Minneapolis-Saint Paul International Airport

Capacity Enhancement Plan

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MINNEAPOLIS-SAINT PAUL METROPOLITAN AIRPORTS COMMISSION
MAC
1943 - 1993

Minneapolis-Saint Paul International Airport

Capacity Enhancement Plan

December 1993

Prepared jointly by the U.S. Department of Transportation, Federal Aviation Administration, Minneapolis-Saint Paul Metropolitan Airports Commission, and the airlines and general aviation serving Minneapolis and Saint Paul.

FEDERAL AVIATION ADMINISTRATION

MINNEAPOLIS-SAINT PAUL METROPOLITAN AIRPORTS COMMISSION
MAC
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MAC
METROPOLITAN AIRPORTS COMMISSION
Welcome to
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Figure 1. Minneapolis-Saint Paul International Airport Minneapolis, Minnesota

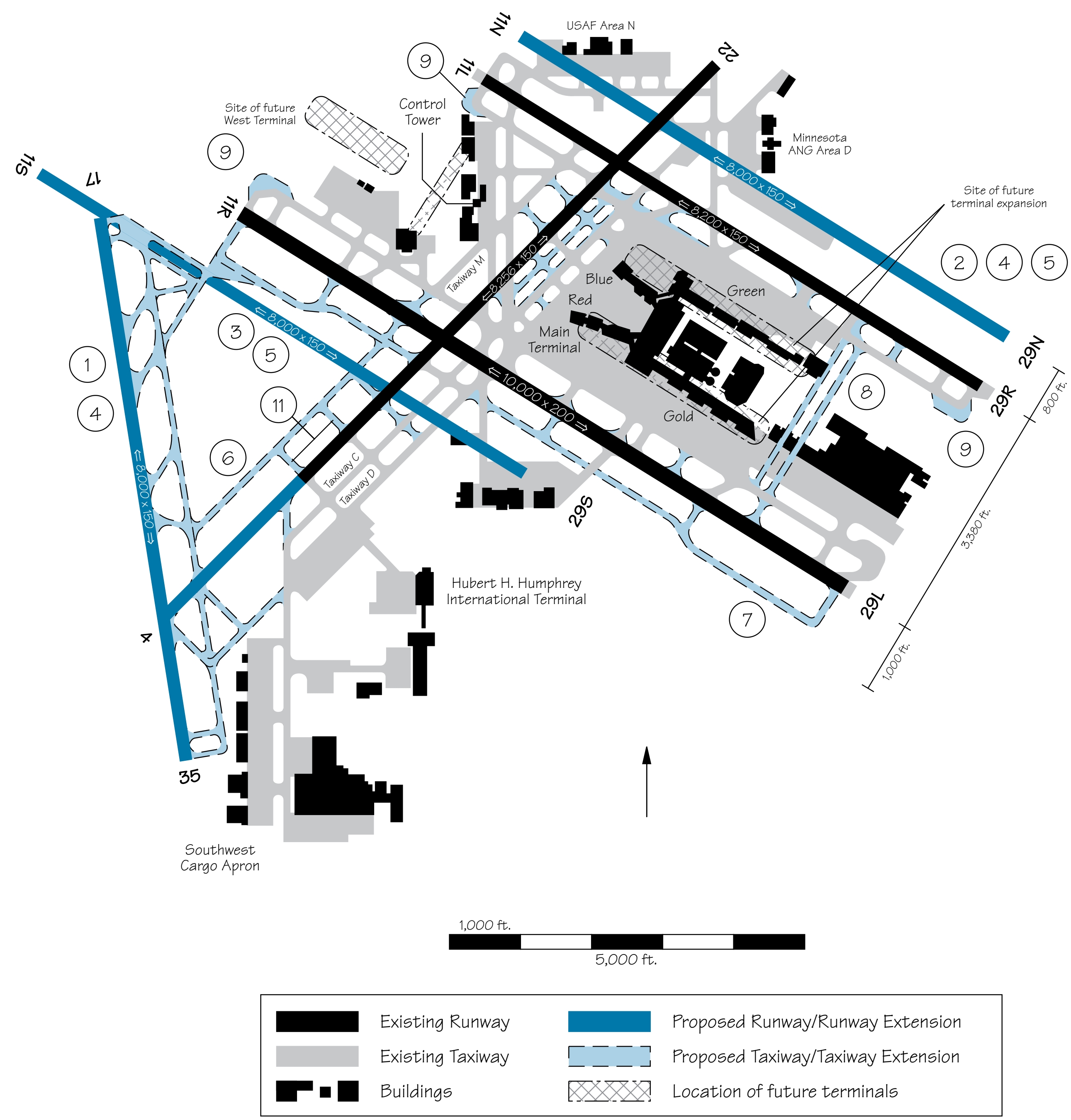


Figure 2. Capacity Enhancement Alternatives and Annual Delay Savings

Alternatives Airfield Improvements	Estimated Annual Delay Savings* (in hours and millions of 1992 dollars) Baseline (420,390)	Future 1 (530,000)	Future 2 (600,000)
1. New N/S Runway 17/35 on west side of airport, south of parallel runways	6,534/$9.5	20,757/$30.0	43,677/$63.2
2. New Runway 11N/29N 800 ft. north of Runway 11L/29R	4,051/$5.9	17,526/$25.4	38,741/$56.1
3. New Runway 11S/29S 1,000 ft. south of Runway 11R/29L with threshold staggered 3,000 ft. to the west	4,127/$6.0	20,147/$29.2	44,936/$65.0
4. New Runways 17/35 and 11N/29N (combines alternatives 1 and 2)	8,438/$12.2	26,296/$38.1	56,548/$81.8
5. New Runways 11N/29N and 11S/29S (combines alternatives 2 and 3)	7,190/$10.4	24,904/$36.0	54,542/$78.9
6. Extend Runway 4/22 2,750 ft. to SW with Taxiways C, D, and M and a queuing taxiway		†	
7. New full-length parallel taxiway 600 ft. south of Runway 11R/29L	927/$1.3	1,147/$1.7	2,340/$3.4
8. Dual crossover taxiways between Runways 11L/29R and 11R/29L	2,084/$3.0	3,294/$4.8	3,787/$5.5
9. Departure sequencing pads on Runways 29R, 11L, and 11R		†	
10. Additional exits on Runways 11R/29L and 11L/29R		†	
11. Additional exits on Runway 4/22		†	
12. Aircraft hold areas (penalty boxes)		†	
Facilities and Equipment Improvements			
13. CAT I ILS approach lights on Runway 29R		†	
14. CAT II/III ILS on Runway 29R with RVR	868/$1.3	2,405/$3.5	3,486/$5.0
15. CAT II/III ILS on Runways 11L and 11R with RVR	864/$1.3	2,402/$3.5	3,520/$5.1
16. Precision Runway Monitor (PRM)	3,182/$4.6	13,822/$20.0	45,834/$66.3
17. Doppler VOR installed at MSP		†	
18. Runway centerline and touchdown zone lights for Runway 4/22		†	
19. RVR for Runway 4/22		†	
Operational Improvements			
20. Reduce in-trail separations to 2.5 nm for like classes of aircraft in IFR	983/$1.4	530/$0.8	583/$0.8
21. Converging IFR approaches		†	
22. FMS transitions to existing approaches		†	
23. Continue enhancement of reliever airports			
23a. 25% of small/slow aircraft	2,655/$3.8	4,466/$6.5	7,304/$10.6
23b. 50% of small/slow aircraft	3,617/$5.2	8,868/$12.8	19,275/$27.9

* The savings for airfield improvements are in addition to the savings for PRM at all demand levels. The savings for facilities and equipment and operational improvements are in addition to the savings for PRM at Future 1 and Future 2. The savings benefits of these alternatives are not necessarily additive.

† 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.

Recognizing the problems posed by congestion and delay within the National Airspace System, 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. Each Capacity Team identifies and evaluates alternative means to enhance existing airport and airspace capacity to handle future demand, decrease delays, and improve airport efficiency and works to develop a coordinated action plan for reducing airport delay. Over 30 Airport Capacity Design Teams have either completed their studies or have work in progress.

The need for this program continues. Minneapolis-Saint Paul International Airport (MSP) is one of the 23 airports that exceeded 20,000 hours of annual aircraft delay in 1992 and, according to FAA forecasts, one of the 33 airports that could exceed 20,000 hours of annual delay in 2002, if no improvements in capacity are made. Steady growth at MSP has made it one of the busiest airports in the country. Activity at the airport has increased from 5,909,000 passenger enplanements in 1983 to 11,377,873 in 1992, an increase of over 90 percent. In 1983, the airport handled 300,358 aircraft operations (takeoffs and landings), and, in 1992, 413,502 aircraft operations, an increase of 38 percent.

The results of separate studies conducted by the Metropolitan Airports Commission and the Metropolitan Council have shown that additional airport capacity will be needed in the future to meet the long-range aviation needs of the region. In response to these studies, the Minnesota Legislature's Metropolitan Airport Planning Act of 1989 established a dual-track planning process designed to preserve the region's major airport options for the future.

One track focused on planning for the proposed development of a new airport. The other track focused on possible ways to improve the capacity of the current airport and developed the Long-Term Comprehensive Plan for Minneapolis-Saint Paul International Airport. The Plan provides a blueprint for development through the year 2020 and is based on the assumption that MSP will continue to be the region's major airport.[1]

Based on the results of the Long-Term Comprehensive Plan, which was developed by the Metropolitan Airport Commission, the MSP Capacity Team identified and assessed various actions which, if implemented, would increase MSP'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 a computer model developed by the FAA to quantify the benefits provided. 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—420,390 operations;
- Future 1—530,000 operations
- Future 2—600,000 operations

Figure 3, on the following page, shows the capacity and delay curves for MSP. These curves were developed for the existing airport configuration and for a future airport configuration with the new north parallel Runway 11N/29N

1. The Long-Term Comprehensive Plan for MSP includes only a new north/south Runway 17/35 on the west side of the airport in its configuration for the year 2020. Development of a new Runway 11N/29N or 11S/29S would only occur if the north/south Runway 17/35 were not possible.

