay levels and delay costs are expected to increase from an estimated 55,400 hours and $96.4 million at the Baseline activity level to nearly 926,300 hours and $1.61 billion by the Future 2 demand level.

The Capacity Team studied various proposals with the potential for increasing capacity and reducing delays at IAH.

The improvements evaluated by the Capacity Team are delineated in Figure 5 and described in some detail in Section 2 — Capacity Enhancement Alternatives.

Objectives

The major goal of the Capacity Team was to identify and evaluate proposals to increase airport capacity, improve airport efficiency, and reduce aircraft delays. In achieving this objective, the Capacity Team:

- Assessed the current airport capacity and the causes of delay associated with the airfield, the immediate airspace, and the apron and gate-area operations.
- Evaluated capacity and delay benefits of alternative air traffic control (ATC) procedures, navigational improvements, airfield development, and operational improvements.

Scope

The Capacity Team limited its analyses to aircraft activity within the terminal area airspace and on the airfield. They considered the technical and operational feasibility of the proposed airfield improvements, but did not address environmental, socioeconomic, or political issues regarding airport development. These issues need to be addressed in future airport system planning studies, and the data generated by the Capacity Team can be used in such studies.

Methodology

The Capacity Team met periodically for review and coordination. The FAA Technical Center's Aviation Capacity Branch provided expertise in airport simulation modeling. Other Capacity Team members contributed suggested improvement options, data, text, and capital cost estimates.

Initial work consisted of gathering data and formulating assumptions required for the capacity and delay analysis and modeling. Where possible, assumptions were based on actual field observations at IAH. Proposed improvements were analyzed in relation to current and future demands with the help of two computer models, the Airport and Airspace Simulation Model (SIMMOD) and the Runway Delay Simulation Model (RDSIM). Appendix B briefly explains these models.

The simulation models considered air traffic control procedures, airfield improvements, and traffic demands. Alternative airfield configurations were prepared from present and proposed airport layout plans. Various configurations were evaluated to assess the benefit of projected improvements. Air traffic control procedures and system improvements determined the aircraft separations to be used for the simulations under both VFR and IFR.

Air traffic demand levels were derived from *Official Airline Guide* data, historical data, and Capacity Team and other forecasts. Aircraft volume, mix, and peaking characteristics were considered for each of the four different demand forecast levels (Baseline, Future 1, Future 2, and Future 3). From this, annual delay estimates were determined based on implementing various improvements. These estimates took into account historic variations in runway configuration, weather, and demand. The annual delay estimates for each configuration were then compared to identify delay reductions resulting from the improvements.

Figure 4 shows the current layout of the airport, plus the airfield improvements considered by the Capacity Team.

Figure 5 lists the capacity enhancement alternatives evaluated by the Capacity Team and presents the estimated annual delay savings benefits for selected improvements. The annual savings are given for the activity levels Baseline, Future 1, Future 2, and Future 3, which correspond to annual aircraft operations of 334,000, 450,000, 650,000 and 900,000 respectively. The delay savings benefits of the improvements are not necessarily additive. Following the evaluation, the Capacity Team developed a plan of recommended alternatives for consideration, which is included in Figure 6.

Figure 4. Houston Intercontinental Airport

Figure 5. Capacity Enhancement Alternatives and Annual Delay Savings

Figure 4. Houston Intercontinental Airport

Note: This figure illustrates the location of several alternative new runways and a runway extension which were examined in this study. The final determination as to which of these projects will ultimately be required at IAH is the subject of an ongoing Master Plan Update. The lateral spacing of the new runways will also be the subject of further study in the Master Plan Update.

