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October 1988

Is the Airport Adequate?

Report of the Minneapolis/St. Paul International Airport Adequacy Study Advisory Task Force to the Metropolitan Council

Part II: Study Issues and Analysis



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Is the Airport Adequate?

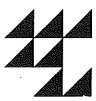
Report of the Minneapolis/St. Paul International Airport Adequacy Study Advisory Task Force to the Metropolitan Council

Part II: Study Issues and Analysis

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Minnesota Business Aircraft Association
Minority Report

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The Minnesota Business Aircraft Association is pleased to have participated in the Minneapolis-St. Paul International Airport Adequacy Task Force and generally concurs with the direction the group has charted for the future of aviation in the Twin Cities. There is a definite need for action now if our region's aviation facilities are to remain adequate into the next century. We applaud the process and the positive thrust the Task Force has taken.

We concur with the Task Force findings that if the Metropolitan Area is to realize long-term economic health and growth, airport/air travel capacity must be expanded. And, that Minneapolis-St. Paul International Airport will be unable to meet that capacity demand in the future.

We also concur with the "Land Bank" principal to allow future airport development on demand.

However, we take exception with the "Single Major Airport" principle which dictates closing MSP. We view MSP as a viable, strategically located major airport which should be retained. An irreplaceable asset. The single airport concept runs counter to a nation-wide trend toward multiple air carrier airports serving major travel markets such as those in New York, Los Angeles, Washington, Dallas, Chicago, Houston, Miami/Ft. Lauderdale, San Francisco/Oakland and now Detroit. We feel strongly that airline service at two or more airports offers competitive advantages to the traveling public and aids expeditious flow of air and ground traffic.

We propose that in lieu of banking land for a single primary airport, that the Metropolitan Council should consider construction of a full scale reliever field which would be developed in increments on demand. An airport of smaller initial magnitude that would be required for the "Single Major Airport" concept yet capable of planned growth. Such an airport would have facilities attractive to business aircraft, air taxi, air freight, charter and international operations.

We have a unique opportunity to develop a positive environment for all aviation interests and in so doing assure our continued status as the business and economic leader of the upper midwest. Let's not waste this opportunity!

We are grateful for having had the opportunity to participate and offer our services for the future.

I. INTRODUCTION

Aviation has long been the nation's fastest growing mode of transport. This growth creates economic and social benefits for the nation as a whole as well as for virtually every region. It also creates problems. Some problems are more difficult to solve than others: reducing the negative impacts from aircraft noise and frequent overflights, for example. Others, such as how to cope with growing demand for air travel, are conceptually easier to solve -- simply add more runways! -- but face substantial political, planning, engineering, and financial obstacles.

For decades, the U.S. airport system was blessed with excess capacity in most major cities. This enabled the system to absorb steady growth year after year and was, in turn, a key factor in encouraging such growth. Aviation experts have been warning for some time that this period of easily available capacity was about to end. The Federal Aviation Administration (FAA) estimates that enplanements will nearly double by the turn of the century. Most importantly, while the rapid rate of industry growth may slow somewhat due to reduced competition brought on by recent mergers and the search for higher profits, the upward trend seems unlikely to change. The consequence is clear: current airport capacity problems will only be exacerbated. This problem is national in scope. The FAA predicts that by 1996, more than two dozen major airports -- including Minneapolis-St. Paul International (MSP) -- will face capacity problems.

The economic value of MSP to the region has been well documented. Today the airport generates more than $2 billion in direct economic impacts for the region. In addition, aviation is responsible for creating 34,000 jobs, nearly 20,000 of which are directly attributable to airport activity.[1] While the current airport configuration can handle existing demand, a key question is what happens to these figures if capacity does not keep pace with growth in aviation -- and the region's economy? If capacity can be expanded in pace with expected demand, the regional economic impact of aviation could reach $3.5 billion a year (in dollars of 1988 purchasing power) within twenty years.

Why the Concern Today?

Even though delays at MSP are somewhat larger now than in years past, many other airports face much more serious capacity and delay problems than does MSP. Given this, why is there any need to even think about adding capacity today?

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[1] See Martin O'Connell and Associates, The Economic Impact of the Minneapolis/St. Paul Airport, prepared for the Greater Minneapolis Chamber of Commerce, January 1988.

First, the long lead time required to plan complex infrastructure investments and the need to develop a political consensus before implementing major public investments means that the region must focus on the level of service that will be provided ten years, twenty years, or even further in the future. In addition, the uncertainty surrounding the speed with which any complex public decision can be made, adds even more lead time.

Second, because cities and regions compete for jobs and economic growth, the ability to find effective solutions to airport capacity problems creates special opportunities for communities with better foresight -- and the ability to act on this vision.

Third, public works play a key role in defining a region's social and economic character and the quality of life that it offers its residents. Because of this role and because of an airport's natural longevity, decisions should be made with a time horizon that measures in decades.

Today, MSP handles roughly 8 million enplanements per year (16 million passengers in total). Within twenty years, this total is expected to increase to about 15 million enplanements with a 20 percent chance of exceeding 17 million. In effect, the MSP Adequacy study is about planning for a future airport roughly the size of Denver today.

Land use constraints present another reason for action relatively soon. Because of noise and safety considerations, a new airport would require 13,000 acres or more of land -- roughly four times the current size of MSP. As the Twin Cities region continues to grow, likely sites within reasonable distance of the downtown will be developed. At some point in the near future, feasible sites may no longer exist, perhaps eliminating the new airport option from consideration. Thus, even if the new airport option is delayed into the next century, land use considerations force an early debate.

Key Questions

In examining the long-term adequacy of MSP, the Metropolitan Council -- and the region in general -- must face several key questions:

- Will air traffic at MSP International outstrip the airport system's ability to accommodate unconstrained growth?
- When is this likely to occur?
- What level of aviation service does the region wish to provide?

- What are the likely economic, social, and environmental consequences of failing to meet demand and thus constraining aviation activity?

- Should the region amass land for a new international airport or would such expenditures entail undue financial risk and community disruption in light of the existing system's long-term ability to handle new traffic?

Because there are major investments to be made and regional impacts to consider, the answer to each question is important to the future of the region's economic base and, ultimately, its quality of life. While true for all types of public works investments from highways to solid waste disposal, an airport represents a special case that requires planning and land procurement (if necessary) well in advance of demand. Without plans that attempt to look decades in advance, the system can fail.

The inputs to the planning decision, however, are difficult to predict and involve risks. An analysis of the long-term adequacy of the airport must, therefore, compare the airport's potential benefits to the region with the costs associated with development alternatives.

In short, with so many variables, only one thing is certain -- virtually every forecast runs the risk of being wrong to some degree. Knowing this, how should the Metropolitan Council of the Twin Cities area assess the pros and cons of their investment choices? More directly, how can the Minneapolis-St. Paul region best compare the long-run capacity of existing facilities with the merit of alternative means of expanding capacity given the multitude of uncertainties about future traffic, possible improvements to air traffic control, economic interactions, and environmental constraints?

The MSP Adequacy Study explicitly recognizes these uncertainties by using a family of techniques called <u>risk assessment</u>. While not in common use, these methods are by no means new, and have been used to assess long-range capital investments by public agencies and private firms alike.[2] By attempting to measure the risks of each of the key factors that might influence a major investment decision and incorporate those risks into the analysis, the resulting analysis does not offer a single "take it or leave it" answer. Rather, information can be presented that reflects the uncertainties involved -- thus allowing the community to make more realistic assessments of long-term investments.

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[2] See for example, <u>Improving the Air Traffic Control System: An Assessment of the National Airspace System Plan</u>, Congressional Budget Office, August 1983.

The risk assessment techniques is more than an interesting way of examining the future implications. By exposing the risks and difficult choices in making demand and capacity forecasts and in assessing the gains or losses from alternative levels of service, the approach also can help shape a regional debate and perhaps help in developing a consensus.

THE ANALYTICAL PROCESS[3]

The analytical process used in the MSP Airport Adequacy Study builds on what has traditionally been a stumbling block for forecasts of all types: variability. For example, forecasts traditionally take one of two forms: first, a single-line "expected outcome," or second, one in which the straight line is supplemented by alternative scenarios, often termed "high" and "low" cases. The limitation of the first is clear -- while it may provide the single best guess,it offers no information about the range of probable outcomes. For short-term forecasts (three to five years in the case of airports) a single estimate may be quite acceptable. A longer term horizon, such as the twenty years or more needed when planning major capital investments, requires a more explicit recognition of uncertainty. Although the second approach attempts to overcome this problem, it in fact exacerbates the problem since it gives no indication of how likely it is that the high and low cases will actually materialize.