Figure 3. Airport Capacity Curves—Hourly Flow Rate Versus Average Delay

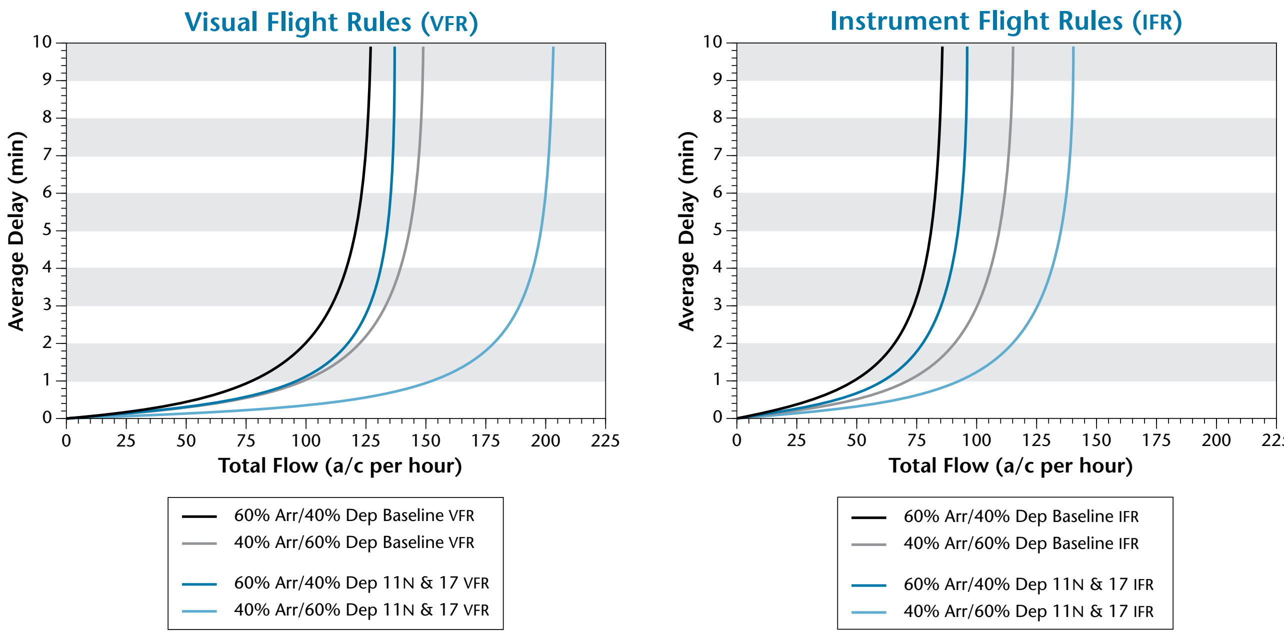
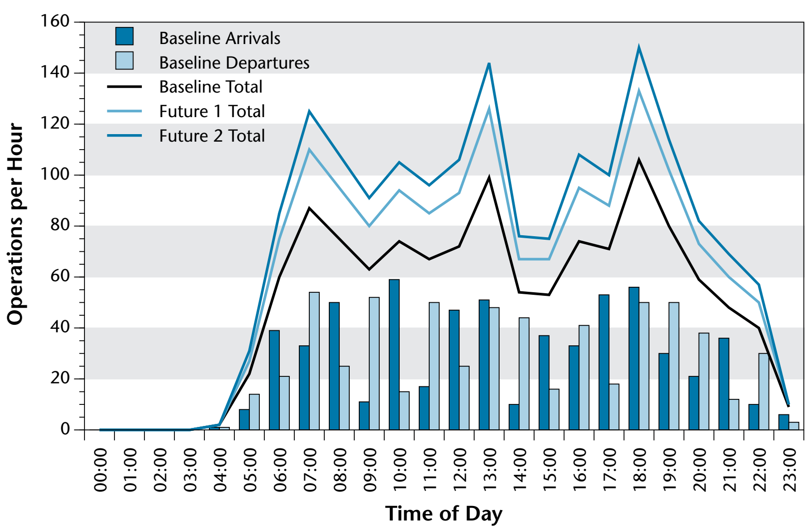


Figure 4. Profile of Daily Demand—Hourly Distribution



and the new north/south Runway 17/35 in place. They show the airport under visual flight rules (VFR) and instrument flight rules (IFR), with a 60/40 and 40/60 split of arrivals and departures. These curves show that, for the existing airport configuration under IFR, aircraft delays will begin to escalate rapidly as hourly demand exceeds 80 to 105 operations per hour. Figure 4 shows that, while hourly demand exceeds 80 operations only during certain hours of the day at Baseline demand levels, 105 operations per hour is frequently exceeded at the demand levels forecast for Future 1 and Future 2.

Figure 5, on the following page, shows how delay will continue to grow at a substantial rate as demand increases if there are no improvements made in capacity, i.e., the Do Nothing scenario. Annual delay cost will increase from 21,440 hours or $31.0 million at the Baseline level of operations to 62,403 hours or $90.3 million by Future 1 and 137,924 hours or $199.6 million by Future 2.

Figure 5 also shows the capacity enhancement alternatives that provide the most significant delay-savings benefits.

Major Capacity Enhancement Alternatives

	Annual Delay Savings			
	Future 1		Future 2	
Alternatives	Hours	1992 $ M	Hours	1992 $ M
• Precision Runway Monitor (PRM)	13,822	$20.0	45,834	$66.3
• New Runways 17/35 and 11N/29N	26,296	$38.1	56,548	$81.8
• New Runways 11N/29N and 11S/29S	24,904	$36.0	54,542	$78.9
• New Runway 11S/29S 1,000 feet south of Runway 11R/29L†	20,147	$29.2	44,936	$65.0
• New Runway 17/35 on west side of airport, south of parallel taxiways‡	20,757	$30.0	43,677	$63.2
• New Runway 11N/29N 800 feet north of Runway 11L/29R†	17,526	$25.4	38,741	$56.1

Note: The annual delay savings for airfield improvement alternatives are in addition to the savings for PRM at all demand levels.

†. This is an alternative to the new Runway 17/35 in the Metropolitan Airport Commission's Long-Term Comprehensive Plan for MSP, if Runway 17/35 cannot be constructed.

‡. This is the prefered option identified in the Metropolitan Airport Commission's Long-Term Comprehensive Plan.

Figure 6 illustrates the average delay in minutes per aircraft operation for these same alternatives. Under the Do Nothing alternative, if there are no improvements made in airfield capacity, the average delay per operation of 3.1 minutes at the Baseline level of activity will increase to 7.1 minutes per operation by Future 1 and 13.8 minutes per operation by Future 2.

Figure 7, on the following page, illustrates the annual delay-savings benefits for each of the improvement alternatives modeled at each of the three activity levels (operations per year). It serves to highlight the alternatives that will provide the greatest savings in delay costs.