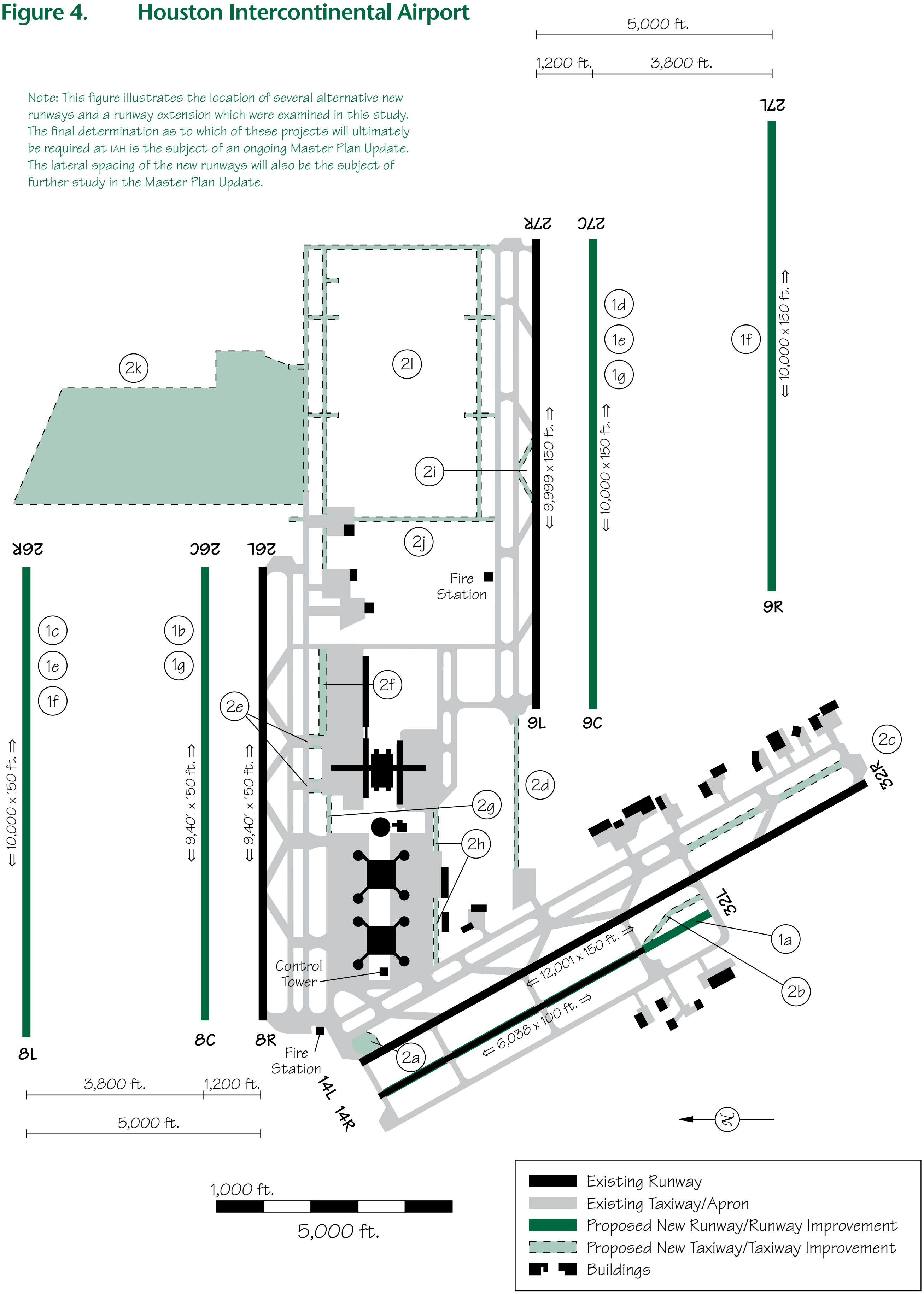


Figure 5. Capacity Enhancement Alternatives and Annual Delay Savings

Alternatives		Baseline 334,000	Future 1 450,000	Future 2 650,000	Future 3 900,000
		Estimated Annual Delay Savings* (in hours and millions of 1992 dollars)			
Airfield Improvements					
	Runway Improvements				
1a.	Extend, widen, and strengthen Rwy 14R/32L for air carrier departures with arrivals on Rwys 26L and 27R	1,300/$2.2	11,400/$20.0	189,600/$330.0	383,000/$666.6
1b.	Construct air carrier Rwy 8C/26C 1,200 ft. north of Rwy 8R/26L	2,800/$4.8	26,400/$46.0	603,400/$1,049.8	1,295,300/$2,254.0
1c.	Construct air carrier Rwy 8L/26R to support triple independent approaches	4,500/$7.6	39,000/$67.9	774,800/$1,348.1	1,658,600/$2,897.5
1d.	Construct air carrier Rwy 9C/27C 1,200 ft. south of Rwy 9L/27R	(2,600/$4.5)	21,000/$36.7	636,500/$1,107.4	1,376,400/$2,395.0
1e.	Construct both Rwy 8L/26R and Rwy 9C/27C	(900/$1.5)	31,300/$54.6	755,700/$1,314.8	1,528,600/$2,839.3
1f.	Construct both Rwy 8L/26R and new air carrier Rwy 9R/27L to support quadruple independent approaches	(11,100/$13.7)	24,000/$41.7	764,400/$1,335.4	1,658,100/$2,901.5
1g.	Construct both Rwy 8C/26C and Rwy 9C/27C	(330/$0.6)	31,100/$54.1	745,800/$1,297.6	1,609,900/$2,801.2
	Taxiway Improvements				
2a.	Expand Rwy 14L staging area to accomodate dual-feed capability for departures on Rwys 14L and 14R.				
	2a.1. With current rwy assignments	(25/$0.04)	(460/$0.8)	o	o
	2a.2. As air taxi/commuter rwy only	(60/$0.1)	18,300/$31.8	o	o
2b.	Add high speed exit off Rwy 14R	1,100/$0.6	7,600/$10.4	313,600/$545.7	o
2c.	Extend Twy WA from Twy WL to Twy WB to allow two-way traffic		**		
2d.	Extend Twy WH to Twy SA (bridging over JFK Boulevard)	450/$0.8	1,200/$2.0	o	o
2e.	Widen Twys NJ and NK to allow two-way traffic	2,500/$4.3	3,500/$6.0	o	o
2f.	Extend Mickey LeLand Memorial International Airlines Building (IAB) Ramp	5/$0.008	90/$0.02	o	o

Figure 5. Capacity Enhancement Alternatives and Annual Delay Savings (cont)

	Estimated Annual Delay Savings* (in hours and millions of 1992 dollars)			
Alternatives	**Baseline** 334,000	**Future 1** 450,000	**Future 2** 650,000	**Future 3** 900,000
2g. Extend North Ramp to connect Terminals B and C	(70/$0.1)	1,400/$2.4	o	o
2h. Add dual twy at South Terminal Ramp (bridging over JFK Boulevard)	700/$1.2	1,500/$2.5	o	o
2i. Add high speed exits at Twys SG and SH	50/$0.08	50/$0.08	o	o
2j. Add second crossfield twy at midfield to provide two-way flow	(2,700/$4.7)	(3,700/$6.5)	o	o
2k. Construct cargo gate and twy complex north side		†		
2l. Construct new terminal		†		
Facilities and Equipment Improvements				
3a. Upgrade to CAT III ILS on Rwy 27R		†		
Operational Improvements				
3b. Conduct dependent IFR approaches to Rwys 14L & 9L and 14L & 26		†		
4. Distribute traffic more uniformly during peak periods		†		
5. Construct new reliever airport on west side		†		
6. Add a public-use heliport at IAH		†		
7. Construct additional airline hub at Terminal B		†		
8. Construct Terminal C Ramp Control Tower		†		

* The savings benefits of these alternatives are not necessarily additive.

** Annualized savings benefits included in savings for alternative 1a.

o During modeling, these alternatives gridlocked at these demand levels. No savings figures are available.

† These improvements were not simulated. Therefore, no dollar figures are available. There is a description of each of these items in Section 2 — Capacity Enhancement Alternatives.

Section 2 Capacity Enhancement Alternatives

Figure 6 presents the recommended action, suggested time frame, and responsible agency for each capacity enhancement alternative considered by the Capacity Team.

The capacity enhancement alternatives are categorized and discussed under the following headings:

- Airfield Improvements
- Facilities and Equipment Improvements
- Operational Improvements

Figure 6. Capacity Enhancement Alternatives and Recommended Actions

Alternatives		Action	Time Frame	Responsible Agency
Airfield Improvements				
	Runway Improvements			
1a.	Extend, widen, and strengthen Runway 14R/32L for air carrier departures, with arrivals on Runways 26L and 27R	Current Study	Baseline	DOA
1b	Construct air carrier Runway 8C/26C 1,200 ft. north of Runway 8R/26L	Current Study	Baseline	DOA
1c.	Construct air carrier Runway 8L/26R to support triple independent approaches	Current Study	Baseline	DOA
1d.	Construct air carrier Runway 9C/27C 1,200 ft. south of Runway 9L/27R	Further Study	Future 1	DOA
1e.	Construct both Runway 8L/26R and 9C/27C	Further Study	Future 1	DOA
1f.	Construct both Runway 8L/26R and new air carrier Runway 9R/27L to support quadruple approaches	Further Study	Future 1	DOA
1g.	Construct both Runway 8C/26C and 9C/27C	Further Study	Future 1	DOA
	Taxiway Improvements			
2a.	Expand Rwy 14L staging area to accomodate dual-feed capability for departures on Rwys 14L and 14R.			
	2a.1. With current runway assignments	Current Study	Baseline	DOA
	2a.2. As air taxi/commuter runway only	Current Study	Baseline	DOA
2b.	Add high speed exit off Runway 14R	Not Recommended	—	—
2c.	Extend Taxiway WA from Taxiway WL to Taxiway WB to allow two-way traffic	Construction Planned	Baseline	DOA
2d.	Extend Taxiway WH to Taxiway SA (bridging over JFK Boulevard)	Not Recommended	—	—
2e.	Widen Taxiways NJ and NK to allow two-way traffic	Current Study	Baseline	DOA
2f.	Extend Mickey LeLand Memorial International Airlines Building (IAB) Ramp	Current Study	Baseline	DOA
2g.	Extend North Ramp to connect Terminals B and C	Construction Planned	Baseline	DOA
2h.	Add dual taxiway at South Terminal Ramp (bridging over JFK Boulevard)	Current Study	Baseline	DOA
2i.	Add high speed exits at Taxiways SG and SH	Current Study	Baseline	DOA
2j.	Add second crossfield taxiway at midfield to provide 2-way flow	Current Study	Baseline	DOA
2k.	Construct cargo gate and taxiway complex on north side	Current Study	Baseline	DOA
2l.	Construct new terminal	Current Study	Baseline	DOA
Facilities and Equipment Improvements				
3a.	Upgrade to CAT III ILS on Runway 27R	Further Study	Future 2	FAA
Operational Improvements				
3b.	Conduct dependent IFR approaches to Runways 14L & 9L and 14L & 26	Not Recommended	—	—
4.	Distribute traffic more uniformly during peak periods	Recommended	Baseline	All Agencies†
5.	Construct new reliever airport on west side	Current Study	Baseline	DOA
6.	Effect of a public-use heliport	Current Study	Baseline	DOA
7.	Construct additional airline hub at Terminal B	Current Study	Baseline	DOA
8.	Construct Terminal C Ramp Control Tower	Current Study	Baseline	DOA/Airlines

* The term "Study" suggests that a specific study be conducted or that it become part of a larger planning effort, such as a Master Plan update or a FAR Part 150 Airport Noise Compatibility Study. These individual proposals require further investigation at a level of detail that is beyond the scope of this effort.

† All Agencies = FAA, DOA, and Airlines

Airfield Improvements

1a. Extend, widen, and strengthen Runway 14R/32L for air carrier departures, with arrivals on Runways 26L and 27R.

Extending Runway 14R/32L and upgrading it to support air carrier operations would provide for an additional departure runway for larger aircraft and allow air traffic control (ATC) greater flexibility in the use of runways.

Estimated 1992 project cost is $13.4 million.

Annual savings at the Baseline activity level would be 1,300 hours or $2.2 million, and, at Future 2 activity levels, 189,600 hours or $330.0 million.

1b. Construct air carrier Runway 8C/26C 1,200 feet north of Runway 8R/26L.

Presently, the parallel Runways 8R/26L and 9L/27R at Houston Intercontinental Airport can support two independent arrival streams under instrument flight rules (IFR). Constructing a new parallel Runway 8C/26C 1,200 feet from the existing Runway 8R/26L would provide for an additional parallel arrival stream, but only under visual flight rules (VFR). Under IFR, runway separation distances of less than 2,500 feet require that parallel runways be treated as a single runway. Constructing the new parallel runway at 1,200 feet, then, would allow for an additional dedicated IFR departure runway in addition to the two existing IFR arrival streams.