An equally significant shortcoming of the second approach is that the "high" case usually assumes that most underlying assumptions deviate in the same direction from their expected value; and likewise for the low case. The forecast may, for example, be portrayed as baseline forecast plus 10 percent (high case) or minus 10 percent (low case). In reality, of course, the likelihood that all underlying factors shift in the same direction simultaneously is quite remote. The net effect is that an attempt to show the possible range of outcomes, actually distorts the reader's perception by presenting ranges unrelated to reality.

Risk Assessment

One way to incorporate and reflect this natural range of uncertainty is risk assessment. In short, employing risk assessment allows the explicit recognition of those factors that

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[3] For a more complete description of how risk assessment and simulation have been employed at MSP International, see "Working Paper II: Analytic Framework," presented to the Airport Adequacy Task Force of the Metropolitan Council of the Twin Cities Area, December 12, 1987.

traditionally were only implied. For MSP, the first step was to define a range of possible values (a "probability distribution") around the best estimate (mean) for each forecast and capacity variable based on expert knowledge of physical and technological limitations. These ranges were then incorporated into the forecasting model using simulation techniques. This results in a probability distribution around each answer that more accurately portrays the potential variability over time.

How does risk assessment -- and probability -- aid decision-making? Consider a simple example. Before the advent of powerful computers, weather forecasters would simply assert their mean expectations or single best guess -- "we do not expect rain today." The decision on today's picnic would be easy -- full steam ahead. Now, the same forecast incorporates the probability for each causal factor in the determination of rain, and the forecaster announces that, "there is a 25 percent chance of rain by mid-afternoon." A more reasoned decision regarding the picnic is now possible. If the event involves costly logistics for hundreds of people, a rain date might well be announced. In the past, provision for risk was not possible and a good many dollars -- not to mention good will and tempers -- were lost.

THE PROCESS FOR THE MSP ADEQUACY STUDY

The forecasting process used in the MSP study involved four steps: (1) Identifying the baseline forecast, (2) development of baseline estimates and initial probability distributions; (3) expert panel review; and (4) combination of results into the model.

Step 1: Defining the Baseline Forecast

Before risk assessment can be applied, the first step is to select the baseline forecasts and ascertain which variables must be considered in the forecasting model. The master planning process conducted by the Metropolitan Airports Commission (MAC) leads to traffic and capacity projections that have been used as the baseline forecasts for this study.[4] In the MAC Master Plan Update, separate forecasts were made for air carrier, regional carrier, cargo, general aviation and military, each with their own independent variables.

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[4] The baseline forecasts were prepared by Howard Needles Tammen and Bergendoff and presented in MSP 2000+: Airport Development Plan for Minneapolis-St. Paul International Airport, (Task 2), February 1988. Maximum use has been made of these forecasts for two reasons: first, a desire to ensure that the two analytical efforts complement each other, and second, because the results appear reasonable.

Step 2: Development of Initial Estimates

The initial estimates of the distribution about each forecast variable were constructed first by recording the baseline assumptions for each forecast factor in a probability chart.

Second, an initial probability distribution for each entry in the charts was defined and for each of the forecast years: 1993, 1998, 2003, 2008, and 2018. The initial probability distributions were developed by the Metropolitan Council's working group. Based upon the group's general knowledge of aviation and informal discussions with MAC and other experts, they represented the working group's initial best estimate of the probability distributions for each factor. These initial steps were completed by the working group in preparation for the expert panel review.

Step 3: Expert Panel Review

The purpose of the expert panel review was to identify factors and issues that the study's working group may have overlooked in its initial estimates. The panel of experts consulted had extensive experience in a range of fields including: economics, aviation technology, engineering, and investment planning and decision making. Although individually each expert may not have had a complete understanding or be able to confidently predict values for each variable, as a group, the panel members could provide estimates which were much more sensitive to the future shifts in the status of the system.

For each of the key variables the panel members were given a sample data sheet showing historical trends and the baseline forecast -- Figure 1 is the one for Average Aircraft Size. Similar data sheets were prepared for each variable that influenced the forecast. The panel members were asked to assess the likelihood of each series of events. The likelihoods were summarized by two members: first, an estimate low enough so that there was only a ten percent chance of the actual number being lower, and second, an estimate high enough that there is only a ten percent chance the actual number will be higher. Thus, the probability of an occurrence between the two values in the range reflects an 80 percent probability, or an 80 percent "confidence interval."[5]

The information provided by the expert reviewers was then converted to more precise data by plotting expert information and fitting a cumulative density function (CDF) curve to it. A probability density function curve can then be developed from the

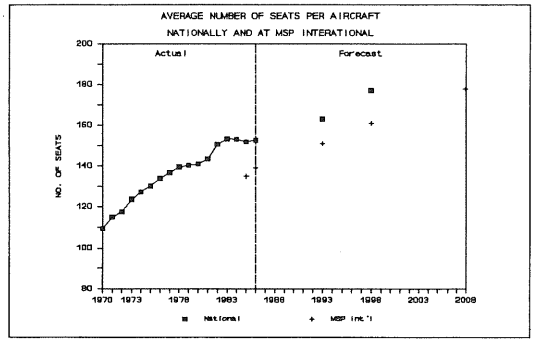
[5] Technically this is given by the area under the normal distribution curve between -1.28 and 1.28 standard deviations.

CDF curve. The CDF function allows the use of uniformly distributed random numbers (easily generated by a computer program) to select individual estimates for each variable according to the distribution defined for each variable and each year in this study.

Step 4: Incorporation into the Model & Monte Carlo Simulation

Once final distributions were generated for all of the identified variables, each distribution was used as input to the Monte Carlo simulation. Monte Carlo simulation is simply a systematic way to combine probabilities. Consider, for example, that the net capacity of MSP ("F") in any year "t" -- and the associated probability distribution -- is determined by GNP, aircraft size, the degree of hubbing, alternative runway layouts, and all the other factors detailed in the lists and enumerated in the data sheets (Figure 2).

Figure 1. Sample Data Sheet Provided to Expert Panel Members



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT *	INDICATE 10% UPPER LIMIT *
1986	139			
1993	151			
1998	161			
2003				
2008	178			
2018				

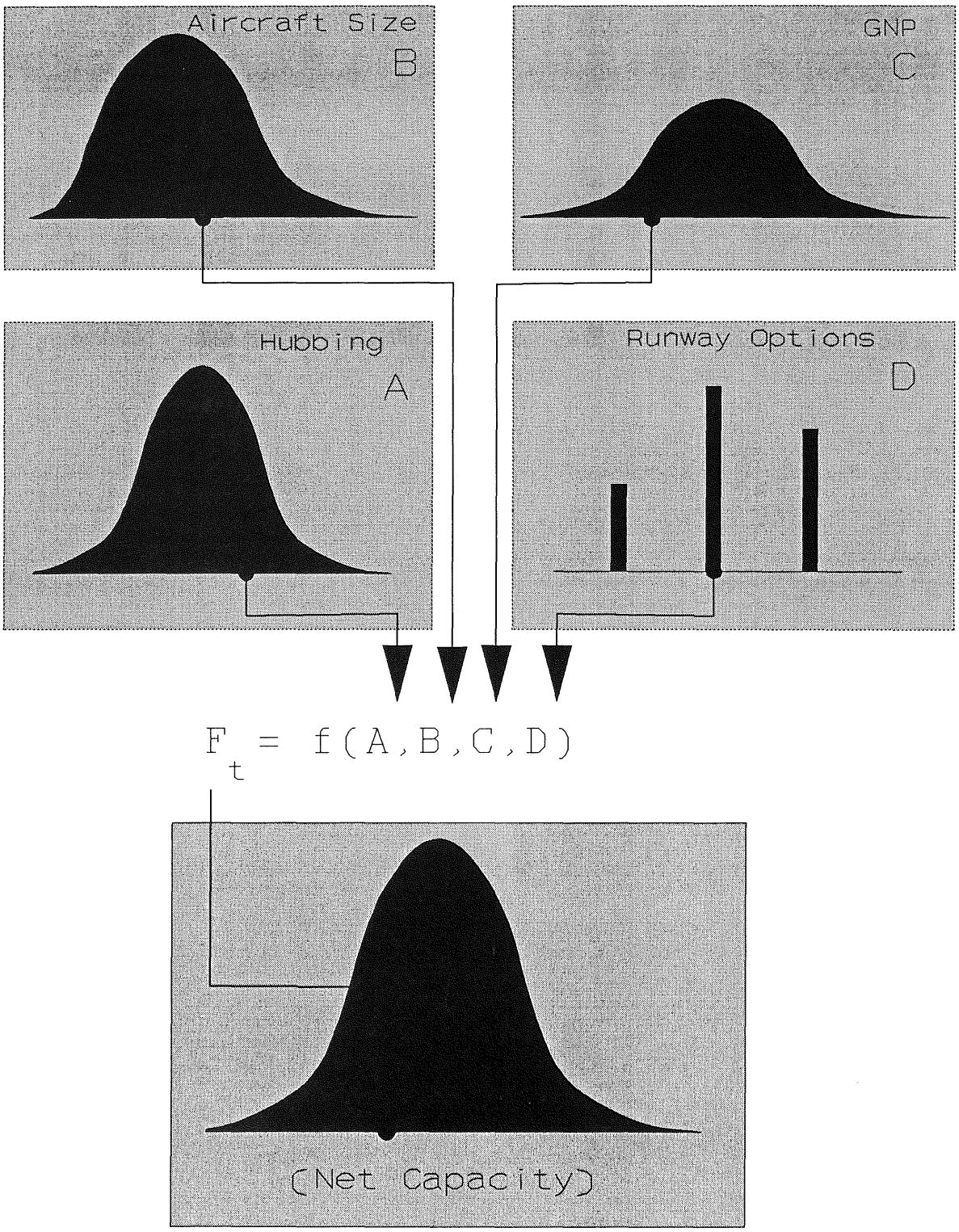
* Indicates the upper and lower limits of an 80% confidence interval for the forecast.