Figure 5. Annual Delay Costs—Capacity Enhancement Alternatives

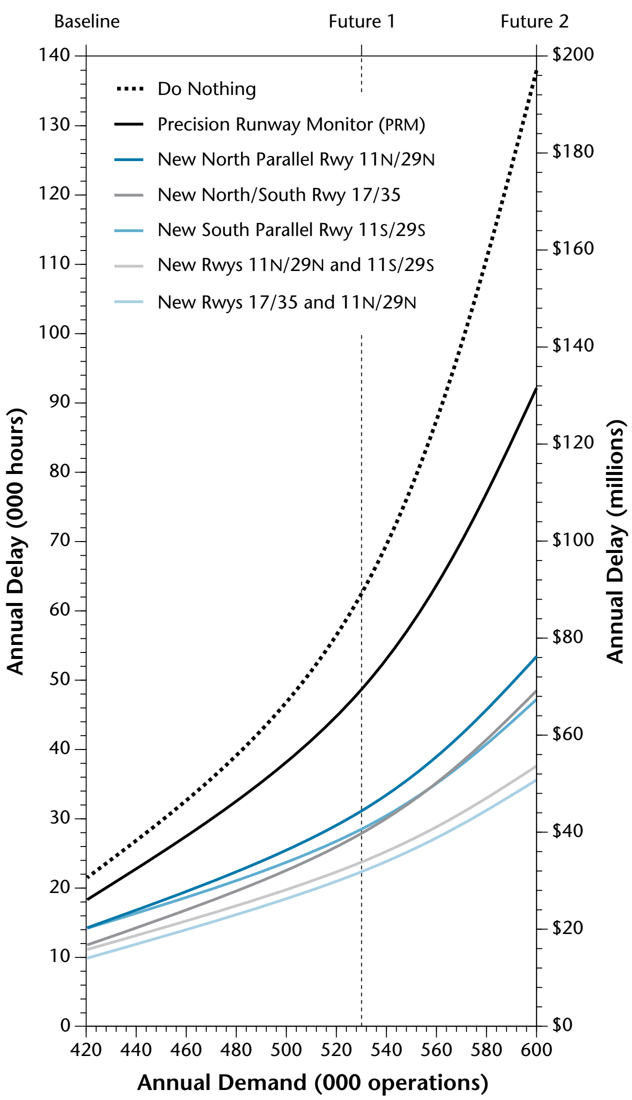


Figure 6. Average Delays—Capacity Enhancement Alternatives

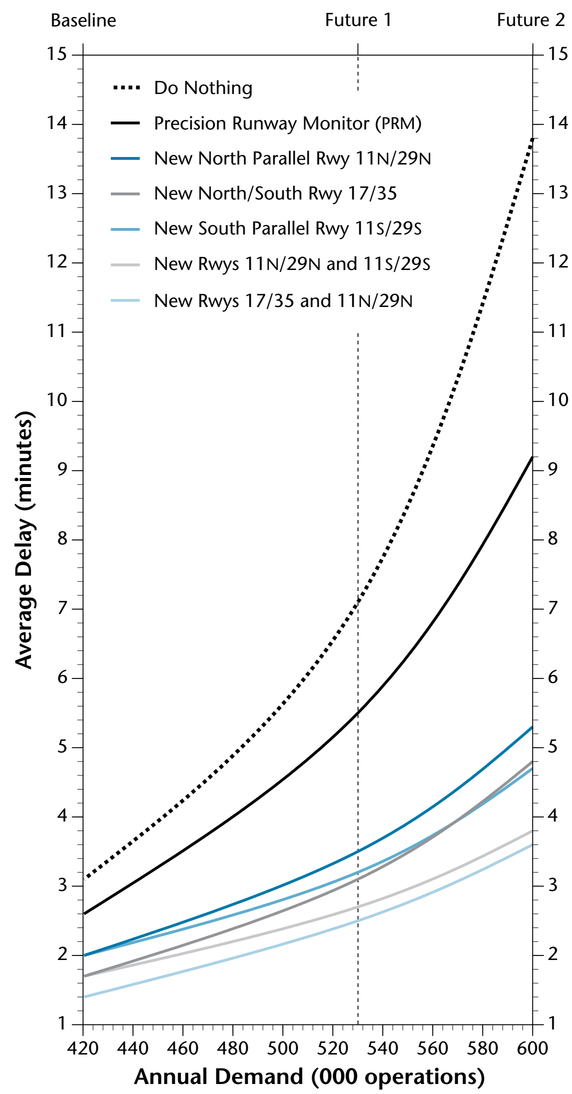
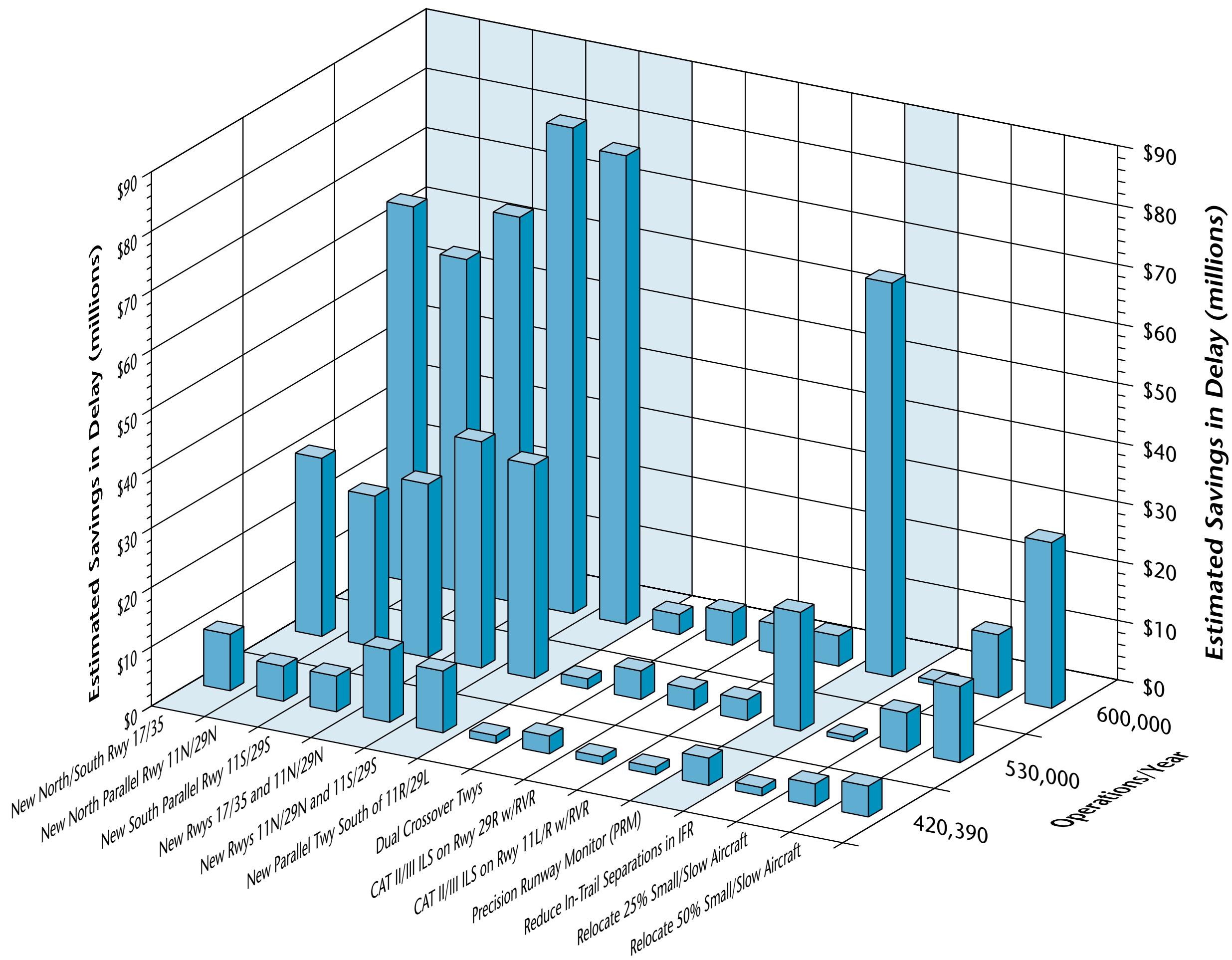


Figure 7. Annual Delay-Savings Benefits— Capacity Enhancement Alternatives



Major Capacity Enhancement Alternatives

- Precision Runway Monitor (PRM)
- New Runways 17/35 and 11N/29N
- New Runways 11N/29N and 11S/29S
- New Runway 11S/29S 1,000 feet south of Runway 11R/29L†
- New Runway 17/35 on west side of airport, south of parallel taxiways‡
- New Runway 11N/29N 800 feet north of Runway 11L/29R†

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†. This is an alternative to the new Runway 17/35 in the Metropolitan Airport Commission's Long-Term Comprehensive Plan for MSP, if Runway 17/35 cannot be constructed.

‡. This is the prefered option identified in the Metropolitan Airport Commission's Long-Term Comprehensive Plan.

Minneapolis-Saint Paul Metropolitan Airport System

Note: South St. Paul Municipal Airport is not owned/operated by MAC.

Section 1

Introduction

Background

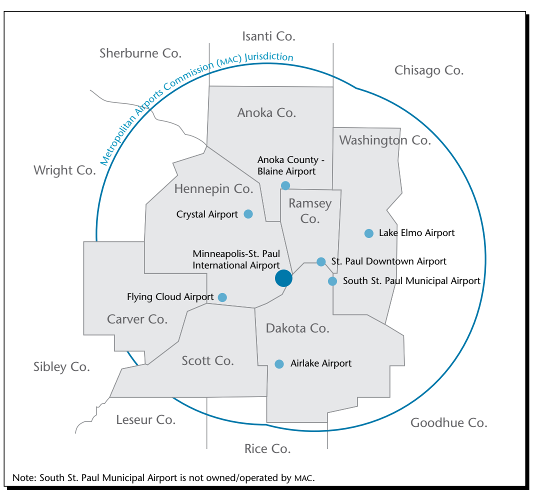
Recognizing the problems posed by congestion and delay within the National Airspace System, the Federal Aviation Administration (FAA) asked the aviation community to study the problem of airport congestion through the Industry Task Force on Airport Capacity Improvement and Delay Reduction chaired by the Airport Operators Council International.

By 1984, aircraft delays recorded throughout the system highlighted the need for more centralized management and coordination of activities to relieve airport congestion. In response, the FAA established the Airport Capacity Program Office, now called the Office of System Capacity and Requirements (ASC). The goal of this office and its capacity enhancement program is to identify and evaluate initiatives that have the potential to increase capacity, so that current and projected levels of demand can be accommodated within the system with a minimum of delay and without compromising safety or the environment.

In 1985, the FAA initiated a renewed program of Airport Capacity Design Teams at various major air carrier airports throughout the U.S. Each Capacity Team identifies and evaluates alternative means to enhance existing airport and airspace capacity to handle future demand and works to develop a coordinated action plan for reducing airport delay. Over 30 Airport Capacity Design Teams have either completed their studies or have work in progress.

The need for this program continues. In 1992, 23 airports each exceeded 20,000 hours of airline flight delays. If no improvements in capacity are made, the number of airports that could exceed 20,000 hours of annual aircraft delay is projected to grow from 23 to 33 by 2002. 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.

Minneapolis-Saint Paul International Airport



Minneapolis-Saint Paul International Airport (MSP) is, in fact, one of the 23 airports that exceeded 20,000 hours of annual aircraft delay in 1992 and, according to FAA forecasts, one of the 33 airports that could exceed 20,000 hours of annual delay in 2002, if no improvements in capacity are made. In the past decade, MSP has been one of the nation's busiest airports. Enplanements at MSP rose from 5,909,000 in 1983 to 11,377,873 in 1992, an increase of over 90 percent. MSP's total aircraft operations (takeoffs and landings) reached 413,502 in 1992, an increase of 38 percent over the 300,358 aircraft operations the airport handled in 1983.

Minneapolis-Saint Paul International Airport is owned and operated by the Metropolitan Airports Commission. The airport is situated on 3,020 acres and is located about 10 miles from the central business district of Minneapolis and about 8 miles from the central business district of Saint Paul. The Twin Cities metropolitan area is also supported by an extensive network of general aviation reliever airports, six of which are owned and operated by the Metropolitan Airports Commission.

Separate studies conducted by the Metropolitan Airports Commission and the Metropolitan Council had shown that additional airport capacity would be needed in the future to meet the long-range aviation needs of the region. In response to these studies, the Minnesota Legislature's Metropolitan Airport Planning Act of 1989 established a dual-track planning process designed to preserve the region's major airport options for the future. This planning is being carried out by the Metropolitan Airports Commission and the Metropolitan Council.

One track in the dual-track planning process focuses on designating a site for a possible replacement airport for the region and preparing a comprehensive plan and environmental analysis for the proposed development of a new airport. The other track focuses on possible ways to improve the capacity of the current airport and developed the Long-Term Comprehensive Plan for Minneapolis-Saint Paul International Airport. The primary goal of the plan is to determine the projected activity and passenger levels for MSP in the year

2020, assess the extent of facilities required to meet this activity, and investigate airfield and terminal alternatives to meet these needs. The Plan provides a blueprint for development through the year 2020 and is based on the assumption that MSP will continue to be the region's major airport.

Minneapolis-Saint Paul Airport Capacity Design Team

An Airport Capacity Design Team for the Minneapolis-Saint Paul International Airport was formed in 1992. Based on the results of the Long-Term Comprehensive Plan developed by the Metropolitan Airports Commission, the MSP Capacity Team identified and assessed various actions which, if implemented, would increase 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.