Estimated 1992 project cost is $44.0 million.

Annual savings at the Baseline activity level would be 2,800 hours or $4.8 million, and, at Future 2 activity levels, 603,400 hours or $1,049.8 million.

1c. Construct air carrier Runway 8L/26R to support triple independent approaches.

The use of triple independent parallel approaches would result in a significant increase in arrival capacity under all weather conditions. Work is currently underway to develop the air traffic control procedures and provide the new technology to support these improvements. Simulations at the FAA Technical Center have resulted in preliminary approval of triple and quadruple simultaneous parallel approaches at Dallas-Fort Worth International Airport (contingent upon final runway location). The success of these simulations has led to further work to develop generic procedures that could be applied at any airport that met the basic criteria, and national standards for triple parallel approaches are under development. These standards are expected to require a minimum of 5,000 feet between the runways when using the current radar systems. New technology, such as high-update-rate radars and improved controller displays, may allow reduced runway spacings.

Estimated 1992 project cost is $52.3 million. This does not include the cost of land acquisition, which would be an additional $23.0 million, for a total cost of $75.3 million.

Annual savings at the Baseline activity level would be 4,500 hours or $7.6 million, and, at Future 2 activity levels, 774,800 hours or $1,348.1 million.

1d. Construct air carrier Runway 9C/27C 1,200 feet south of Runway 9L/27R.

Presently, the parallel Runways 8R/26L and 9L/27R at Houston Intercontinental Airport can support two independent arrival streams under instrument flight rules (IFR). Constructing a new parallel Runway 9C/27C 1,200 feet from the existing Runway 9L/27R would provide for an additional parallel arrival stream, but only under visual flight rules (VFR). Under IFR, runway separation distances of less than 2,500 feet require that parallel runways be treated as a single runway. Constructing the new parallel runway at 1,200 feet, then, would allow for a dedicated IFR departure runway in addition to the two existing IFR arrival streams.

Estimated 1992 project cost is $41.0 million.

At the Baseline activity level, there would be an annual cost penalty of 2,600 hours or $4.5 million. At Future 2 activity levels, there would be an annual savings of 636,500 hours or $1,107.4 million.

1e. Construct both Runway 8L/26R and Runway 9C/27C.

At the Baseline activity level, there would be an annual cost penalty of 900 hours or $1.5 million. At Future 2 activity levels, there would be an annual savings of 755,700 hours or $1,314.8 million.

Estimated 1992 project cost is $116.3 million.

1f. Construct both Runway 8L/26R and new air carrier Runway 9R/27L to support quadruple independent approaches.

The use of quadruple independent parallel approaches would result in a significant increase in arrival capacity under all weather conditions. Work is currently underway to develop the air traffic control procedures and provide the new technology to support these improvements. Simulations at the FAA Technical Center have resulted in preliminary approval of triple and quadruple simultaneous parallel approaches at Dallas-Fort Worth International Airport (contingent upon final runway location). The success of these simulations has led to further work to develop generic procedures that could be applied at any airport that met the basic criteria, and national standards for quadruple parallel approaches are under development. These standards are expected to require a minimum of 5,000 feet between the runways when using the current radar systems. New technology, such as high-update-rate radars and improved controller displays, may allow reduced runway spacings.

Estimated 1992 cost to construct Runway 9R/27L is $57.0 million. This does not include the cost of land acquisition, which would be an additional $3.2 million, for a total cost of $60.2 million.

Estimated 1992 project cost to construct both Runway 8L/26R (alternative 1c) and Runway 9R/27L is $135.5 million.

At the Baseline activity level, there would be an annual cost penalty of 11,100 hours or $13.7 million. At Future 2 activity levels, there would be an annual savings of 764,400 hours or $1,335.4 million.

1g. Construct both Runway 8C/26C and Runway 9C/27C.

Total estimated 1992 project cost is $85.0 million.

At the Baseline activity level, there would be an annual cost penalty of 330 hours or $0.6 million. At Future 2 activity levels, there would be an annual savings of 745,800 hours or $1,297.6 million.

2a. Expand Runway 14L staging area to accomodate dual-feed capability for departures on Runways 14L and 14R.

This project would improve the flow of ground traffic and reduce taxi interference and delays when Runways 14R and 14L are used primarily for departures. The present configuration requires that aircraft taxiing from the main terminal area to Runway 14R hold in the queue area east of Runway 14L along with departures for Runway 14L. Expanding the staging area would improve the ability of departing aircraft to bypass aircraft which may be waiting for departure clearance and enable controllers to more efficiently sequence successive departures.

When combined with alternative 1a (extend Runway 14R to the south), both Runways 14L and 14R could be used for air carrier jet departures, and the expanded staging area would be used to efficiently sequence departures.

Alternatively, if Runway 14R is not extended and jet departures are limited to Runway 14L, other operational scenarios would have to be examined to take advantage of the expanded staging areas. For example, the development of seperate departure tracks so that commuter aircraft would not be mixed with faster turbojet aircraft en route to handoff fixes might be beneficial. This might be accomplished by layering the departure route, or by establishing dual routes to fixes. However, the airspace structure of combined IAH and HOU traffic may eliminate the effectiveness of this scenario. In addition, turbojet departure traffic already exceeds the capacity of one departure runway. For these reasons, additional examination of a preferred operating scenario and associated facility development will be undertaken in the ongoing IAH Master Plan Update.

Estimated 1992 project cost is $3.8 million.

2a.1. Use with current runway assignments.

The annual cost penalty at the Baseline activity level would be 25 hours or $0.04 million, and, at Future 1 activity levels, 460 hours or $0.8 million.

2a.2. Use strictly as air taxi/ commuter runway.

At the Baseline activity level, there would be an annual cost penalty of 60 hours or $0.1million. At Future 1 activity levels, there would be an annual savings of 18,300 hours or $31.8 million.

2b. Add high speed exit off Runway 14R at 6,000 feet.

Constructing an improved, high-speed exit would reduce runway occupancy time and enhance capacity if the runway were used for arrivals. However, primary use of this runway would be for departures.

Estimated 1992 project cost is $0.72 million.

Annual savings at the Baseline activity level would be 1,100 hours or $0.6 million, and, at Future 2 activity levels, 313,600 hours or $545.7 million. These savings are contingent upon extending, widening, and strengthening Runway 14R/32L for air carrier operations (alternative 1a).

2c. Extend Taxiway WA from Taxiway WL to Taxiway WB to allow two-way traffic.

By allowing two-way traffic along the entire length of Runway 14L/32R for arriving and departing aircraft to taxi to and from the terminal, this project will reduce taxi interference and delays. In addition, this improvement will provide for more efficient sequencing of departures on Runway 32R. Construction of this taxiway extension has already begun.

Estimated 1992 project cost is $5.5 million.

2d. Extend Taxiway WH to Taxiway SA (bridging over JFK Boulevard).

The existing Taxiway SX South Bridge only allows for one-way traffic when traveling to and from the east and west sides of the airport. This project would reduce taxi interference and delays primarily by eliminating the need for general aviation (GA) and cargo aircraft taxiing to and from Runway 9L/27R to use the South Bridge. This project would require the relocation of the west cargo area.

Estimated 1992 project cost is $10.0 million.

Annual savings at the Baseline activity level would be 450 hours or $0.8 million, and, at Future 1 activity levels, 1,200 hours or $2.0 million.

2e. Widen Taxiways NJ and NK to allow two-way traffic.

By allowing two-way traffic and providing a more direct route for arriving and departing aircraft to taxi to and from the terminal, widening Taxiways NJ and NK would reduce taxi interference and delays. This project will affect the Phase 2 expansion of the Mickey LeLand Memorial International Airlines Building (IAB).

Estimated 1992 project cost is $1.15 million.

Annual savings at the Baseline activity level would be 2,500 hours or $4.3 million, and, at Future 1 activity levels, 3,500 hours or $6.0 million.

2f. Extend Mickey LeLand Memorial International Airlines Building (IAB) Ramp.

Extending the IAB ramp to the north will allow aircraft to taxi past pushbacks and thereby improve the flow of ground traffic and reduce taxi interference and delays. This project will affect the Phase 2 expansion of the IAB.

Estimated 1992 project cost is $5.25 million.