Actual conduct of the risk analysis involves three key steps:

- Define mathematically the algorithms that relate forecast factors to traffic, environmental capacity, and physical capacity;
- Develop the simulation computer program based on the algorithms defined above; and
- Run simulations.

Each run of the simulation represents one forecast. The simulation is then run at least 1,000 times, with the results summed to create a probability distribution for each forecast output.

Figure 2. Monte Carlo Simulation: A Way to Combine Probabilities



II. BACKGROUND

INTRODUCTION

Change in the operation and technical requirements of the nation's systems of airports and airways has always occurred at a faster pace than that of other types of public works infrastructure. Indeed, aviation's long-term growth has exceeded that of most other industries. At the local level, that growth creates special problems -- and opportunities -- in all aspects of airport operation and management. To assess development alternatives objectively, however, one must first understand the environment within which that facility operates.

In sum, trends in traffic at MSP have reflected the increased volatility of the market within which it operates. Primarily as a result of the emergence of MSP as a hub, growth of air traffic at MSP has outpaced national trends. Nationally, for example, enplanements rose by 28 percent over the period 1980 to 1985. Over that same period at MSP, enplanements grew by 66 percent -- more than twice the national average.

Financial trends, on the other hand, suggest a strong and stable financial presence. Thus, even while coping with strong growth in traffic at MSP, the finances of MSP have remained strong and even improved somewhat.

NATIONAL TRENDS IN AVIATION

In 1950, U.S. airports enplaned 50,000 passengers daily. During 1984, that number surpassed 1 million. Throughout this period of rapid growth, the real cost of air travel has declined almost every year. The Federal Aviation Administration (FAA) estimates that enplanements will nearly double by the turn of the century. The primary consequence has been a rapid escalation in the number and size of delays at airports nationwide. Most importantly, while the rapid rate of industry growth may slow somewhat due to reduced competition brought on by recent mergers and aviation's recent market penetration, the upward trend seems unlikely to change.

System Projections

FAA's most recent forecast of passenger traffic calls for an average annual growth rate of 5.8 percent for the next two years

and 4.5 percent through the end of the century.[6] While rapid, these trends are somewhat slower than recent years -- 9.9 percent in 1986 and 5.6 percent average from 1980 through 1986. Some of this slower growth may be due to the much slower decline in average ticket prices forecast by the FAA -- a real (after inflation) average annual decline of about 1.4 percent a year for the next twelve years versus the 18.1 percent real decline in the last two years alone. This change may result in part from decreased competition due the to recent rash of airline mergers but also reflects the belief that the airline industry cannot continue to adapt to rapid price declines.

This growth will affect both airports and air traffic control. The FAA projects traffic at airports with FAA towers to increase by 34 percent by 1998 and traffic handled at the FAA's enroute air traffic control centers to grow by 33 percent. The FAA foresees little overall change in the mix of aircraft that use these airports, however, where general aviation will still account for more than 62 percent of operations and air carriers for almost 21 percent. In contrast, the traffic mix handled by enroute centers is projected to shift somewhat, with commuter airlines and air taxi aircraft increasing from about 15 percent of the workload in 1986 to 20 percent in 1998. Air carriers, general aviation, and the military all show small relative declines.

HISTORICAL TRENDS AT MSP

Because of changes in the nature of airport operations at MSP International, growth at the airport has outpaced national trends. Due to the emergence of MSP as a hub, MSP enplanements have grown significantly faster than the national average over the past five years. Nationally, for example, enplanements rose by 28 percent over the period 1980 to 1985. Over that same period at MSP, enplanements grew by 66 percent -- more than twice the national average. Regional forecasts indicate that commercial and commuter activity will continue to grow rapidly, whereas general aviation traffic will grow only slightly.

The ability of the current airport configuration to withstand the pressure brought on by rapid growth will ultimately determine the current and potential impacts of aviation on the MSP region. Two factors in particular merit special scrutiny: air traffic activity and the current financial status of regional aviation.

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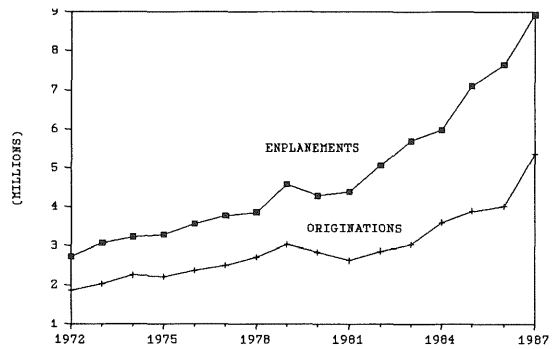
[6] This and other forecasts of national aviation activity are derived from the FAA Aviation Forecasts, Fiscal Years 1987-1998, Federal Aviation Administration, (February 1987).

Air Traffic Activity

In the aggregate, data on enplanements reveal that activity at MSP has increased considerably over the period 1980 to 1985. Underlying this trend, however, is a significant change in the type and source of activity. Not surprisingly, since the emergence of MSP as a hub airport, the number of passenger originations, while increasing rapidly, has not kept pace with connecting enplanements (Figure 3). Whereas originations comprised two-thirds of all enplanements in 1972, for example, they now represent only one half, the greatest shift occurring in the early 1980s (Table 1).

The change in the type of aviation activity is primarily attributable to the activities of the one airline that uses MSP as a hub, Northwest Airlines (NWA). With the acquisition of Republic Airlines by Northwest in 1986, combined NWA activity at MSP International now represents approximately 75 percent of total passengers and 60 percent of total commercial operations.

Figure 3. Passenger Enplanements at MSP International



Additionally, due in part to NWA's hubbing and in part to changes in passenger loads, the average number of enplanements per departure at MSP has been increasing steadily. From 47 per plane in 1972, enplanements per departure has increased to over 60 today. This trend, while continuing to grow, demonstrates high volatility from year to year.

Table 1.
Originations and Connecting Enplanements
As a Percent of Total Enplanements, Selected Years
(In Percent)

Year	Originations	Connecting Enplanements	Total
1972	68.5	31.5	100.0
1975	67.2	32.8	100.0
1980	66.3	33.7	100.0
1985	54.7	45.3	100.0

Source: Master Plan Update, prepared by Howard Needles Tammen & Bergendoff, January 1987.