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 420,390 aircraft operations (takeoffs and landings) was established based on the expected annual traffic level for 1992. Two future traffic levels, Future 1, and Future 2, were established at 530,000 and 600,000 annual aircraft operations respectively, based on Capacity Team consensus of potential traffic growth at Minneapolis-Saint Paul. If no improvements are made at MSP, annual delay levels and delay costs are expected to increase from an estimated 21,440 hours and $31.0 million at the Baseline activity level to 62,403 hours and $90.3 million by the Future 1 demand level and 137,924 hours and $199.6 million by Future 2.

The Capacity Team studied various proposals with the potential for increasing capacity and reducing delays at MSP. The improvements evaluated by the Capacity

Team are delineated in Figure 2 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.
- Examined 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 operational benefits 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 planning studies, and the data generated by the Capacity Team can be used in such studies.

Methodology

The Capacity Team, which included representatives from the FAA, the Metropolitan Airports Commission, the State of Minnesota Department of Transportation, and various aviation industry groups (see Appendix A), met periodically for review and coordination. The Capacity Team members considered suggested capacity improvement alternatives proposed by the FAA's Office of System Capacity and Requirements, Technical Center, and Regional Aviation Capacity Program Manager, and by other members of the Team. Alternatives that were considered practicable were developed into experiments that could be tested by simulation modeling. The FAA Technical Center's Aviation Capacity Branch provided expertise in airport simulation modeling. The Capacity Team validated the data used as input for the simulation modeling and analysis and reviewed the interpretation of the simulation results. The data, assumptions, alternatives, and experiments were continually reevaluated, and modified where necessary, as the study progressed. A primary goal of the study was to develop a set of capacity-producing recommendations, complete with planning and implementation time horizons.

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 MSP. Proposed improvements were analyzed in relation to current and future demands with the help of an FAA computer model, the Airport and Airspace Simulation Model (SIMMOD). The relationship between delay and demand presented in Figures 3 and 14 was generated using the FAA's Runway Delay Simulation Model (RDSIM). Appendix B briefly explains these models.

The simulation model 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 three different demand forecast levels (Baseline, Future 1, and Future 2). 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. Following the evaluation, the Capacity Team developed a plan of recommended alternatives for consideration.

Section 2

Capacity Enhancement Alternatives

Figure 8. Capacity Enhancement Alternatives Studied and Recommended Actions

Alternatives Airfield Improvements		Action	Time Frame
1.	New N/S Runway 17/35 on west side of airport, south of parallel runways	Recommended	Future 1
2.	New Runway 11N/29N 800 feet north of Runway 11L/29R	Alternative to Airfield Improvement 1	Future 1
3.	New Runway 11S/29S 1,000 feet south of Runway 11R/29L with threshold staggered 3,000 feet to the west	Alternative to Airfield Improvement 1	Future 1
4.	New Runways 17/35 and 11N/29N (combines improvements 1 and 2)	Recommended	Future 2
5.	New Runways 11N/29N and 11S/29S (combines improvements 2 and 3)	Alternative to Airfield Improvement 4	Future 2
6.	Extend Runway 4/22 2,750 feet to southwest with Taxiways C, D, and M and a queuing taxiway	Recommended	Baseline
7.	New full-length parallel taxiway 600 feet south of Runway 11R/29L	Recommended	Baseline
8.	Dual crossover taxiways between Runways 11L/29R and 11R/29L	Recommended	Baseline
9.	Departure sequencing pads on Runways 29R, 11L, and 11R	Recommended	Baseline
10.	Additional exits on Runways 11R/29L and 11L/29R	Recommended	Baseline
11.	Additional exits on Runway 4/22	Recommended	Baseline
12.	Aircraft hold areas (penalty boxes)	Recommended	Baseline
Facilities and Equipment Improvements			
13.	CAT I ILS approach lights on Runway 29R	Further Study	—
14.	CAT II/III ILS on Runway 29R with RVR	Further Study	—
15.	CAT II/III ILS on Runways 11L and 11R with RVR	Further Study	—
16.	Precision Runway Monitor (PRM)	Recommended	Baseline
17.	Doppler VOR installed at MSP	Recommended	Baseline
18.	Runway centerline and touchdown zone lights for Runway 4/22	Recommended	Baseline
19.	RVR for Runway 4/22	Recommended	Baseline
Operational Improvements			
20.	Reduce in-trail separations to 2.5 nm for like classes of aircraft in IFR	Recommended	Baseline
21.	Converging IFR approaches	Recommended	Future 1
22.	FMS transitions to existing approaches	Recommended	Future 1
23.	Continue enhancement of reliever airports	Recommended	Baseline

Note: "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.

Background

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

- Airfield Improvements
- Facilities and Equipment Improvements
- Operational Improvements

Figure 1 shows the current layout of the airport, plus the airfield improvements considered by the Capacity Team.

Figure 2 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, and Future 2, which correspond to annual aircraft operations of 420,390, 530,000, and 600,000 respectively. The delay savings benefits of the improvements are not necessarily additive.

Figure 8 presents the recommended action and suggested time frame for each capacity enhancement alternative considered by the Capacity Team.

Airfield Improvements

1. New north/south Runway 17/35 on west side of airport, south of parallel runways.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	6,534	20,757	43,677
$M	$9.5	$30.0	$63.2

The new north/south Runway 17/35 would be used primarily for departures to the south and arrivals to the north. In both cases, the new runway would supplement the existing capacity of the parallel Runways 11R/29L and 11L/29R since they can be operated independently of the new runway under most visual flight rules (VFR) conditions and some instrument flight rules (IFR) conditions.

During peak departure periods in a north flow traffic condition, the new runway would be used for arrivals from the south, thus allowing intensive use of the parallel Runways 29R and 29L for departures. During an arrival peak with a north flow of traffic, the new runway would again be used for arrivals along with Runways 29R and 29L. The limited number of departures that occur during an arrival peak would use the parallel runways.

During departure peaks in south flow conditions, the new runway would be used for departures, in conjunction with departures on Runways 11L and 11R, with arrivals also occurring on Runways 11L and 11R. During arrival peaks in south flow, the new runway would handle all departures, freeing up all of the capacity of the parallel runways for arrivals.

Estimated 1992 project cost is $116 million.

Annual savings at the Baseline activity level would be 6,534 hours or $9.5 million; at Future 1, 20,757 hours or $30.0 million; and, at Future 2 activity levels, 43,677 hours or $63.2 million.

2. New Runway 11N/29N 800 feet north of Runway 11L/29R.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	4,051	17,526	38,741
$M	$5.9	$25.4	$56.1

Constructing a new parallel northwest/southeast runway, Runway 11N/29N, 800 feet north of Runway 11L/29R would provide for an additional independent parallel arrival and departure stream under VFR. Parallel runways separated by distances of less than 2,500 feet are considered dependent under IFR. Under IFR, these two runways must be treated as a single runway for arrivals and departures. However, the ability to segregate arrivals and departures to two runways does provide some capacity benefit for dependent parallel runways.

Estimated 1992 project cost is $191 million.

Annual savings at the Baseline activity level would be 4,051 hours or $5.9 million; at Future 1, 17,526 hours or $25.4 million; and, at Future 2 activity levels, 38,741 hours or $56.1 million.

3. New Runway 11S/29S 1,000 feet south of Runway 11R/29L with threshold staggered 3,000 feet to the west.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	4,127	20,147	44,936
$M	$6.0	$29.2	$65.0

Constructing a new dependent parallel Runway 11S/29S 1,000 feet south of the existing Runway 11R/29L would provide for an additional independent parallel stream for arrivals and departures under VFR. Under IFR, these runways would be dependent since they are separated by less than 2,500 feet. However, the ability to segregate arrivals and departures to two runways does provide some capacity benefit for dependent parallel runways. The 3,000 foot stagger between the thresholds of Runways 11S/29S and 11R/29L may create wake vortex avoidance problems for some aircraft.

Estimated 1992 project cost is $82 million.

Annual savings at the Baseline activity level would be 4,127 hours or $6.0 million; at Future 1, 20,147 hours or $29.2 million; and, at Future 2 activity levels, 44,936 hours or $65.0 million.

4. New Runways 17/35 and 11N/29N.

(combines alternatives 1 and 2)

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	8,438	26,296	56,548
$M	$12.2	$38.1	$81.8

Estimated 1992 total project cost is $307 million.

Annual savings at the Baseline activity level would be 8,438 hours or $12.2 million; at Future 1, 26,296 hours or $38.1 million; and, at Future 2 activity levels, 56,548 hours or $81.8 million.

5. New Runways 11N/29N and 11S/29S.

(combines alternatives 2 and 3)

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	7,190	24,904	54,542
$M	$10.4	$36.0	$78.9

Estimated 1992 total project cost is $273 million.

Annual savings at the Baseline activity level would be 7,190 hours or $10.4 million; at Future 1, 24,904 hours or $36.0 million; and, at Future 2 activity levels, 54,542 hours or $78.9 million.

6. Extend Runway 4/22 2,750 feet to the southwest with Taxiways C, D, and M and a queuing taxiway.

As currently configured, Runway 4/22 intersects Runways 11L/29R and 11R/29L. Air traffic control procedures for operations conducted on intersecting runways are, by necessity, more restrictive than for operations conducted on non-intersecting or parallel runways. As a result, Runway 4/22 does not add any capacity to MSP.

As currently proposed by the Metropolitan Airports Commission (MAC), the runway would be extended 2,750 feet to the southwest with a 1,550 foot displaced landing threshold on Runway 4. The takeoff point on Runway 22 would be shifted to approximately 700 feet southwest of the Runway 4/22 and 11L/29R intersection. This would effectively eliminate the intersection of the two runways and increase their capacities when used in combination when wind and weather conditions permit. This runway use configuration is one of the preferred modes for purposes of noise abatement, which is the primary purpose of the extension.

The elimination of the Runway 4/22 intersection with Runway 11L/29R for most operations would also permit a runway use configuration including landing on Runways 29L and 29R, with takeoffs on Runways 29R and 22. This mode would produce a very slight increase in airport capacity, when wind and weather permit its use (about 35 percent of the time). However, queuing problems for Runway 22 departures would limit use of this configuration during the peak hours.

Additionally, the extension of Runway 4/22 would allow some aircraft to operate at higher gross takeoff weights, carrying either more passengers or serving more distant markets. This capability is particularly important to long-haul international operations in the high temperature conditions experienced during the summer months. The extension would also permit the airport to maintain long-haul international operations during those times when Runway 11R/29L is not in service. Currently, Runway 4/22 is the longest runway when Runway 11R/29L is not available, but at its current length, long-haul operations would experience weight restrictions. An extended Runway 4/22 would permit the airport to perform maintenance on Runway 11R/29L without restricting long-haul operations.