Annual savings at the Baseline activity level would be 5 hours or $0.008 million, and, at Future 1 activity levels, 90 hours or $0.02 million.

2g. Extend North Ramp to connect Terminals B and C.

Extending the North Ramp the width of a taxiway to connect Terminal B and C would improve the flow of ground traffic and reduce taxi interference and delays.

Estimated 1992 project cost is $4.6 million.

At the Baseline activity level, there would be an annual cost penalty of 70 hours or $0.1 million. At Future 1 activity levels, there would be an annual savings of 1,400 hours or $2.4 million.

2h. Add dual taxiways at South Terminal Ramp (bridging over JFK Boulevard).

The existing Taxiway SX South Bridge only allows for one-way traffic when traveling to and from the east and west sides of the airport. This project would extend Taxiway SD to Taxiway WG. By providing additional parallel taxiways for arriving and departing aircraft to taxi to and from the terminal area and the runways, it would reduce taxi interference, expedite ground movement, and thereby reduce delays. This project would require removal of the existing cargo and taxiway bridge and construction of two new taxiway bridges.

Total estimated 1992 project cost is $65.4 million, which includes $15.4 million for the taxiways and $50.0 million for relocating the facilities affected by the project.

Annual savings at the Baseline activity level would be 700 hours or $1.2 million, and, at Future 1 activity levels, 1,500 hours or $2.5 million.

2i. Add high speed exits at Taxiways SG and SH.

Constructing improved, high-speed exits would reduce runway occupancy times and enhance capacity.

Estimated 1992 project cost is $1.1 million.

Annual savings at the Baseline activity level would be 50 hours or $0.08 million, and, at Future 1 activity levels, 50 hours or $0.8 million.

2j. Add second crossfield taxiway at midfield to provide two-way flow.

Constructing a second crossfield taxiway to provide two-way flow would improve the flow of ground traffic and reduce taxi interference and delays.

Estimated 1992 project cost is $17.0 million, which includes $12.0 million for the taxiway and $5.0 million for the relocation and buyout of the facilities affected by the taxiway construction and safety zones.

Annual cost penalty at the Baseline activity level would be 2,700 hours or $4.7 million, and, at Future 1 activity levels, 3,700 hours or $6.5 million.

2k. Construct cargo gate and taxiway complex north side.

Estimated 1992 project cost is $23.3 million, which includes $19.0 million for land acquisition .

2l. Construct new terminal.

Facilities and Equipment Improvements

3a. Upgrade to CAT III ILS on Runway 27R.

Instrument flight rules (IFR) that severely restrict operations (CAT II or less) occur less than 0.1 percent of the time, but the impact of the associated delays can be significant. Installing a Category III Instrument Landing System (ILS) would reduce visibility minimums and enhance operational flexibility and thereby help to maintain capacity during IFR. CAT III ILS capability already exists for Runway 26L.

Estimated 1992 project cost is $1.2 million for the ILS and $2.0 million for the associated approach light system (ALS), for a total cost of $3.2 million.

Operational Improvements

3b. Conduct dependent IFR approaches to Runways 14L & 9L and 14L & 26.

Under visual flight rules (VFR), it is common to use non-intersecting converging runways for independent streams of arriving aircraft. Because of the reduced visibility and ceilings associated with instrument flight rules (IFR), simultaneous (independent) use of runways is currently permitted for aircraft arrivals only during relatively high weather minimums.

4. Distribute traffic more uniformly during peak periods.

A more uniform distribution of airline flights during peak periods would promote a more orderly flow of traffic, reduce arrival and departure delays, and reduce ground congestion near the terminal and on the taxiway system.

However, IAH is the heart of a major hub-and-spoke operation, and uniform distribution of traffic is not consistent with such an operation. Hubbing creates efficiencies that cannot be measured in a delay study of this type. This system of operations provides frequent service between city-pairs that could not support frequent direct service. Frequent flights provide an economic benefit to consumers, in particular the business flyer. It is doubtful the hubbing operation at IAH will change in the foreseeable future.

5. Construct new reliever airport on west side.

The percentage of general aviation activity is expected to remain relatively constant at 7 percent of annual operations for the three demand levels. GA is an integral part of the aviation system and provides a vital service to businesses and the local community. Every effort should be made to accommodate these aircraft at enhanced "reliever airports" with equal or better access to the metropolitan area. These reliever airports would need to provide services similar to those available at IAH. "Similar services" would include longer and wider runways with associated lighting and increased pavement strength, all-weather approach capability, parallel taxiways, larger aprons, and such ancillary services as rental cars and easy access to public and private transportation.

6. Construct a public-use heliport at Houston Intercontinental Airport.

A heliport would have little effect on fixed-wing traffic at IAH. If helicopter traffic increased, a local control position could be established to handle the extra work load during VFR operations. During IFR operations, helicopters would share the instrument approaches with fixed-wing traffic.

7. Construct additional airline hub at Terminal B.

Terminal B, with its current configuration of 25 gates, could easily handle a minor hub operation of 150 flights per day. This increase in flight activity is presumed to occur in four to five banks. These banks are expected to occur at similar times to the current Continental banks. This increased activity during already congested times could cause additional demands on the airfield system.

8. Construct a Terminal C Ramp Control Tower.

A ramp control tower built on the top of Terminal C would provide for a more orderly flow of traffic on non-movement areas in the vicinity of Terminal C and thereby reduce congestion and delay.

Section 3 Summary of Technical Studies

Overview

The Houston Intercontinental Airport Capacity Team evaluated the efficiency of the existing airfield and the proposed future configurations. Figure 7 illustrates airfield weather conditions and Figure 8, runway utilization. The potential benefits of various improvements were determined by examining airfield capacity, airfield demand, and average aircraft delays.

The Capacity Team used the Runway Delay Simulation Model (RDSIM) to determine aircraft delays during peak periods. Delays were calculated for current and future conditions.

Daily operations corresponding to an average day in the peak month were used for each of the forecast periods. Daily delays were annualized to measure the potential economic benefits of the proposed improvements. The annualized delays provide a basis for comparing the benefits of the proposed changes. The benefits associated with various runway use strategies were also identified.

The fleet mix at Houston Intercontinental Airport (IAH) has an average direct operating cost of $29.00 per minute. This figure represents the costs for operating the aircraft and includes such items as fuel, maintenance, and crew costs, but it does not consider lost passenger time, disruption to airline schedules, or any other intangible factors.

The cost of a particular improvement was measured against its annual delay savings. This comparison indicates which improvement will be the most effective.