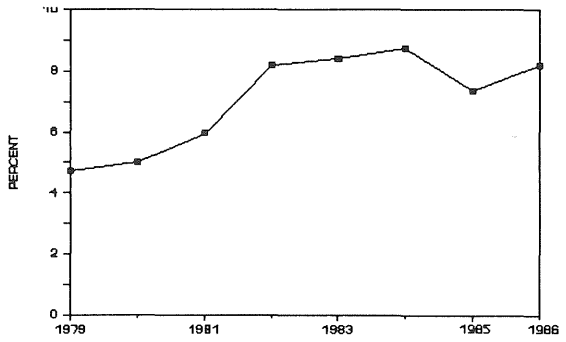
At the reliever airports the picture is considerably different. Between 1977 and 1982, operations at relievers actually declined by an average of 6 percent annually. However, since that time, operations have rebounded, increasing at an average annual rate of 6 percent. Even with these fluctuations, no single reliever has come to dominate the market with the distribution of operations remaining relatively stable over the last ten years.

Financial Performance of MSP and the Metropolitan Airports Commission (MAC)

MSP is in a solid financial position. In spite of extraordinary growth in facility demand at MSP International, the MAC has managed to maintain and, by certain measures, improved its financial standing, a conclusion supported by a variety of financial measures. This performance has been attained even while simultaneously providing operating subsidies (through user fees) to the reliever airports under MAC's jurisdiction.

Management and Performance Ratios. Various measures were tabulated to measure the effectiveness of ongoing management and performance including Return on Assets, Net Income, and Operating Income. The measure Return on Assets (ROA) is calculated by comparing net income as a percentage of total (depreciated) assets. In essence, it is a reflection of how effectively the existing asset base is being used. For the period 1980 to 1985, ROA has been maintained at a steady rate of between 7 and 9 percent (See Figure 4). The ability to maintain this trend is particularly noteworthy in light of the high degree of volatility in MSP activity over this period.

Figure 4. Return on Assets, MAC



Net income is the difference between total revenues and total expenses. It indicates how well the facilities as well as finances are being managed. Operating income, on the other hand, is strictly a reflection of how well management is doing its job, since it is tabulated exclusive of interest income and expense. Both measures have shown continued improvement over the 1980 to 1985 period. Operating income in particular increased markedly in 1983, a fluctuation whose impact was mitigated by effective financial management, suggested by the steady growth in net income.

The MAC issues two forms of indebtedness: Airport Revenue Bonds and General Obligation Revenue Bonds. A recent issue of MAC bonds (December 1986) received ratings of AAA (the highest possible) from both Moody's and Standard and Poor's rating services.[7] Two ratios, Debt-Equity and Debt Service Coverage, suggest why. Over the last eight years, the debt-equity ratio has declined from 1.1 to 0.5. This suggests that the MAC is operating with a lower degree of leverage and thus at a reduced risk. The debt service coverage ratio, on the other hand, a measure of an entity's ability to pay the costs of debt incurred, has improved continually over the same period.

Reliever Subsidies. The relationship between the main commercial airport (MSP International) and other general aviation facilities is a key factor in the success of the region's reliever airport system. As part of MAC policy, user fees at reliever airports are intentionally below cost in order to encourage pilots to use these facilities whenever possible. MSP International generates these revenues to compensate for this cost by charging slightly higher user fees (Table 2).

TRENDS AT SIMILAR HUB AIRPORTS[8]

Amidst industry-wide capital expansion, the demand for services at Minneapolis-St. Paul Airport continues to exceed growth. This section compares the impact of this rapidly growing demand on the airport with conditions at five other hubs - Atlanta, Denver, Houston, Kansas City and St. Louis. Specific factors of analysis include:

- traffic, including forecast growth rates;
- general layout, taking into consideration the size of each airport in acres as well as the configuration;
- planned capital investments; and
- and financial characteristics.

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[7]It should be noted that the "General Obligation Revenue Bond" is guaranteed by both the revenue of the project being financed and the authority to levy any required taxes on the assessed valuation of the seven county metropolitan area.

[8]Further detail on these analyses and other factors such as runway configuration, orientation, and noise contours is included in "Comparative Analysis of Minneapolis St-Paul and Five Hubs," a report prepared for the Metropolitan Council of the Twin Cities Area, August 1988.

Table 2.
Revenues and Expenses By Airport Facility
(1986)

Airport	Operating Revenue	Operating Expense	Operating Income
MSP	$55,441	$38,895	$16,546
St.Paul Downtown	279	1,096	(817)
Flying Cloud	141	383	(242)
Crystal	67	285	(218)
Anoka	69	283	(214)
Lake Elmo	29	167	(138)
Airlake	28	165	(137)
TOTAL	$56,054	$41,274	$14,780

Source: Comprehensive Annual Report, Metropolitan Airports Commission, 1986, p. 7.

The five hub airports selected for detailed analysis were elected because of the similarity of each to MSP on the basis of regional population, physical location relative to the market served, and hubbing characteristics. As shown in Table 3, below, for example, each of the airports selected was similar in terms of operations and population. Thus, the characteristics of demand at each of these airports is similar. In addition, each of these airports is currently considering or undertaking major physical expansion to accommodate rapid growth in demand.

Table 3.
Comparison of Enplanements, Operations, and Population by Hub

HUB NAME	ENPLANEMENTS	OPERATIONS	POPULATION
NEW YORK/NEWARK	35,540	1,106	17,931
CHICAGO	25,892	1,015	8,085
DALLAS/FT. WORTH	21,689	834	3,512
LOS ANGELES	21,481	1,331	12,738
ATLANTA	**20,952**	**775**	**2,472**
SAN FRANCISCO/SAN JOSE	16,797	1,142	5,809
DENVER	**15,371**	**521**	**1,827**
WASHINGTON/BALTIMORE	14,389	880	5,743
MIAMI/FT. LAUDERDALE	11,939	569	2,878
HOUSTON	**10,167**	**578**	**3,623**
ST. LOUIS	**9,798**	**461**	**2,412**
BOSTON	9,674	420	4,051
DETROIT	8,140	405	4,581
MINNEAPOLIS/ST. PAUL	**8,001**	**402**	**2,262**
PHOENIX	7,456	412	1,847
PITTSBURGH	7,349	366	2,337
HONOLULU	7,180	364	815
SEATTLE/TACOMA	6,479	254	2,247
ORLANDO	5,746	218	866
CHARLOTTE	5,623	361	1,049
LAS VEGAS	5,537	352	557
PHILADELPHIA	5,387	368	5,776
TAMPA/ST. PETERSBURG	4,631	426	1,869
SALT LAKE CITY	4,606	270	1,025
SAN DIEGO	4,419	164	2,133

Sources: Federal Aviation Administration and Statistical Abstract of the United States, 1987.

Traffic

Traffic analysis includes analysis of market concentration, comparisons of the forecast growth in total, commercial and regional enplanements and operations, along with general aviation operations.[9] Based on such analyses we can expect continued industry-wide growth. The growth rate of all hubs should decrease slightly around 2000, but remain significant. Growth at Minneapolis-St. Paul should exceed the average of the five hubs.

Primary markets of MSP are widely distributed. Except for the concentration of passenger trips to Chicago, for example, trips are distributed across a relatively narrow numerical range and across a wide geographical range (see Table 4).

Among the six hubs, including Minneapolis-St. Paul, the number of total enplanements is expected to increase at 4.6 percent annually between 1986 and 2000. Denver shows the highest growth rate (5.8 percent), based on assumptions related to the impending construction of the new airport. MSP ranks second, with an estimated growth rate of just over 5 percent. Regional enplanements are a primary reason why MSP's growth should be so strong. The FAA expects regional enplanements to increase 9.0 percent annually, compared to the average of the six hubs, 4.5 percent. The growth in commercial enplanements, which make up the bulk of total enplanements, is also expected to be above average at MSP.

Growth in total operations at MSP is also projected to exceed the average for the six hubs. This, however, is a direct result of the much greater than average increase in regional operations (6.4 percent per year versus 1.1 percent). Were it not for the rapid growth of regional operations, growth in total operations would be below average. Specifically, commercial operations growth is expected to be slightly lower than that of the other hubs (1.8 percent annually versus 2.5 percent), while general aviation operations at MSP are expected to decline at the rate of 1.97 percent per year.

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[9] All forecast data, detailed in Appendix A, are from the FAA through hub forecasts and other documents.