Estimated 1992 project cost is $27 million.

7. New full-length parallel taxiway 600 feet south of Runway 11R/29L.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	927	1,147	2,340
$M	$1.3	$1.7	$3.4

A new parallel taxiway on the south side of Runway 11R/29L would improve the flow of ground traffic to and from the runway and around the terminal area. Departures originating in the cargo, general aviation (GA), and maintenance areas south of Runway 11R/29L would have access to the departure queue without having to cross the runway. Similarly, arriving cargo and GA traffic would have access to their terminal areas without crossing the runway. This improvement would reduce congestion in the Gold Concourse apron area and would reduce the risk of runway incursions by traffic crossing the runway.

Estimated 1992 project cost is $16 million.

Annual savings at the Baseline activity level would be 927 hours or $1.3 million; at Future 1, 1,147 hours or $1.7 million; and, at Future 2 activity levels, 2,340 hours or $3.4 million.

8. Dual crossover taxiways between Runways 11L/29R and 11R/29L.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	2,084	3,294	3,787
$M	$3.0	$4.8	$5.5

A new dual crossfield taxiway on the east side of the terminal area would reduce taxi-in/taxi-out times for aircraft at the Green and Gold Concourses. Additionally, it would alleviate congestion on Taxiways C and D in front of the Red and Blue Concourses, the baggage handling tunnel area between the Gold and Red Concourses, and the Green Concourse gate pod. This taxiway improvement would significantly improve the ability to get aircraft from one side of the terminal to the other and reduce taxi times.

Currently, aircraft at the Gold Concourse assigned to Runway 29R or aircraft at the Green Concourse assigned to Runway 29L must taxi past the Red, Blue, Green, and Gold Concourses to reach their respective departure queues. Along this route, there are several constrained areas within which the airport traffic control tower must already coordinate all ground movements to prevent gridlock on the airfield. These constrained areas, along Taxiway C and D, the tunnel between the Red and Gold Concourses, and the gate pod on the Green Concourse, could be bypassed using this new taxiway. Additionally, the taxi travel distance between the Green Concourse and Runway 29L and between the Gold Concourse and Runway 29R would be shortened. Due to the current taxiway structure, the additional capacity created by any airfield improvement could not be realized without this crossfield taxiway in place. Furthermore, these taxiways would allow the tower to establish a circular taxi flow around the terminal complex.

A new terminal is planned on the west side of the airport, and the existing Red, Blue, Green, and Gold Concourses would then be realigned into two long piers. The space between the piers would be paved to permit aircraft to park between the concourses. With this new terminal development, the crossover taxiway will be essential to the flow of ground traffic to and from the runways. Until the terminal is developed, however, construction of the crossover taxiways would be extremely difficult, due to the presence of Northwest Airlines maintenance facilities, the configuration of the airport roadways, and the location of the post office.

Estimated 1992 project cost is $20 million.

Annual savings at the Baseline activity level would be 2,084 hours or $3.0 million; at Future 1, 3,294 hours or $4.8 million; and, at Future 2 activity levels, 3,787 hours or $5.5 million.

9. Departure sequencing pads on Runways 29R, 11L, and 11R.

Air traffic flow control often dictates that aircraft hold at the runway thresholds before take-off because of departure flow restrictions. Construction of holding areas for Runways 29R, 11L, and 11R would improve the ability of departing aircraft to bypass those aircraft waiting for departure clearance and relieve congestion on the taxiways. These pads could also serve as runway-end deicing facilities.

Estimated 1992 project cost is $24 million.

10. Additional exits on Runways 11R/29L and 11L/29R.

The addition of improved exits on Runway 11R/29L and 11L/29R would aid in reducing occupancy time for arrivals on the two runways. By reducing arrival runway occupancy times, the airfield can be operated more efficiently when arrivals and departures are evenly mixed. Additionally, a reduction in runway occupancy times to an average of 50 seconds or less would facilitate reducing arrival-to-arrival in-trail separations on final approach to 2.5 nm for aircraft of similar class, thereby providing an important additional capacity advantage.

Estimated 1992 project cost is $10.5 million.

11. Additional exits on Runway 4/22.

The addition of improved exits on Runway 4/22 would aid in reducing occupancy time for arrivals on the runway. By reducing arrival runway occupancy times, the airfield can be operated more efficiently when arrivals and departures are evenly mixed. Additionally, a reduction in runway occupancy times to an average of 50 seconds or less would facilitate reducing arrival-to-arrival in-trail separations on final approach to 2.5 nm for aircraft of similar class, thereby providing an important additional capacity advantage.

Estimated 1992 project cost is $16.5 million.

12. Aircraft hold areas (penalty boxes).

Construction of holding areas for arriving aircraft waiting for gate space would relieve congestion near the terminal area and allow more efficient taxiway utilization.

Facilities and Equipment Improvements

13. Category I ILS approach lights on Runway 29R.

Instrument flight rules (IFR) that restrict operations (IFR 1—ceiling 200 to 1,000 feet and visibility 0.5 to 3 sm) occur about 8.2 percent of the time, and the impact of the associated delays can be significant. Installing CAT I ILS standard approach lights on Runway 29R would reduce visibility minimums from 3/4 to 1/2 sm and provide an improved precision approach, thereby increasing capacity and reducing delays. Installation of the lights is complicated by the Minnesota River and public parks to the east of the runway.

Estimated 1992 project cost is $1.7 million.

14. Category II/III ILS on Runway 29R with Runway Visual Range (RVR).

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	868	2,405	3,486
$M	$1.3	$3.5	$5.0

IFR that severely restrict operations (IFR 2—ceiling below 200 feet and visibility below 0.5 sm) only occur about 0.2 percent of the time, but the impact of the associated delays can be significant. Installing a CAT II/III ILS on Runway 29R would reduce visibility minimums and enhance operational flexibility by providing a second CAT II/III ILS and thereby help to maintain capacity during very low instrument meteorological conditions (IMC). Installing an additional RVR on Runway 29R would reduce visibility minimums and enhance operational flexibility and thereby help to maintain capacity during very low IMC.

Estimated 1992 project cost is $6.4 million.

Annual savings at the Baseline activity level would be 868 hours or $1.3 million; at Future 1, 2,405 hours or $3.5 million; and, at Future 2 activity levels, 3,486 hours or $5.0 million.

15. Category II/III ILS on Runways 11L and 11R with RVR.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	864	2,402	3,520
$M	$1.3	$3.5	$5.1

As an alternative to installing a CAT II/III ILS on Runway 29R, CAT II/III ILS approaches could be installed on Runways 11L and 11R to provide dual approaches, if these installations were more feasible. Installing additional RVRs on Runways 11L and 11R would reduce visibility minimums and enhance operational flexibility and thereby help to maintain capacity during very low IMC.

Estimated 1992 project cost is $5.9 million.

Annual savings at the Baseline activity level would be 864 hours or $1.3 million; at Future 1, 2,402 hours or $3.5 million; and, at Future 2 activity levels, 3,520 hours or $5.1 million.

16. Precision Runway Monitor (PRM).

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	3,182	13,822	45,834
$M	$4.6	$20.0	$66.3

The capacity of MSP would be significantly increased by the ability to conduct simultaneous (independent) parallel approaches in all weather conditions. With existing radar equipment, current FAA criteria require 4,300 feet between parallel runway centerlines.

A developmental program known as the Precision Runway Monitor (PRM) has demonstrated that simultaneous independent parallel approaches can be conducted in all weather conditions on runways spaced less than 4,300 feet apart. This program relies on improved radar surveillance with higher update rates of aircraft positions and a new air traffic controller display system. When PRM equipment becomes available, installing it at MSP would allow independent parallel ILS approaches to be implemented. National standards for simultaneous (independent) parallel approaches using the PRM to runways separated by 3,400 to 4,300 feet were published in November 1991. MSP's parallel runways are separated by 3,380 feet, and a waiver has been obtained to conduct simultaneous (independent) operations using the PRM. Current FAA plans call for a PRM to be operational at MSP in May 1995.

Estimated 1992 project cost is $6 million.

Annual savings at the Baseline activity level would be 3,182 hours or $4.6 million; at Future 1, 13,822 hours or $20.0 million; and, at Future 2 activity levels, 45,834 hours or $66.3 million.

17. Doppler VHF Omnidirectional Range (VOR) installed at MSP.

The installation of a Doppler VOR at Minneapolis-Saint Paul would provide an additional source of accurate fix information to pilots performing instrument approaches to MSP. The replacement of the existing VOR (preferably at a site consistent with the Master Plan for MSP) would provide for improved instrument approaches, enhance safety, and better serve the needs of the users.

Estimated 1992 project cost is $0.9 million.

18. Runway centerline and touchdown zone lights for Runway 4/22.

Installing runway centerline and touchdown zone lighting would reduce visibility minimums for Runway 4 from 2,400 feet to 1,800 feet. The primary benefit would be in adverse weather.

Estimated 1992 project cost is $1 million if done as part of another project and $2 million if done as a standalone project.

19. Runway Visual Range (RVR) for Runway 4/22.

Installing an RVR on Runway 22 (Runway 4 has an RVR) would reduce departure visibility minimums on Runway 22 to at least 1,600 feet and reduce approach visibility minimums from 3/4 sm to 4,000 feet. The primary benefit would be in adverse weather.

Estimated 1992 project cost is $0.2 million.

Operational Improvements

20. Reduce in-trail separations to 2.5 nm for like classes of aircraft in IFR.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	983	530	583
$M	$1.4	$0.8	$0.8

Reducing separation minimums to 2.5 nm for aircraft of similar class would increase arrival rates and runway capacity. Aircraft capable of takeoff weights of 300,000 pounds or more and the Boeing 757 may participate in the separation reduction as trailing aircraft only. In order to use reduced final approach in-trail separations, it must be demonstrated that runway occupancy times for arrivals are consistently 50 seconds or less.

Annual savings at the Baseline activity level would be 983 hours or $1.4 million; at Future 1, 530 hours or $0.8 million; and, at Future 2 activity levels, 583 hours or $0.8 million.