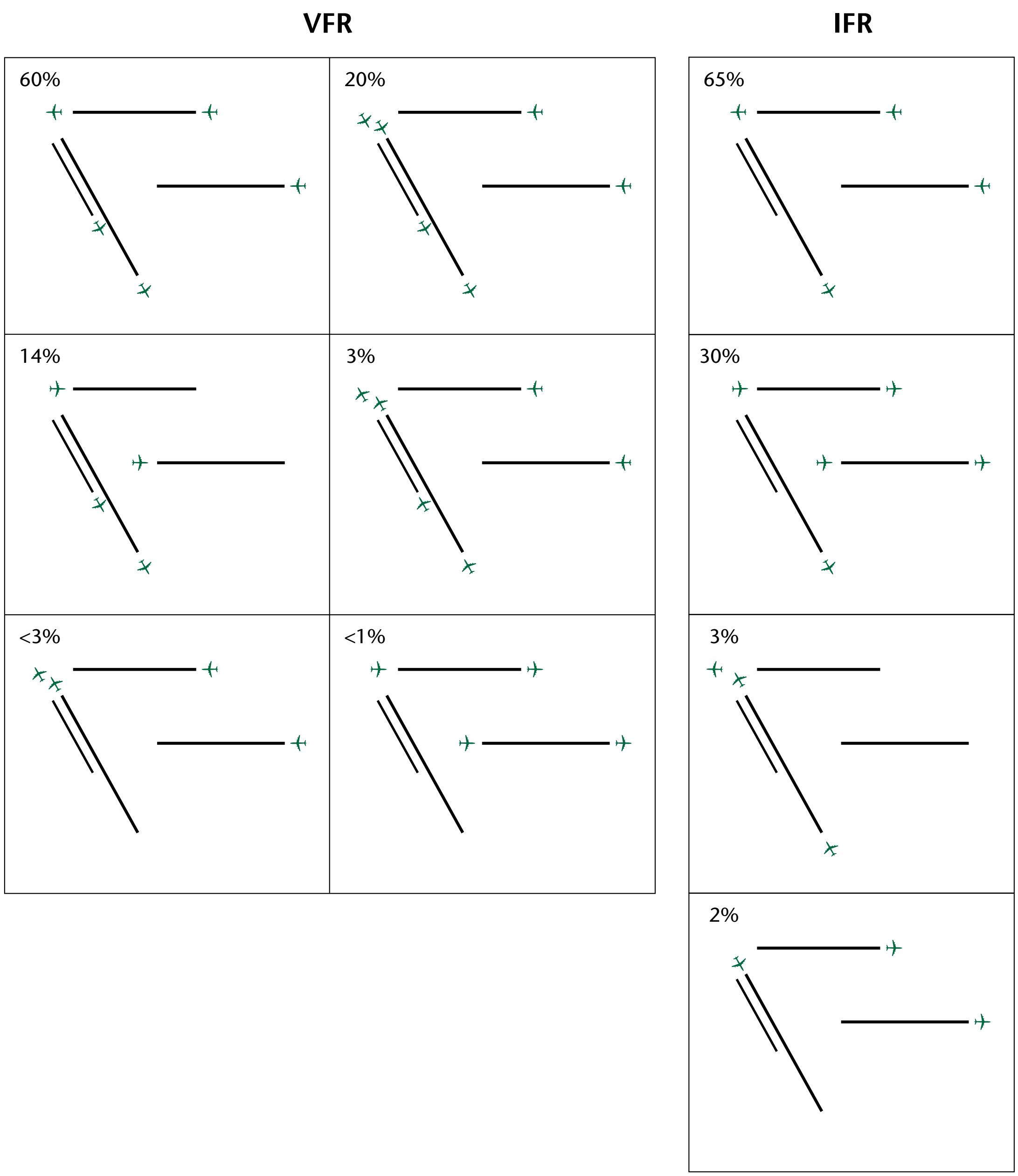
For expected increases in demand, a combination of improvements can be implemented to allow airfield capacity to increase while aircraft delays are minimized.

Figure 7. Airfield Weather

	Ceiling/Visibility	Occurrence (%)
VFR	1,000 feet and above/3 sm and above	89
IFR	below 1,000 feet/below 3 sm	11
	Total	100

VFR – visual flight rules
IFR – instrument flight rules
sm – statute miles

Figure 8. Runway Utilization (percentage use)



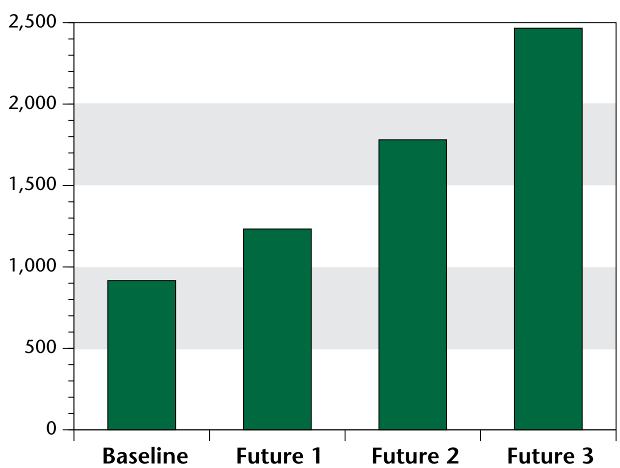
Airfield Capacity

The IAH Capacity Team defined airfield capacity to be the maximum number of aircraft operations (landings or takeoffs) that can take place in a given time. The following conditions were considered:

- Level of delay
- Airspace constraints
- Ceiling and visibility conditions
- Runway layout and use
- Aircraft mix
- Percent arrival demand

Figure 9 illustrates the average-day, peak-month arrival and departure demand levels for IAH for each of the four annual activity levels used in the study, Baseline, Future 1, Future 2, and Future 3.

Figure 9. Airfield Demand Levels



	Annual	24-Hour Day*	Peak Hour
Baseline	334,000	916	83
Future 1	450,000	1,233	108
Future 2	650,000	1,781	154
Future 3	900,000	2,466	210

* Average Day, Peak Month

Figure 10 presents the airport capacity curves for IAH. The curves were developed for the current airfield configuration at IAH, with an 80/20, 20/80, and 50/50 split of arrivals and departures, under instrument flight rules (IFR). These curves are based on the assumption that arrival and departure demand is randomly distributed within the hour. Other patterns of demand can alter the demand/delay relationship.

The curves in Figure 10 illustrate the relationship between airfield capacity, stated in the number of operations per hour, and the average delay per aircraft. They show that, as the number of aircraft operations per hour increases, the average delay per operation increases exponentially.

Figure 11 illustrates the hourly profile of daily demand for the Baseline activity level of 334,000 aircraft operations per year. It also includes a curve that depicts the profile of daily operations for the Future 3 activity level of 900,000 aircraft operations per year.

Comparing the information in Figures 10 and 11 shows that:

- aircraft delays will begin to rapidly escalate as hourly demand exceeds 70 to 110 operations per hour, and,
- while hourly demand exceeds 70 operations during certain hours of the day at Baseline demand levels, 110 operations per hour is frequently exceeded at the demand levels forecast for Future 2.

Figure 10. Airport Capacity Curve — Average Flow Rate Versus Average Daily Delay — IFR Operations

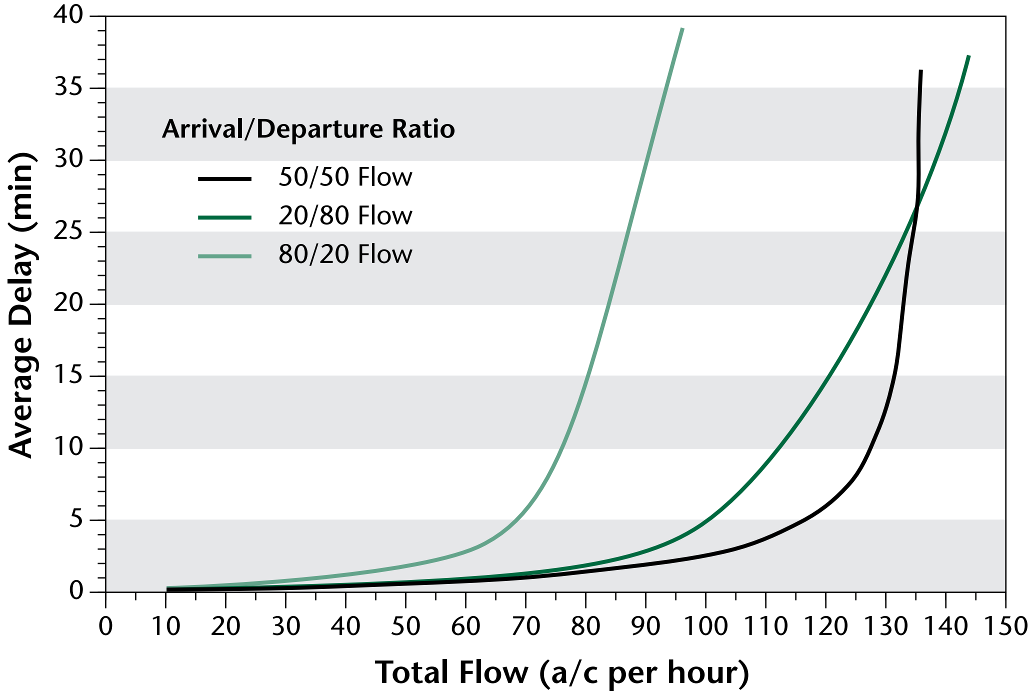
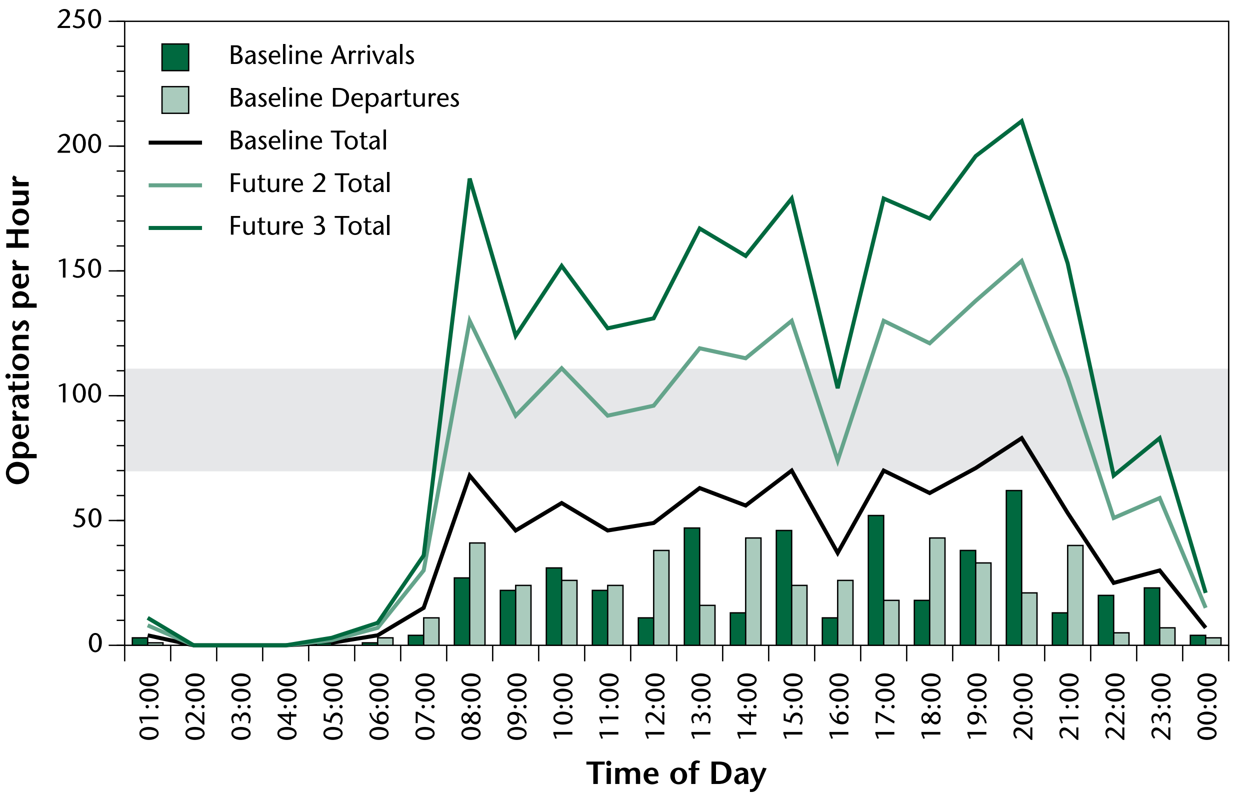