Table 4.
1986 Domestic O & D Passenger Traffic Top 25 Markets at Minneapolis-St. Paul International Airport

MARKET	PASSENGERS
CHICAGO	1,050,920
NEW YORK/NEWARK	643,850
LOS ANGELES HUB	438,520
SAN FRANCISCO HUB	305,550
WASHINGTON/BALTIMORE	305,210
PHOENIX	245,910
DETROIT	243,420
DALLAS/FT. WORTH	214,150
BOSTON	208,340
SEATTLE	171,310
ATLANTA	161,630
ST. LOUIS	153,140
ORLANDO	147,950
MILWAUKEE	134,210
TAMPA	131,990
SAN DIEGO	130,130
KANSAS CITY	129,920
PHILADELPHIA	124,160
MIAMI	117,540
HOUSTON HUB	113,260
OMAHA	105,010
CLEVELAND	93,130
LAS VEGAS	86,700
PORTLAND	76,410
SALT LAKE	68,920

SOURCE: FAA Aviation Forecasts

Layout

MSP appears small compared to the other five airports. With only 3,100 acres, it ranks second smallest. The only smaller airport in our study is Lambert-St. Louis International (2,300 acres). In contrast, Kansas City International covers 7,200 acres, and Houston Intercontinental is 7,840 acres.

Not surprisingly, the number of enplanements is not necessarily a function of the size of an airport nor the number of runways. In terms of acreage, for example, Kansas City is more than three times the size of Lambert. While Kansas City currently has two commercial and one general aviation runway, Lambert has three commercial and two commuter/general aviation runways. In spite of the size differences, in terms of total enplanements in 1986, Lambert had over 10 million and Kansas City had less than 4 million. Lambert also had significantly more total operations, with 461,000 in 1986 compared to 206,000 at Kansas City.

The average number of passenger enplanements per year per commercial runway was slightly more than 3.3 million. Atlanta's Hartsfield had the most enplanements per runway in 1986, with over 5.5 million, while Kansas City's International had the fewest with a little less than 2 million. The number of enplanements per runway at MSP was 2.8 million, well below average for the six hubs.

The amount of acreage per runway yielded similarly interesting results. For example, while the average among the hubs was 1684 acres per runway, the degree of variability was considerable. With 7200 acres and just two runways, Kansas City International easily had the most acres per runway. Lambert-St. Louis, with 575 acres per runway, had the fewest. MSP was below average with 1033.

Planned Capital Investments

Currently, a wide variety of hubs are in the process of either undertaking or planning major capital investments. Many are planning to improve their IFR operations capacity (Table 5), while others are planning additions to terminal and landside capacity. Atlanta, for example, has already set-aside land (often referred to as "land-banking") for a new airport deemed necessary after the year 2000 and is in the process of building a new runway and purchasing additional safety zones for the existing site. Denver and Austin airports, on the other hand, are now both in the process of building completely new facilities.[10]

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[10]Many other airports not listed in the table are in the planning stages for new airport facilities including New Orleans, San Diego, and, depending on the ultimate outcome of the three-hub airport analyses underway, the Chicago area as well.

At Houston's Intercontinental Airport, a new runway is planned for the next ten years. This runway will be parallel to and north of existing runway 8/26, with a spacing between the two runways of 3500 feet. In conjunction with runways 9/27 and 8/26, this runway has the potential for allowing triple IFR approaches. Another new runway, parallel to and south of 8L/26R, is also planned. Because of its proximity to a parallel runway, however, there appears to be no potential for additional multiple approaches.

At Kansas City's International Airport, a new runway will be constructed parallel to and east of existing runway 1/19. The spacing between the two runways will be 6575 feet, thus allowing the potential for parallel IFR operations.

In addition, Denver recently proceeded with plans for an all new 45 square-mile airport to be built eighteen miles northeast of the city. The $1.7 billion project, expected to be completed in the early- to mid-1990s, will have 6 runways and 120 gates when opened with planned expansion to 12 runways and 206 gates by 2020. When the planned airport begins operation, Stapleton Airport is to be closed permanently.

Comparison of Financial Indicators

An analysis of financial indicators among airports similarly positioned further confirms the conclusion asserted above that MSP stands on solid finances. For the purpose of this analysis, four hub airports -- Atlanta Hartsfield, Denver Stapleton, St. Louis Lambert, and Kansas City International -- were analyzed on a variety of financial measures which were, where possible, then compared to national averages.[11] The ratios in this section, derived from the annual financial reports of each airport, provide measures of debt-servicing capacity (coverage and safety margins) and profitability (operating ratio and net take-down).

Debt Servicing Capacity. Two measures were developed to compare the relative long-term strength of each airport: debt service coverage ratio and debt service safety margin. In general, the debt ratio, which is calculated from the balance sheet, signifies the airport's reliance on debt financing and its capacity to support additional debt. Specifically, coverage levels demonstrate both current and prospective debt repayment ability. Calculated as the ratio of net revenues divided by principal and interest requirements for that year, a range of 1.5 to 2.0 is considered well within the safe range. In spite of large infusions of debt-supported capital, Atlanta still maintains a sound coverage ratio. Only two airports, however, maintain ratios well above the hub or national averages: MSP and Kansas City International (KCI).

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[11] National averages were taken from analyses prepared by Moody's Investors Services.

Table 5.
Planned New Runways and Their Potential IFR Capacity Yields

AIRPORT	RUNWAY NEW CONFIG.	CAPACITY (ARRIVALS/HOUR) CURRENT	BEST
Houston (IAH)	**8L/26R**	**61.9**	**25.4**
Las Vegas (LAS)	7R/25L	24.0	24.0
Kansas City (MCI)	**1R/19L**	**55.0**	**27.5**
Orlando (MCO)	17/35 4th Parallel	50.2 75.3	25.1
Salt Lake City (SLC)	16/34	50.8	36.2
Cincinnati (CVG)	18L/36R	53.2	26.6
Indianapolis (IND)	4R/22L	38.2	26.7
Milwaukee (MKE)	7L/25R	51.4	51.4
Nashville (BNA)	2R/20L	50.2	25.1
Norfolk (ORF)	5R/23L	24.7	24.7
New Orleans (MSY)	N/S rwy	49.6	24.8
Sacramento (SMF)	16L/34R	49.2	24.6
San Jose (SJC)	11/29	24.5	24.5

Source: Aviation Safety Commission

Safety margins, on the other hand, denote additional levels of protection. While the national average is 30 percent, MSP is well above that average at more than 35 percent. While deviations do not necessarily suggest problems with credit quality they may highlight an unusual event such as a debt restructuring or recent debt issuance.

Profitability. The net take-down, or net revenues divided by gross revenue and income, reflects the degree to which normal operation and maintenance (O&M) expenses influence profitability. In short, a higher value suggests lower O&M costs, and potentially higher profitability. While there is no "correct" value for net take-down, the national municipal airport average is 50 percent.

For this sampling of hubs, however, the average is slightly higher at 60 percent, with the percentage decreasing with airport size. Atlanta, for example, shows the largest percent at 80. The lower reliance on O&M reflected in these data suggest that hub operations continue to increase in efficiency with greater size at least across the range of airports considered here. In addition, the average across these hubs is slightly higher than might otherwise be expected because Atlanta has recently taken on large quantities of debt.

III. DEMAND FORECASTS

A key first step in determining the adequacy of any infrastructure system must be developing forecasts of the expected level of demand. The second step, to estimate the likely capacity of the system to meet that demand, is described in a following section. This section summarizes the results of the first half of this process -- the expected demand for aviation services at Minneapolis-St. Paul International Airport (MSP).

The MSP Adequacy Study has chosen a risk assessment approach in developing its long-term forecasts. By expressing results in terms of the probability of being able to meet a given level of demand, risk assessment allows the public to make a much more informed decision regarding how much capacity should be added and how soon.

The forecasts show a very high probability of strong continued growth in aviation demand for the Metropolitan Region. This is not surprising given the continued economic growth in the region. There is, for example, a more than two-thirds chance that enplanements will increase by 50 percent or more within ten years (1998), increasing to 12 million from roughly 8 million today (See Table 6). Twenty years from now, there is better than a one-third chance that enplanements will have doubled (exceeding 16 million each year) and an 84 percent chance that they will have doubled within thirty years.

Table 6.
Probabilities of Changes in Enplanements

A. Likelihood of 50 Percent Increase in Enplanements Within:

Five Years	10 %
Ten Years	69 %
Fifteen Years	86 %
Twenty Years	93 %
Thirty Years	97 %

B. Likelihood of 100 Percent Increase in Enplanements Within:

Five Years	0 %
Ten Years	1 %
Fifteen Years	9 %
Twenty Years	34 %
Thirty Years	84 %

In developing these forecasts, some 20 variables were examined and incorporated into the simulation of future traffic. Future demand was measured in terms of originating passengers, enplanements, and aircraft operations (annual and peak hour). Several factors appear to be particularly important in determining future traffic: employment, aircraft prices, the amount of connecting traffic (hubbing activity), the size of aircraft, and the growth in regional carriers.