21. Converging IFR approaches.

Under VFR, it is common to use converging runways for independent streams of arriving aircraft. Because of the reduced ceilings and visibility associated with operations under IFR, the FAA has established a procedure for conducting simultaneous instrument approaches to converging runways in IMC. This procedure uses non-overlapping Terminal Instrument Procedures (TERPS) obstacle-clearance surfaces as a means of separation for aircraft executing simultaneous missed approaches. It requires a 3 nm separation between the missed approach points on each approach. "TERPS+3" (as this procedures is often called) is an independent approach procedure that requires no dependency between the two aircraft on converging approaches. At MSP, these requirements would result in landing minimums of approximately 1,000 feet, which are basically VFR minimums, with arrivals using new Runway 35 and Runways 29L and 29R.

New FAA procedures and technology may permit use of converging approaches to Runway 35 in IFR conditions. This may be achieved by allowing an overlap between missed approach airspace for Runways 35 and 29L, using time to separate approaches instead of distance. Precision missed approach guidance, using Global Positioning System (GPS) satellite navigation or other new technologies may also permit lower minimums. These changes may potentially provide for minimums as low as 400 feet with arrivals using Runways 35, 29L, and 29R.

22. Flight Management System (FMS) transitions to existing approaches.

Many of the current generation of aircraft are equipped with on board Flight Management Systems (FMS) that are capable of precise area navigation both en route and in the terminal area. FMS demonstration programs have been implemented at several major airports with positive results. FMS can be used in the terminal area to generate arrival and departure paths that are independent of VOR radials. Because of its ability to fly tracks and pre-defined vertical paths, FMS will eliminate much of the radar vectoring process and communication present in today's terminal environment.

FMS-equipped aircraft also have the ability to fly non-precision instrument approaches independent of ground-based NAVAIDs. This ability will permit many of today's charted visual approach procedures to be used as non-precision approaches, which will help to maintain arrival capacity during periods of reduced visibility. In addition, new non-precision approach procedures can be designed to take better advantage of the existing runway structure.

Current FMS systems, and future systems based on GPS satellite navigation, will allow airspace procedures specialists unprecedented flexibility in designing terminal and en route procedures. These systems will also increase safety, reduce operating costs for the users, aid in addressing environmental issues, and increase airport capacity. By 1996, airlines and other operators are expected to have a significant percentage of their fleets equipped with either the existing FMS systems or the newer GPS-based systems. This will allow FMS procedures to become the baseline for designing terminal airspace.

23. Continue enhancement of the reliever airport system in order to accommodate small/slow aircraft operations.

Alternative 23a.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	2,655	4,466	7,304
$M	$3.8	$6.5	$10.6

Alternative 23b.

Estimated Savings in Delay

Demand	Baseline	Future 1	Future 2
Hrs	3,617	8,868	19,275
$M	$5.2	$12.8	$27.9

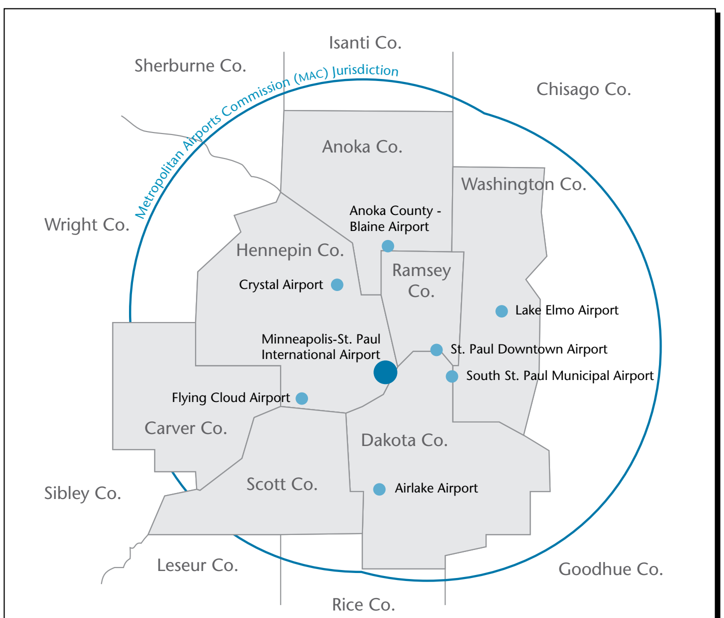
Reliever airports can ease capacity constraints by attracting small/slow aircraft away from primary airports, especially where small/slow aircraft constitute a significant portion of operations. The segregation of aircraft operations by size and speed increases effective capacity because required time and distance separations are reduced between planes of similar size and speed.

With 25 percent of MSP's small/slow aircraft operating out of reliever airports, there would be an annual savings at the Baseline activity level of 2,655 hours or $3.8 million; at Future 1, 4,446 hours or $6.6 million; and, at Future 2 activity levels, 7,304 hours or $10.6 million.

With 50 percent of MSP's small/slow aircraft operating out of reliever airports, there would be an annual savings at the Baseline activity level of 3,617 hours or $5.2 million; at Future 1, 8,868 hours or $12.8 million; and, at Future 2 activity levels, 19,275 hours or $27.9 million.

Every effort should be made to accommodate these aircraft at enhanced "reliever airports" with easy access to various locations within the metropolitan area. The reliever airports would need to provide services that are appropriate for the category of users at each airport.

Minneapolis-Saint Paul Metropolitan Airport System



Note: South St. Paul Municipal Airport is not owned/operated by MAC.

Section 3

Summary of Technical Studies

Overview

The Minneapolis-Saint Paul International Airport (MSP) Capacity Team evaluated the efficiency of the existing airfield and the proposed future configurations. A brief description of the computer model and methodology used can be found in Appendix B. Certain standard inputs were used to reflect the operating environment at MSP. Details can be found in the data packages produced by the FAA Technical Center during the course of the study. Figure 9 shows the characteristics of the aircraft fleet currently operating at MSP, and Figure 10, current airfield weather conditions. Figure 11 illustrates runway utilization for various baseline runway configurations, and Figure 12, for future configurations with new Runway 17/35 in place. The potential benefits of various improvements were determined by examining airfield capacity, airfield demand, and average aircraft delays.

The fleet mix at MSP has a weighted-average direct operating cost of $1,447 per hour, or $24 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.

Daily operations corresponding to an average day in the peak month were used for each of the forecast periods. The Airport and Airspace Simulation Model (SIMMOD) was used to determine aircraft delays during peak periods. Delays were calculated for current and future conditions. Daily delays were annualized to measure the potential economic benefits of the proposed improvements. The annualized delays provided a basis for comparing the benefits of the proposed changes. The benefits associated with various runway use strategies were also identified. The cost of a particular improvement was measured against its annual delay savings. This comparison indicated which improvements would 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 9. Aircraft Fleet Characteristics

Aircraft Class	Aircraft Types	Baseline Demand	Departure Runway Occupancy Time (seconds)	Approach Speeds (knots)	
				VFR	IFR
Class 4	Single- and twin-engine props under 12,500 lbs.	3.9%	34	110	110
Class 3	Twin-engine props over 12,500 lbs.	24.8%	34	120	110
Class 2	All non-heavy jets	63.6%	39	140	140
Class 1	Heavy aircraft over 300,000 lbs.	7.7%	39	155	155

Figure 10. Airfield Weather

Ceiling/Visibility		Occurrence (%)
VFR 1	3,200 feet and above/8 sm and above	70.7
VFR 2	1,000 to 3,200 feet/3 to 8 sm	20.9
IFR 1	200 to 1,000 feet/0.5 to 3 sm	8.2
IFR 2	Below 200 feet/below 0.5 sm	0.2
		Total: 100.0

VFR–Visual Flight Rules
IFR–Instrument Flight Rules
sm–statute miles

Figure 11. Baseline Runway Configuration (percentage use)

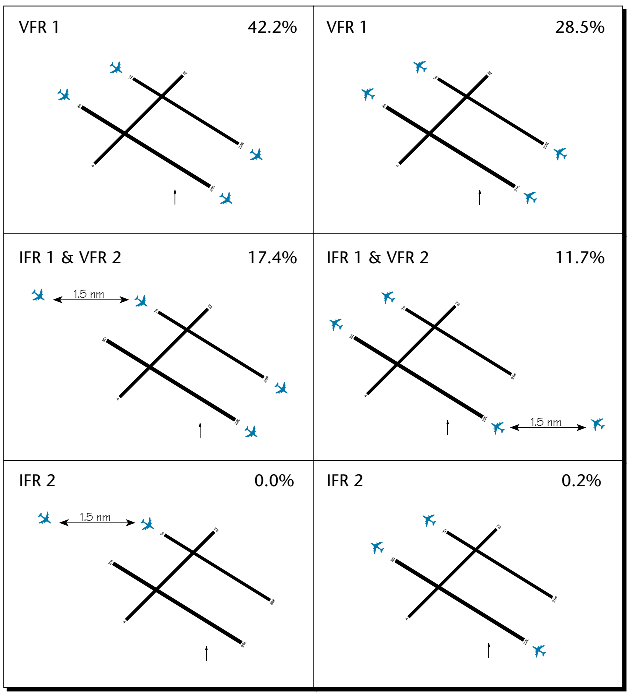
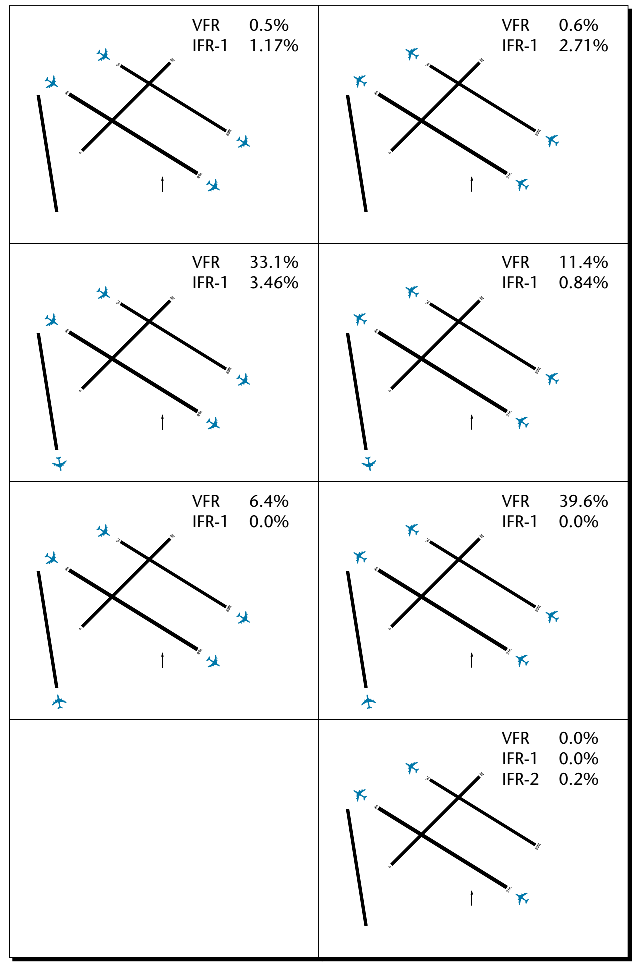