Figure 11. Profile of Daily Demand — Hourly Distribution



Aircraft Delays

Aircraft delay is defined as the time above the unimpeded travel time for an aircraft to move from its origin to its destination. Aircraft delay results from interference from other aircraft competing for the use of the same facilities. The major factors influencing aircraft delays are:

- Weather
- Airfield and ATC system demand
- Airfield physical characteristics
- Air traffic control procedures
- Aircraft operational characteristics

Average delay in minutes per operation was generated by the Runway Delay Simulation Model (RDSIM). A description of this model is included in Appendix B. If no improvements are made in airport capacity, the average delay per operation of 10 minutes in Baseline will increase to 128 minutes per operation by Future 3.

Under the Do Nothing situation, if there are no improvements in airfield capacity, the annual delay cost could increase as follows:

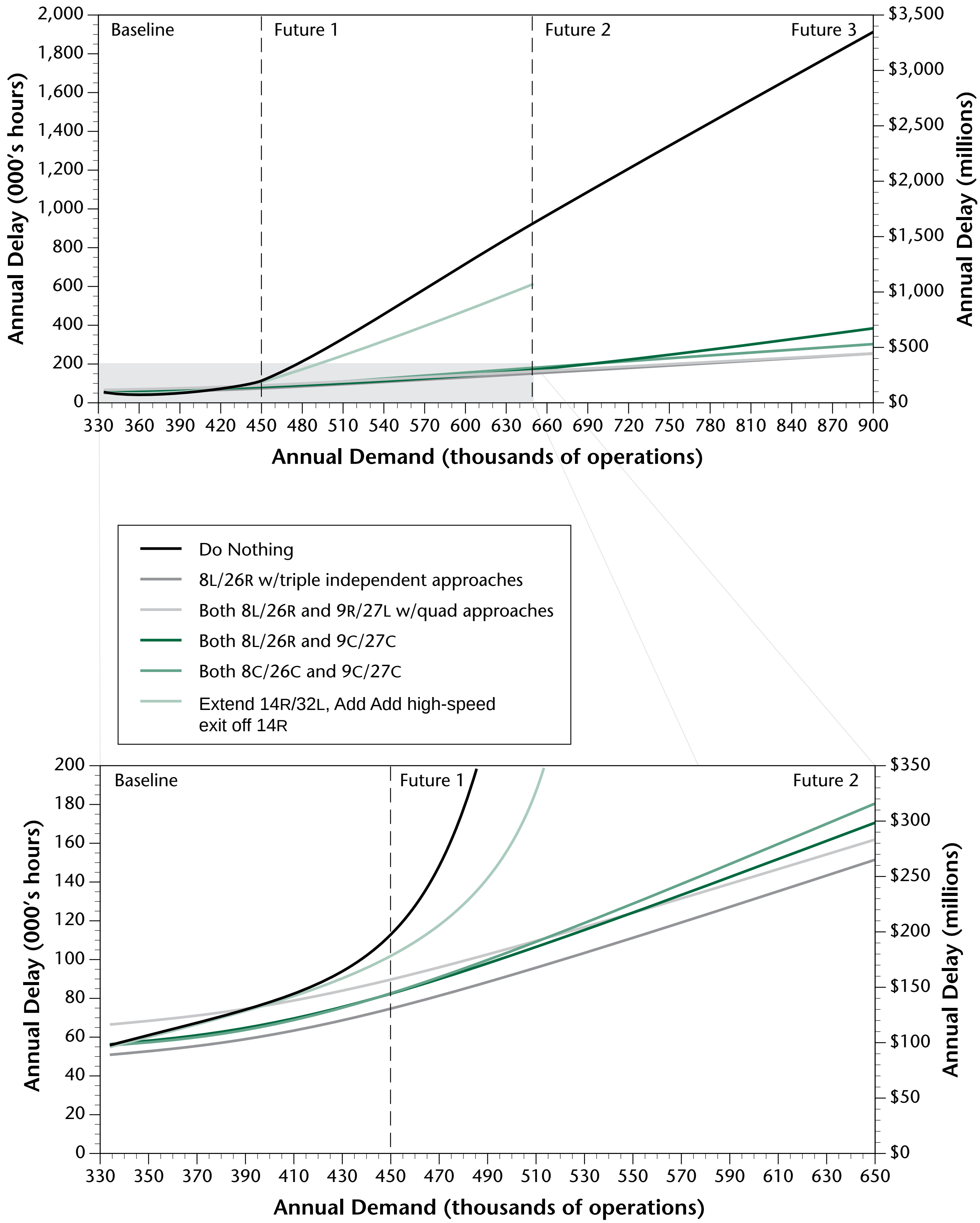
	Annual Delay Costs	
	Hours	Millions of 1992 $
Baseline	55,400	$96.4
Future 1	113,700	$197.8
Future 2	926,300	$1,611.7
Future 3	1,912,700	$3,328.1

Conclusions

Figure 12 demonstrates the impact of delays at Houston Intercontinental Airport. The chart shows how delay will continue to grow at a substantial rate as demand increases if there are no improvements made in airfield capacity, i.e., the Do Nothing scenario. The graphs also show that the greatest savings in delay costs would be provided by:

- Constructing air carrier Runway 8L/26R to support triple independent approaches
- Constructing both air carrier Runway 8L/26R and new carrier Runway 9R/27L to support quadruple independent approaches
- Constructing both Runway 8L/26R and Runway 9C/27C
- Constructing both Runway 8C/26C and Runway 9C/27C
- Extending, widening, and strengthening Runway 14R/32L for air carrier departures, with arrivals on Runways 26L and 27R and adding a high-speed exit off Runway 14R