The results of this forecast indicate demand will exceed the current capacity of MSP by a substantial amount. Indeed, there is a only a twenty percent chance that the current airport configuration will be able to meet the demand expected in the early 1990s and less than five percent chance that of doing so twenty years from now. A shortfall of this magnitude will not likely happen since the region will undoubtedly take significant steps to improve its aviation capacity over the next decade.

KEY VARIABLES

Aviation demand was estimated for each major component of traffic:

- Domestic air carriers;
- Regional carriers;
- General aviation; and
- Freight and military.

As an example of this forecasting process, Figure 5 presents a forecast model structure and logic diagram for air carrier traffic -- the most important component of future demand at MSP. Table 7 describes the individual inputs into the logic diagram. Similar logic models and data tables were created for each of the other components of total air travel.

The model is broken into two sections. The first is the econometric model, a statistical relationship between historical traffic and variables thought to affect traffic growth. This section produces a forecast of air carrier traffic originating at MSP. The second is called accounting-type factors and covers factors (future aircraft size, for example) used to adjust the expected level of originating traffic into other enplanements and aircraft operations.

Figure 5. Logic Model for Domestic Air Carrier Activity Forecast

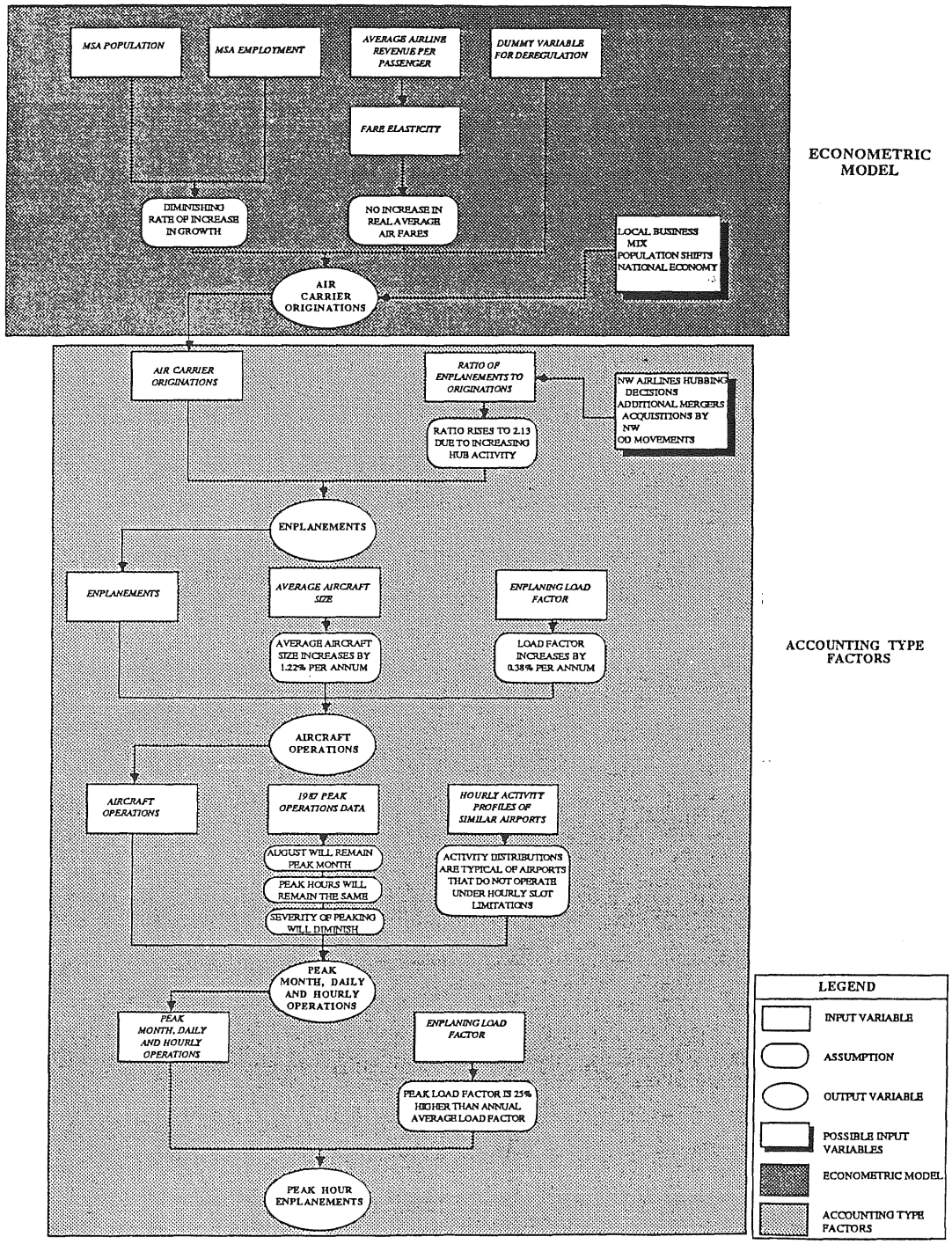


Table 7.
Key Factors for Domestic Air Carrier Forecasts

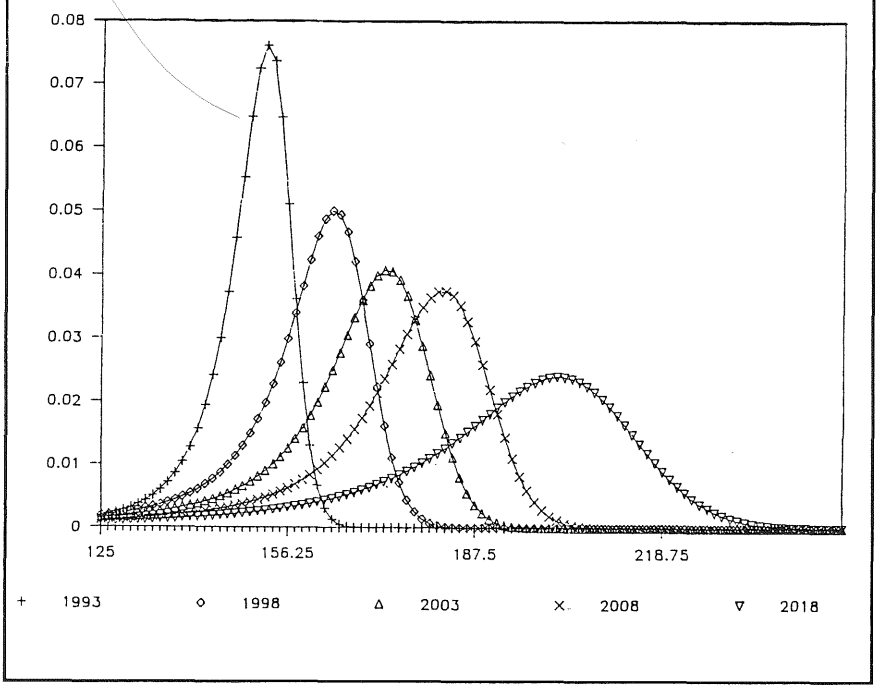
INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
MSA population MSA employment Average airline revenue per passenger ($1972) Dummy variable for deregulation	Air carrier originations	Economic/demographic projections assume continuous growth but at a diminishing rate of increase. No increase occurs in the real average fare level over the period.	OD movements Local business mix Population shifts National economy
Air carrier originations Ratio of enplanements to originations	Enplanements	The ratio of enplanements to originations rises to 2.3 by 1993 due to increasing hub activity at MSP by NW and then remains constant beyond 1993 as airports with high connecting ratios become less intensive in connecting activity.	NW airlines hubbing activity decisions Additional mergers/acquisitions by NW
Enplanements Average aircraft size Enplaning load factor	Aircraft operations	The average size of aircraft is expected to increase by 1.22% per annum and beyond 1998 the growth rate of aircraft size will be lower at 1.0% per year. The load factor is expected to increase by 0.38% per annum. On the basis of the known aircraft acquisition plans of NW and increasing emphasis of MSP as a connecting hub, these national growth rates appear appropriate.	
Annual aircraft operations 1987 data on peak operations Hourly activity profiles of similar airports	Peak month, daily and hourly operations	August will remain the peak month with 9.06% of the annual operations. It is assumed that 8:00-8:59 am, 1:00-1:59 pm and 5:00-5:59pm will remain the peak hours in the future. The relative severity of the peaking will likely diminish over time as the effective operating day is extended in the early morning and late evening and relatively more flights are scheduled during the day. The activity distributions are typical of airports that do not operate under hourly slot limitations or curfews.	
Peak houly operations Enplaning load factor	Peak hour enplanements	The load factor will be 25 percent higher than the annual average load factor.	