Figure 12. Future Runway Configuration with New Runway 17/35 (percentage use)



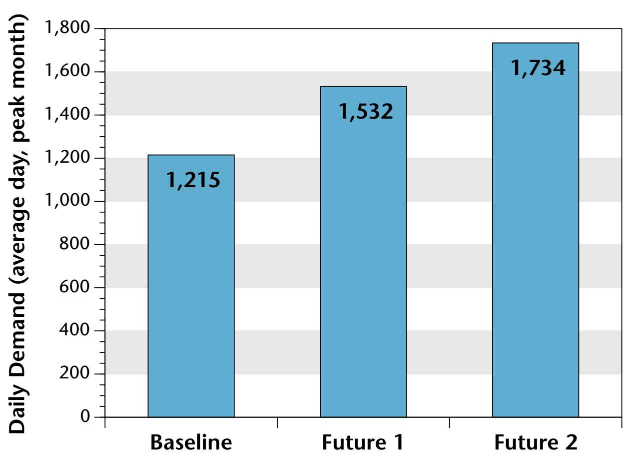
Airfield Capacity

The MSP 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 13 illustrates the average-day, peak-month demand levels for MSP for each of the three annual activity levels used in the study, Baseline, Future 1, and Future 2.

Figure 13. Airfield Demand Levels



Annual Demand		24-Hour Day*	Peak Hour
Baseline	420,390	1,215	106
Future 1	530,000	1,532	133
Future 2	600,000	1,734	150

* Average Day, Peak Month

Figure 14 presents airport capacity curves for MSP. The curves were developed for the existing airport configuration and for a future airport configuration with the new north parallel Runway 11N/29N and the new north/south Runway 17/35 in place.[2] They show the airport under visual flight rules (VFR) and under instrument flight rules (IFR), with a 60/40 and 40/60 split of arrivals and departures. 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 14 illustrate the relationship between airfield capacity, stated in the number of operations per hour, and the average delay per aircraft—as the number of aircraft operations per hour increases, the average delay per operation increases exponentially. Figure 15 illustrates the hourly profile of daily demand for the Baseline activity level. It also includes curves that depict the profile of daily operations for Future 1 and Future 2 activity levels. Comparing the information in Figures 14 and 15 shows that, for the existing airport configuration:

- Aircraft delays will begin to escalate rapidly under IFR as hourly demand exceeds 80 to 105 operations per hour, and,
- While hourly demand exceeds 80 operations only during certain hours of the day at Baseline demand levels, 105 operations per hour is frequently exceeded at the demand levels forecast for Future 1 and Future 2.

2. The Long-Term Comprehensive Plan for MSP includes only a new north/south Runway 17/35 on the west side of the airport in its configuration for the year 2020. Development of a new Runway 11N/29N or 11S/29S would only occur if the north/south Runway 17/35 were not possible.

Figure 14. Airport Capacity Curves—Flow Rate Versus Average Delay

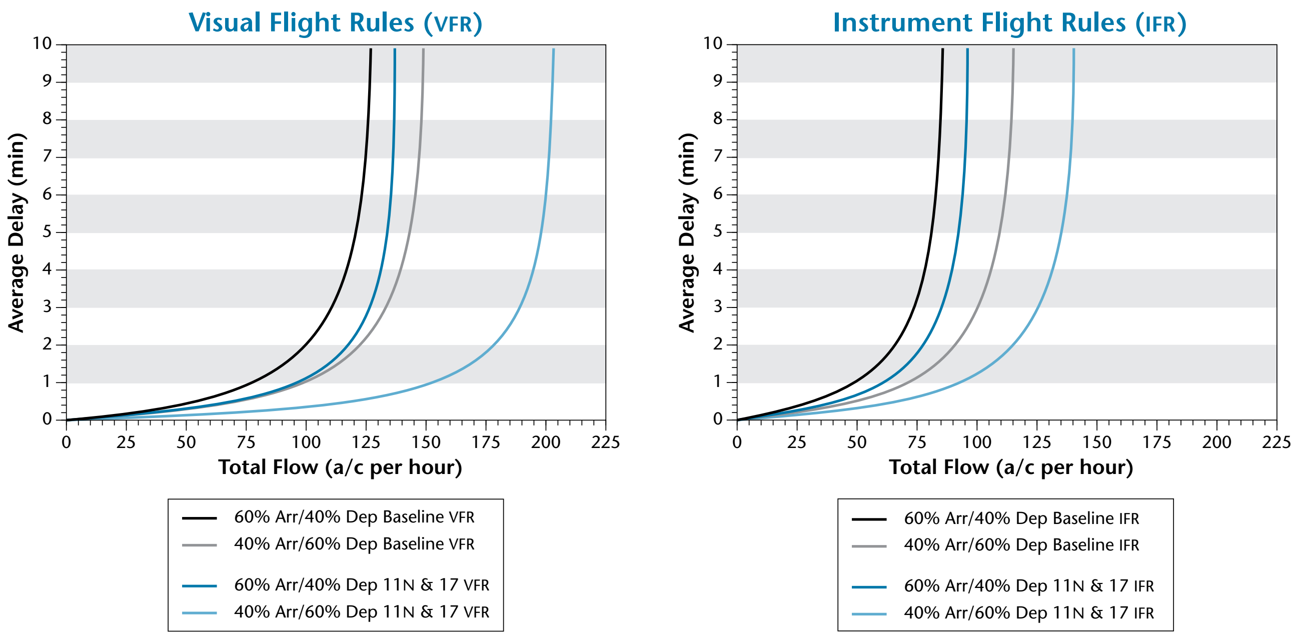
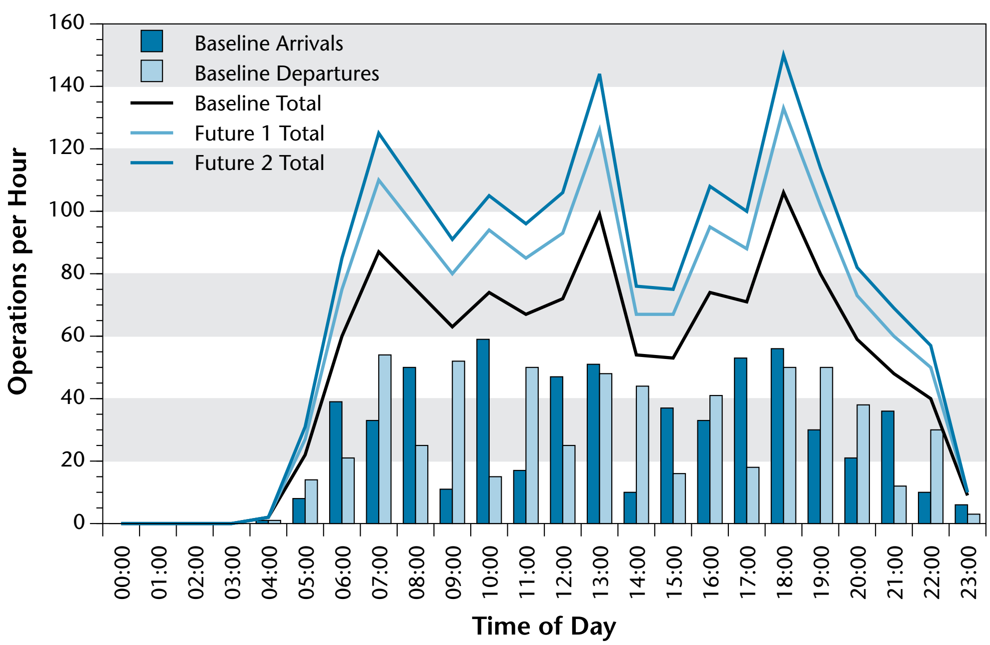


Figure 15. Profile of Daily Demand—Hourly Distribution



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:

- Ceiling and visibility conditions
- 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 Airport and Airspace Simulation Model (SIMMOD). A description of this model is included in Appendix B. If no improvements are made in airport capacity, the average delay per operation of 3.1 minutes in Baseline will increase to 7.1 minutes per operation by Future 1 and 13.8 minutes per operation by Future 2. Under this Do Nothing scenario (no improvements in capacity), the annual delay cost could increase as follows:

	Annual Delay Costs	
	Hours	1992 $(M)
Baseline	21,440	$31.0
Future 1	62,403	$90.3
Future 2	137,924	$199.6

Conclusions

Figure 16 demonstrates the impact of delays at Minneapolis-Saint Paul International 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:

- Precision Runway Monitor (PRM)
- New Runways 17/35 and 11N/29N
- New Runways 11N/29N and 11S/29S
- New Runway 11S/29S 1,000 feet south of Runway 11R/29L†
- New Runway 17/35 on west side of airport, south of parallel taxiways‡
- New Runway 11N/29N 800 feet north of Runway 11L/29R†

Figure 17 illustrates the average delay in minutes per aircraft operation for these same alternatives. Under the Do Nothing alternative, if there are no improvements made in airfield capacity, the average delay per operation of 3.1 minutes at the Baseline level of activity will increase to 7.1 minutes per operation by Future 1 and 13.8 minutes per operation by Future 2.

Figure 18 illustrates the annual delay-savings benefits for each alternative and for each of the three annual activity levels (operations per year). It serves to highlight the alternatives that will provide the major delay-savings benefits.

†. This is an alternative to the new Runway 17/35 in the Metropolitan Airport Commission’s Long-Term Comprehensive Plan for MSP, if Runway 17/35 cannot be constructed.