Figure 12. Annual Delay Costs — Capacity Enhancement Alternatives

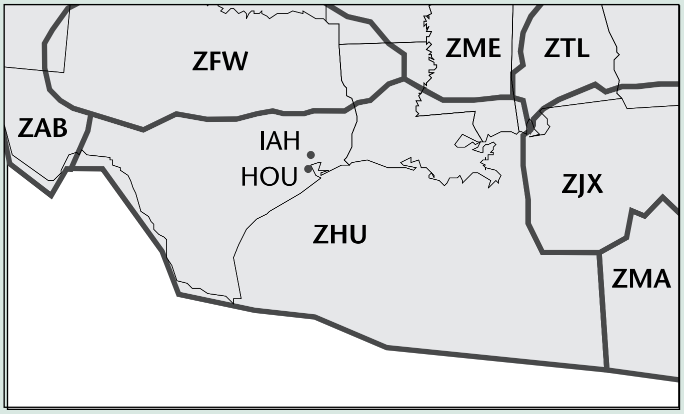


Houston Intercontinental Airport

Airport and Airspace Capacity Enhancement Plan

Part Two

Terminal Airspace Modeling



Section 1 Introduction

Background

During the Airport Capacity Design Team Study, representatives from the Capacity Team were concerned that their efforts to improve the capacity of Houston Intercontinental Airport (IAH) would not be effective if the terminal airspace in the Houston area could not adequately handle the increased traffic. The Design Team recommended that the capacity study include airspace modeling in order to show airport improvements from a total airspace system perspective, including the impact of operations at William P. Hobby Airport (HOU) and Ellington Field (EFD).

The Federal Aviation Administration (FAA), Office of System Capacity and Requirements (ASC), had been sponsoring a series of airspace capacity design projects intended to identify and evaluate operational alternatives with the potential to improve efficiency, increase capacity, and reduce delay within the National Airspace System (NAS). They had begun planning to expand this program to include airspace capacity design studies of the terminal and en route airspace associated with delay-affected airports across the country. These studies were originally intended to follow the Airport Capacity Design Team Studies. In the case of Houston Intercontinental Airport, the Capacity Team decided to combine the airport capacity study and airspace modeling into a single project.

Objectives

The purpose of the airspace modeling was:

- To determine which airport improvements would offer the most benefit in terms of increased capacity and reduced delays at Future 1, Future 2, and Future 3 demand levels, and
- To determine at what level of operations new air traffic control procedures and airspace restructuring would be required for the terminal and adjacent en route airspace.

Methodology

SIMMOD is the FAA's Airport and Airspace Simulation Model. It can model the operations of airport and airspace systems ranging in size from an individual terminal gate to a major airspace route network. SIMMOD simulates the movement of every aircraft, step by step, along each segment of a flight or taxi path, resolving conflicts and monitoring the time and fuel consumed. Once the basic structure of the airport or airspace system has been prepared, SIMMOD can be used to develop and evaluate new alternatives by adjusting selected input parameters. A brief description of the model is included in Appendix B.

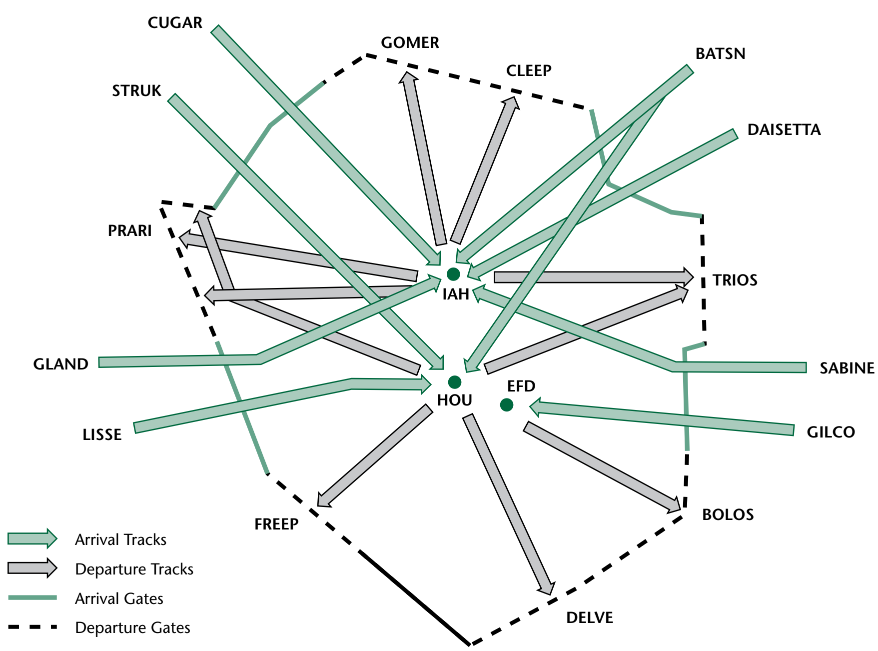
SIMMOD was loaded with data to reflect current operations in the Houston Metropolitan Area (e.g., airfield layouts, terminal airspace structures, aircraft flight tracks and schedules, and operating procedures). Simulation runs were conducted to compare SIMMOD results with actual traffic statistics in order to calibrate and verify model performance. Additional simulation runs were conducted for the baseline system with both the baseline and future traffic demands. Projected increases in operations at IAH, HOU, and EFD were included in the simulations, with particular emphasis being placed on the demand at arrival and departure gates. An analysis was conducted to determine at what point the existing capacity of the supporting airspace would be exceeded and, as demand continued to increase, to determine the delays that would be incurred with the current airspace system.

The airspace study concentrated on the arrival and departure fixes serving the Houston terminal airspace. Specific levels of traffic that represented the existing hourly capacity levels of each fix were provided for SIMMOD. The Baseline air traffic demand was then increased to the Future 1, Future 2, and Future 3 demand levels to determine when existing capacity would be reached for each of the arrival and departure gates. Delays were calculated for each demand level. Upon completion of the simulation runs, sets of output were provided for analysis: A brief summary of the results from the analysis of each scenario follows in Section 3.

Section 2 Description of Current Airspace Operations

The Houston area airspace consists of four arrival gates and five departure gates. These gates are used to feed aircraft into and out of the Houston Terminal Radar Approach Control (TRACON). Figure 13 shows the arrival and departure gates for the Houston TRACON.

Figure 13 Houston TRACON Arrival and Departure Gates



The arrival gates use two paths with three altitude levels to feed traffic in the Houston area. One of the paths at a gate is for arrivals to Houston Intercontinental only, the other, for arrivals to William P. Hobby and Ellington Field. Aircraft are fed into the Houston TRACON airspace by the Houston Center at 6-mile-in-trail separation intervals. Once in the TRACON's airspace, the in-trail separations are reduced to 3 miles. The three altitude levels for arrival traffic are based on aircraft type, one for jets, one for turbo props, and one for small props. The different altitudes allow for segregation of traffic to control aircraft separation and speed. Once the aircraft are closer to the airports, they are merged to the common approach for the runway they will be landing on.

Departures from the Houston airspace are segregated at two altitude levels, one for jets and one for props. Equivalent aircraft using the same route must be separated by 5 miles before entering the Center's airspace.

Given today's air traffic control procedures and airport configurations, the Houston Center has established capacity levels for the arrival gates at Houston TRACON. These capacity levels have been developed in relation to the arrival and departure gates described earlier and are denoted by the fixes the aircraft fly over. Figure 14 lists the capacity levels for each arrival and departure gate. These capacity levels take into account the surrounding and en route airspace passing the Houston TRACON. They apply only to Houston's TRACON and will be used to compare the results established in the simulations.

Figure 14. Houston TRACON Current Capacity Levels

Arrival and Departure Gates	Capacity Levels (Assigned by Houston Center)
Arrival Gates	
DAS/BATSN	45 / hour
SABINE/GILCO	45 / hour
GLAND/LISSE	45 / hour
STRUK/CUGAR	45 / hour
Departure Gates	
GOMER/CLEEP	60 / hour
TRIOS	45 / hour
BOLOS	30 / hour
PRARI	45 / hour
FREEP	30 / hour

Section 3 Results, Conclusions, and Recommendations

Analysis Results

Figure 15 compares the current Houston TRACON capacity levels and future activity levels simulated in the airspace study. The shaded areas signify that the current capacity levels have been met or exceeded, and the number next to the capacity value indicates the number of times in a day that this happened. A single occurrence is when the number of aircraft meets or exceeds the assigned capacity level during a 15 minute period.