NOTES: The forecast methodology is from the Minneapolis-Saint Paul International Airport Master Plan Update, February 1988 prepared by Howard Needles Tammen & Bergendoff.
MSA defines the Minneapolis-Saint Paul metropolitan statistical area.

The table considers four aspects of the baseline forecast made for the MAC master plan. First, it lists the input factors used such as the Metropolitan Statistical Area (MSA) employment, and average airline revenue per passenger. Next, it presents the output measure calculated from these input factors. Examples of outputs include measures of demand such as air carrier originations, enplanements and aircraft operations. Key assumptions that were made about the behavior of the input factors or the model are described in the next column. These cover assumptions about growth rates, load factors, and Northwestern Airlines' hubbing activity. Finally, other factors that could have an effect on the outputs are also listed. From the table it can be seen that outputs from one step of the forecast often become inputs for the next.

For each variable in the logic model and for each forecast year (1993, 1998, 2003, 2008, and 2018), and individual probability distribution was estimated. These were developed and subsequently modified after consultation with expert panels. Each probability curve reflects both the degree of confidence around a central point and the likelihood that the actual result will be higher or lower than the central number (the mean). For example, Figure 6 shows the probability distribution for average aircraft size. Over time, there is less confidence that any given number will be correct -- the curves become wider and flatter -- and the expert panel felt that there was a better chance that aircraft would be slightly smaller than forecast. Thus, the curves have a larger proportion of their total area to the left, or low end, of the graph.

Figure 6. Forecast Probabilities of Average Aircraft Size

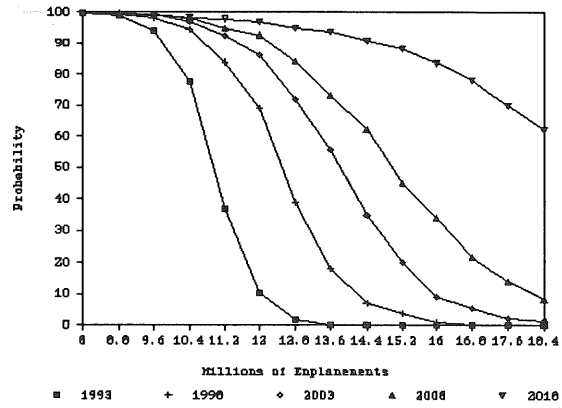


RESULTS

A demand forecast based on a risk assessment approach is not simply an estimate of demand, but an estimate of the likelihood of specific levels of demand materializing. Figure 7 shows the probability that the level of enplanements will exceed certain levels for each of the forecast years. For example, while the most likely estimate of traffic in 2008 is some 15.3 million enplanements, there is a 30 percent chance that traffic will be roughly 10 percent higher.

COMPARISON WITH OTHER FORECASTS

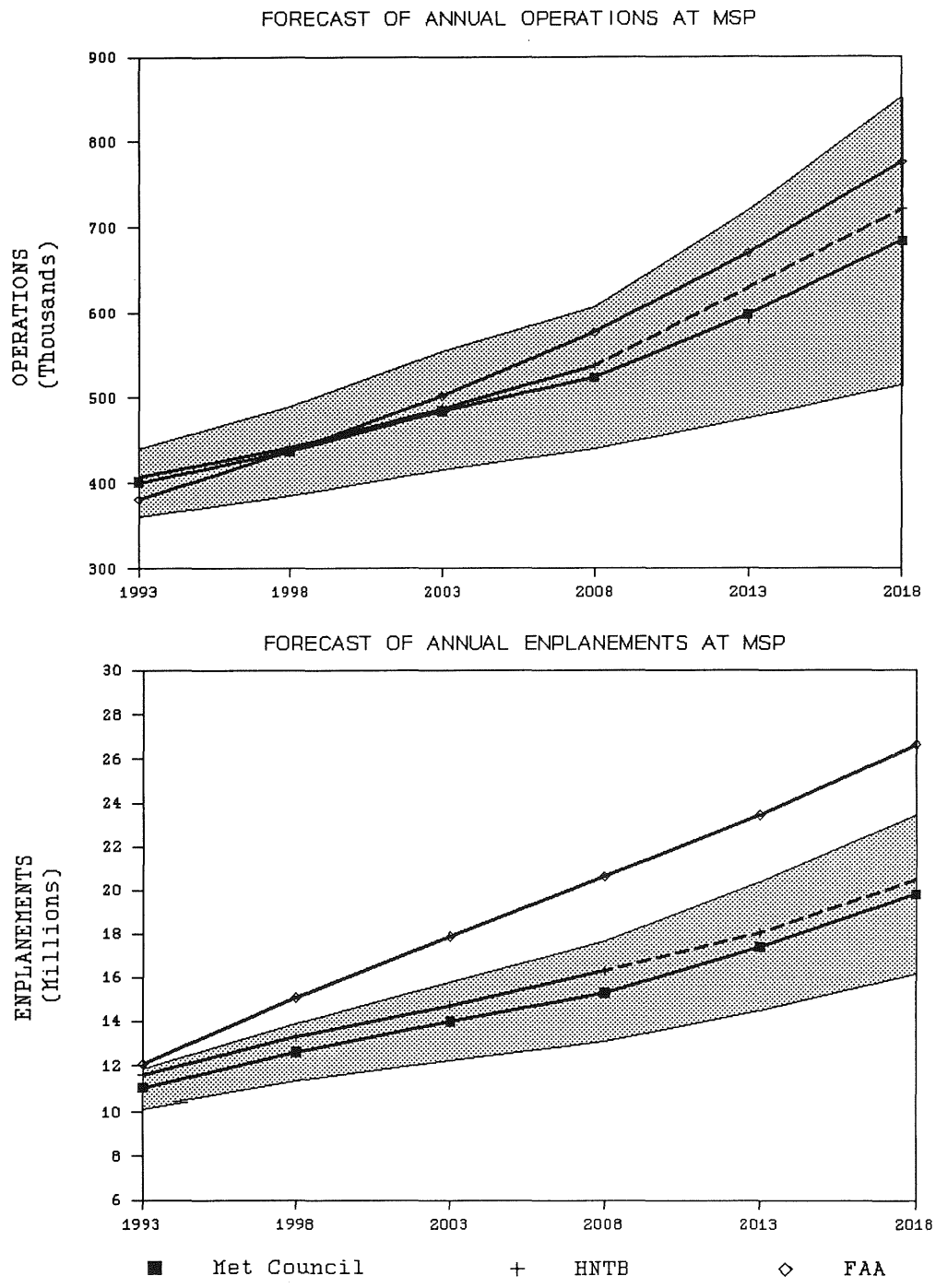
Figure 7. Probability that Enplanements will Exceed Indicated Level



The traffic forecasts used in this study have been linked closely to those developed as part of the MSP Master Plan. Both the Master Plan and the Metropolitan Council study are based on the same econometric equations. Both these sets of estimates, however, are lower than the forecasts prepared recently by the FAA. Figure 8, for example, compares the three estimates of future unconstrained operations and enplanements at MSP.[12] The grey band covers Metropolitan Council estimates with roughly a two-thirds probability of including the actual future levels.

[12]"Unconstrained" forecasts describe the best estimate of demand under a scenario of unchanged levels of service. Thus, future years imply that additional capacity must be available to meet demand.

Figure 8. Comparison of Forecasts for MSP International



Notes: (a) Shaded area represents +/- one standard deviation from the mean of the Metropolitan Council's forecast.
(b) Dashed line represents carry-forward of HNTB forecast.

IV. CAPACITY OPTIONS AND FORECASTS

WHAT IS CAPACITY?