‡. This is the prefered option identified in the Metropolitan Airport Commission’s Long-Term Comprehensive Plan.

Figure 16. Annual Delay Costs—Capacity Enhancement Alternatives

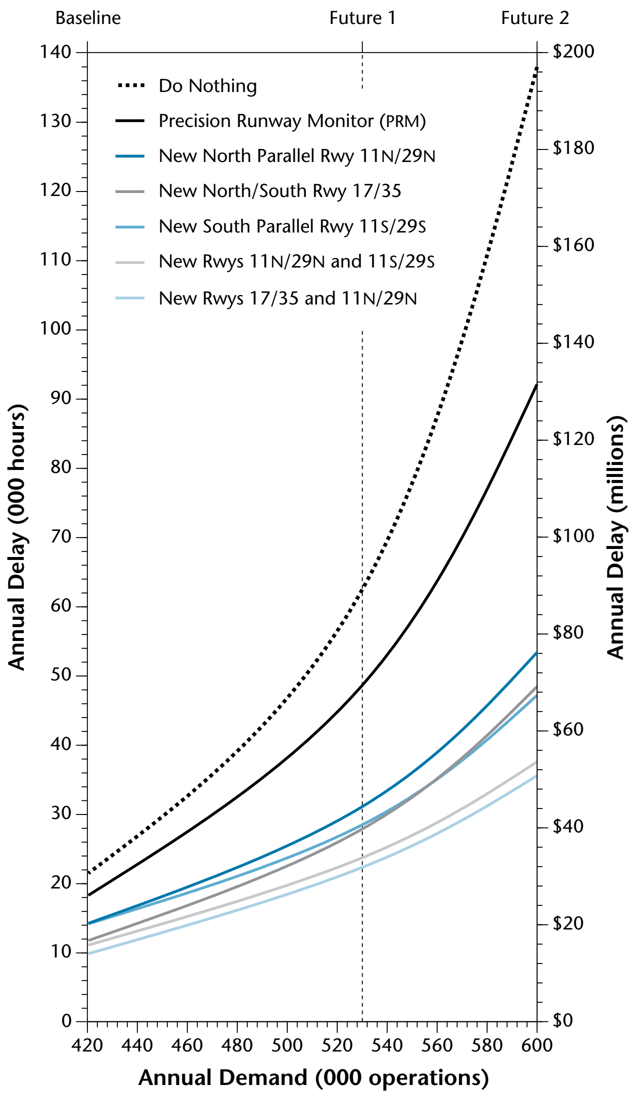


Figure 17. Average Delays—Capacity Enhancement Alternatives

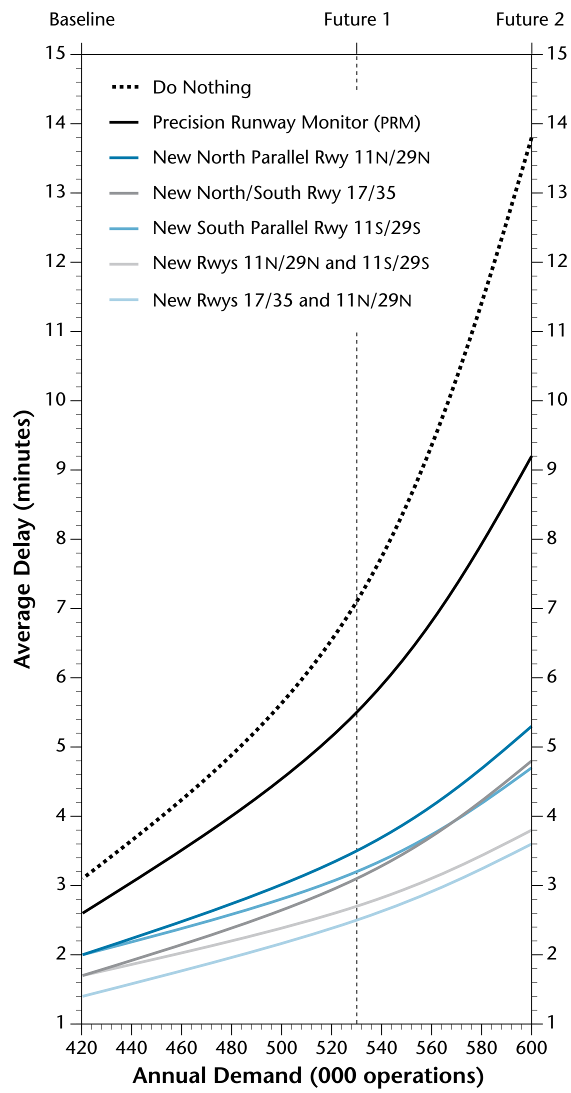
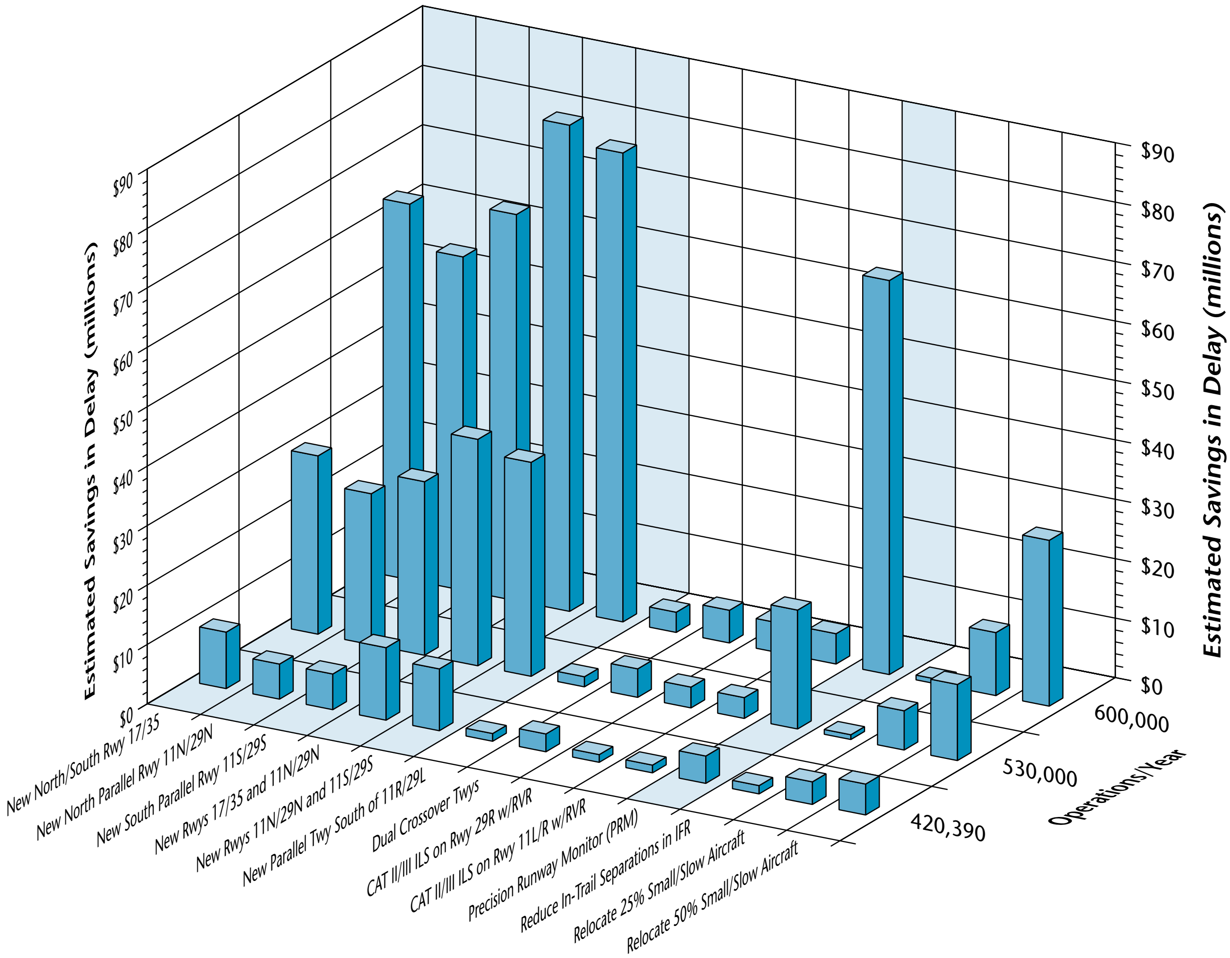


Figure 18. Annual Delay-Savings Benefits—Capacity Enhancement Alternatives



Major Capacity Enhancement Alternatives

- Precision Runway Monitor (PRM)
- New Runways 17/35 and 11N/29N
- New Runways 11N/29N and 11S/29S
- New Runway 11S/29S 1,000 feet south of Runway 11R/29L†
- New Runway 17/35 on west side of airport, south of parallel taxiways‡
- New Runway 11N/29N 800 feet north of Runway 11L/29R†

†. This is an alternative to the new Runway 17/35 in the Metropolitan Airport Commission's Long-Term Comprehensive Plan for MSP, if Runway 17/35 cannot be constructed.

‡. This is the prefered option identified in the Metropolitan Airport Commission's Long-Term Comprehensive Plan.

Appendix A

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Appendix B

Computer Models and Methodology

The Minneapolis-Saint Paul 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 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. It describes significant movements of aircraft on the airport and the effects of delay in the adjacent airspace. The model 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 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 replicated each experiment forty times, using Monte Carlo sampling techniques to introduce system variability, which occurs on a daily basis in actual airport operations. The results were 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 MSP to ensure 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, simulation analysts 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 MSP 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, different airfield configurations were 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.

Appendix C

List of Abbreviations

ARTCC	Air Route Traffic Control Center
ASC	Office of System Capacity and Requirements, FAA
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
CAT	Category—of instrument landing system
FAA	Federal Aviation Administration
FMS	Flight Management System
GA	General Aviation
GPS	Global Positioning System
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
MAC	Metropolitan Airports Commission
MSP	Minneapolis-Saint Paul International Airport
NAVAID	Navigational Aid—aviation navigation facility
NM	Nautical Miles
PRM	Precision Runway Monitor
RVR	Runway Visual Range
SIMMOD	Airport and Airspace Simulation Model
SM	Statute Miles
TERPS	Terminal Instrument Procedures
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Range—course information only

Notes:

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