Figure 15. Comparison of Arrival and Departure Gate Capacity and Current and Future Demand

Arrival and Departure Gates	Current Capacity Levels (assigned by Houston Center)	Baseline Peak Activity Level** (720,000 ops/year)	Future 1 Peak Activity Level** (880,000 ops/year)	Future 2 Peak Activity Level** (1,140,000 ops/year)	Future 3* Peak Activity Level** (1,430,000 ops/year)
Arrival Gates					
DAS/BATSN	45 / hour	38 / hour	46 / hour – 1	58 / hour – 8	53 / hour – 14
SABINE/GILCO	45 / hour	26 / hour	32 / hour	36 / hour	43 / hour
GLAND/LISSE	45 / hour	18 / hour	20 / hour	28 / hour	31 / hour
STRUK/CUGAR	45 / hour	31 / hour	38 / hour	46 / hour – 1	50 / hour – 4
Departure Gates					
GOMER/CLEEP	60 / hour	41 / hour	45 / hour	60 / hour – 1	76 / hour – 15
TRIOS	45 / hour	14 / hour	19 / hour	28 / hour	35 / hour
BOLOS	30 / hour	21 / hour	26 / hour	31 / hour – 1	43 / hour – 5
PRARI	45 / hour	20 / hour	20 / hour	23 / hour	28 / hour
FREEP	30 / hour	14 / hour	19 / hour	24 / hour	33 / hour – 4

* Because of the high demand, this simulation was only run for one iteration; thus, the decrease in the flow rate for DAS/BATSN.

** Peak activity levels include Houston Intercontinental, Houston Hobby, and Ellington Field.

Conclusions

Although Houston Intercontinental Airport is experiencing aircraft delays based on the current level of demand and the current airfield capacity, Figure 15 highlights the fact that the current Houston TRACON airspace can handle traffic demand at the current, or Baseline, level of activity. However, at the Future 1 demand level, the arrival gate DAS/BATSN will reach the current capacity level assigned to the gate by the Houston Center. At this demand level, aircraft traffic will start producing more delays because of the airspace restriction at the DAS/BATSN arrival fix. At the Future 2 and Future 3 demand levels, the number of gates reaching or exceeding their assigned capacity will increase as will the number of occurrences.

Figure 16 illustrates the annual delay costs that will result from the airspace restrictions at the arrival and departure gates for each level of demand. The increasing delay costs indicate that, when the Houston TRACON traffic level approaches 80 percent of Future 2 demand levels, a change in air traffic control procedures or an airspace restructuring should be further studied.

Figure 16. Airspace Delay Costs Per Year — Current-Capacity-Level Restrictions Versus Unrestricted Airspace

Demand Level	Delay Cost Per Year (Hours)	(Millions of 1992 $)
Baseline	0	$0
Future 1	24	$0.04
Future 2	7,545	$13.13
Future 3	34,840	$60.62

Recommendations

The Houston terminal airspace analysis project examined air traffic issues of concern in the Houston Metropolitan Area. Potential solutions to particular capacity and delay problems in the future may include realignment of airspace, modifications to fixed routes, changes in aircraft flight routing, and revisions to air traffic control procedures.

Based on the analysis performed in this study, the following studies are recommended for future analysis of air traffic operations in the Houston area:

- Restructuring terminal area airspace to provide additional arrival and departure gates.
- Updating air traffic control procedures.

This analysis should include concepts of airspace restructuring that offer the potential for improving arrival and departure air route capacity in conjunction with recent and planned airport improvements.

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Appendix B Computer Models and Methodology

The IAH Capacity Team studied the effects of various improvements proposed to reduce delay and enhance capacity. The options were evaluated considering the anticipated increase in demand. The analysis was performed using several computer modeling techniques. A brief description of the models and the methodology employed follows.

Computer Models

Runway Delay Simulation Model (RDSIM)

RDSIM is a short version of the Airfield Delay Simulation Model (ADSIM). ADSIM is a fast-time, discrete event model that employs stochastic processes and Monte Carlo sampling techniques and describes significant movements of aircraft on the airport and the effects of delay in the adjacent airspace. ADSIM was validated in 1978 at Chicago O'Hare International Airport against actual flow rates and delay data.

RDSIM, on the other hand, simulates only the runways and runway exits. There are two versions of the RDSIM model. The first version ignores the taxiway and gate complexes for a user-specified daily traffic demand and is used to calculate daily demand statistics. In this mode, the model replicates each experiment forty times, using Monte Carlo sampling techniques to introduce daily variability of results, which are averaged to produce output statistics. The second version also simulates the runway and runway exits only, but it creates its own demand using randomly assigned arrival and departure times. The demand created is based upon user-specified parameters. This form of the model is suitable for capacity analysis.

For this study, RDSIM was calibrated against field data collected at IAH to insure that the model was site specific. For a given demand, the model calculated the hourly flow rate and average delay per aircraft during the full period of airport operations. Using the same aircraft mix, computer specialists simulated different demand levels for each run to generate demand versus delay relationships.

Airport and Airspace Simulation Model (SIMMOD)

SIMMOD is a fast-time, event-step model that simulates the real-world process by which aircraft fly through air traffic controlled en route and terminal airspace and arrive and depart at airports. SIMMOD traces the movement of individual aircraft as they travel through the gate, taxiway, runway, and airspace system and detects potential violations of separations and operation procedures. It simulates the air traffic control actions required to resolve potential conflicts to insure that aircraft operate within procedural rules. Aircraft travel time, delay, and traffic statistics are computed and provided as model outputs. The model was calibrated for this study against field data collected at IAH to ensure it was site specific. Inputs for the simulation model were also derived from empirical field data. The model repeated each experiment 10 times using Monte Carlo sampling techniques to introduce system variability. The results were then average to produce output statistics.

Methodology

Model simulations included present and future air traffic control procedures, various airfield improvements, and traffic demands for different times. To assess the benefits of proposed airfield improvements, the FAA used different airfield configurations derived from present and projected airport layouts. The projected implementation time for air traffic control procedures and system improvements determined the aircraft separations used for IFR and VFR weather simulations.

For the delay analysis, agency specialists developed traffic demands based on the *Official Airline Guide*, historical data, and various forecasts. Aircraft volume, mix and peaking characteristics were developed for three demand periods (Baseline, Future 1, and Future 2). The estimated annual delays for the proposed improvement options were calculated from the experimental results. These estimates took into account the yearly variations in runway configurations, weather, and demand based on historical data.

The potential delay reductions for each improvement were assessed by comparing the annual delay estimates with the Do Nothing case.

The RDSIM model, in its capacity mode, was used to perform the capacity analysis for IAH.

Appendix C List of Abbreviations

ADSIM	Airfield Delay Simulation Model
ARFF	Aircraft Rescue and Fire Fighting
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASC	Office of System Capacity and Requirements, FAA
ATC	Air Traffic Control
CRDA	Converging Runway Display Aid
EFD	Ellington Field
HOU	William P. Hobby Airport
IAB	Mickey LeLand Memorial International Airlines Building
IAH	Houston Intercontinental Airport
FAA	Federal Aviation Administration
GA	General Aviation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
NAS	National Airspace System
NM	Nautical miles
OAMP	Off-Line Aircraft Management Program
PRM	Precision Runway Monitor
RDSIM	Runway Delay Simulation Model
SAR	System Analysis Recording
SIMMOD	Airport and Airspace Simulation Model
SM	Statute miles
TERPS	Terminal Instrument Procedures
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
ZAB	Albuquerque Center — Albuquerque Air Route Traffic Control Center (ARTCC)
ZFW	Fort Worth Center — Fort Worth Air Route Traffic Control Center (ARTCC)
ZHU	Houston Center — Houston Air Route Traffic Control Center (ARTCC)
ZJX	Jacksonville Center — Jacksonville Air Route Traffic Control Center (ARTCC)
ZME	Memphis Center — Memphis Air Route Traffic Control Center (ARTCC)
ZTL	Atlanta Center — Atlanta Air Route Traffic Control Center (ARTCC)

Credits:

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