Capacity sounds like a simple concept, but in practice it has a variety of meanings and nuances.[13] That is, capacity estimates are not simply mechanical engineering formulas, but require some art and judgment as well. Most importantly, capacity is not a fixed barrier that can never be exceeded. Rather, the capacity of most public works systems depends on the quality of service to be provided. In general, the higher the level of service that the public demands (less likelihood of delay, for example) the lower will be the physical capacity.

Two measures -- aircraft operations and passenger enplanements -- are most often used to describe the potential physical output of an airport. These two terms measure different aspects of capacity. Aircraft operations, for example, offer a useful measure of the capability of the airfield and the air traffic control system that feeds it. As such, operations measures the interaction of local physical facilities and FAA safety regulations on overall airfield capacity.

Enplanements, on the other hand, are most relevant to the capacity of the terminal and the ability of local highways and transit to provide access to the airport for people and goods. Enplanements and operations are closely related of course, since passenger enplanements depend on the average number of seats and the average load factor in commercial aircraft.

Capacity is not simply the number of operations or the number of passengers handled per unit of time but instead represents the overall ability to accommodate demand for service. Overall airport capacity is determined by examining a series of potential bottlenecks including landside access, terminal, and airfield as well as air traffic control restrictions. At any given time, an airport's effective capacity may be limited by one or more of these factors. Doubling capacity in one area does not mean that overall capacity will be doubled since another part of the airport may be more restrictive.

The effective capacity of each of these depends, in turn, on a variety of sub-components and how they vary over time. In the terminal, for example, passenger throughput depends on counter space, check-in facilities, baggage handling, the number of gates, and the characteristics of passenger facility use (that is the

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[13] See "Working Paper No. 7; Factors That Affect Capacity," prepared for the Metropolitan Council's MSP Airport Adequacy Study, (December 1987).

percent of passengers whose trips begin or end at an airport versus the number of hub transfers).

Similarly, airfield capacity is determined by the interaction among the number and size of runways, air traffic control procedures, land use or noise constraints, the mix of aircraft using the airport (general aviation or commercial craft), the effectiveness of airlines in using each plane (load factors and hours of operation), and the weather.

Preliminary results from MAC's Master Plan indicate that both terminal and landside facilities at MSP are likely to be either sufficient to handle considerably more traffic, or expandable.[14] While significant financial resources may be needed to solve these problems, there appear to be no insurmountable problems of inadequate physical space. Consequently, this report focuses on airfield capacity (runways and taxiways) -- the one area that may be the most significant long-term limit on airport capacity.

GENERAL OPTIONS

Three sets of options for improving net airfield capacity at MSP are considered here. Two of these, adding runways and improving air traffic control, will increase the actual capacity of the airport while the third, demand management, aims to reduce the level of peak period demand.

- o Runway alternatives, which includes three options in addition to the "Base Case," or present runway configuration;

- o Changes to air traffic control procedures, or those scenarios under which current FAA rules may be changed or relaxed as a result of new technologies or improved operating procedures; and

- o Demand management techniques, which includes pricing and regulatory methods that can alleviate long-term facility constraints by shifting demand to other airports or to less crowded times of day (depeaking).

Runway Configurations

There are several sets of objectives in considering new runway layouts. Most obviously, these include the need for additional

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[14] MSP 2000+ Airport Development Plan, February 1988, prepared by Howard, Needles, Tammen, and Bergendoff for the Metropolitan Airport Commission.

capacity to handle peak-period aircraft operations. If capacity is limited relative to demand, a series of economic costs will be imposed on air travellers in the Twin Cities Region. In short, trips will become more expensive because of longer delays and some traffic will not occur or be shifted to other airports or other times. In addition, some options are designed to help alleviate noise impacts. Other options may have significant effects on the size and location of terminals and on ground access needs.

More than ten separate options were considered. The three presented here offer a range of potential improvements, including what may be the maximum possible without going beyond the boundary of the existing site. Some options, particularly what is called Strategy B, do however, involve taking land now not controlled by the MAC and would require the purchase of nearby residential areas and part of Fort Snelling Park as well as the relocation of certain nearby land uses, including the Air National Guard and Air Force operations.

Table 8 summarizes the runway and taxiway additions contained in these options. The first, or Base Case, is a "current policy" case where the current runway layout and improvements already underway (or planned in the Capital Improvements Plan) remain unchanged.

Table 8.
Runway Configuration Options

Option	Description
Base Case	Extend Runway 4-22 Add taxiway improvements No other changes to the current configuration and investment plans
Strategy A	Extend Runway 4-22 Add taxiway improvements **New North-South Runway**
Strategy B	Extend Runway 4-22 Add taxiway improvements **New North-South runway** **"Far" parallel**

The capacity possible under these options varies widely, from the average of 103 operations per hour possible under VFR (good

weather) conditions today, to more than 180 operations per hour under Strategy B (this adds two new runways). Capacity under IFR (instrument flight rules) is substantially less that VFR capacity today. True IFR conditions prevail less than nine percent of the time at MSP, but low ceilings force use of IFR rules another 20 to 30 percent of the time (called modified VFR). IFR capacity estimates range from an average of 78 per hour to 138 per hour under Strategy B.

These IFR estimate are misleading for long-term projections since improvements are expected in air traffic control procedures that will, in time, bring the IFR capacity much closer to what is possible under VFR flight rules. The discussion of the implications of each option reflects the likely effect of these air traffic control changes in the future. By the year 2003, the combined effect of these air traffic control changes is expected to bring IFR capacity to within 10 percent of the VFR capacity, By 2018, this difference is expected to be under five percent.

Table 9 provides detail on the baseline VFR and IFR estimates for each option. These estimates assume that each option was implemented under today's the air traffic control rules. As discussed before, capacity estimates are not a hard science and considerable judgment must be used. The effect of future changes to air traffic control rules is added later as part of the simulation runs.

Table 9
Summary of Potential Average Hourly Capacities

Airside Configuration	Hourly Capacity	
	IFR	VFR
Base Case	78	103
Strategy A		
Base	78	103
New North South Runway	18	32
Total	96	135
Strategy B		
Widely Spaced Parallels	120	120
New North South Runway	18	32
Center Parallel	0	30
Total	138	182

These estimates assume a 50-50 split between arrivals and departures. While capacity during departure peaks is usually higher than this, capacity during arrival peaks is lower. For example, during an arrival peak with 70 percent arrivals, capacity may be as much as 20 percent -- or 20 operations an hour or more -- below the official VFR capacity. As a result, these estimates should be viewed as optimistic regarding the levels that can be sustained during peak-periods.

Clearly, the greatest long-term capacity gains at the present site are possible under Strategy B. The need to implement this option depends both on the level of aviation service that the region wishes to provide and on the projected demand. The ability to implement the option depends in turn on the land use, noise, and cost implications of adding the two runways included in this option.

AIR TRAFFIC CONTROL PROCEDURAL MODIFICATIONS

Air Traffic Control procedures and equipment are continually changing to keep up with greater demand and technological advancements. The modifications detailed in this section include those that can be reasonably expected to occur over the forecast period. Because of the special nature of these changes, the likelihood of their implementation is discussed in addition to their potential impact on operations.

The three basic options considered here are:

- Independent parallel approaches during IFR weather conditions on parallel runways separated by 3,380 feet -- the current separation at MSP;
- Terminal area automation that will permit closer spacing of aircraft, reduced runway occupancy time and other efficiency improvement; and
- The introduction of Micro-wave Landing Systems (MLS) that permit curved approaches during IFR conditions, rather than the straight-ahead approaches required with today's instrument landing equipment (ILS)

Of these changes, independent parallel approaches offers the most significant capacity improvements. As with all such changes, however, there is no certainty that it will be approved. Field tests of equipment (new radars) and procedures are currently underway in Memphis and Raleigh-Durham. Some reduction in the current 4,300 foot separation appears likely, but how soon and whether or not it will be as far as 3,400 feet remains unknown.

The Working Paper on capacity describes these options in detail. In short, after assessing the technology risks, the risks of delay in the FAA approving new operating rules, and the likely "learning curve" delays as air traffic controllers adjusted to these new rules, the study team concluded that the potential benefits for MSP had a high probability of occurring, but not until some time early in the next century. Thus, counting on early gains from technology appears to involve high risks.

DEMAND MANAGEMENT TECHNIQUES

Runway or air traffic control procedural changes imply changes in MSP's physical capacity. A third approach -- called demand management -- requires no physical modification to the existing airside configuration. Rather, this group would use prices or regulations to shift traffic to different times (off-peak, for example) or to different places (one of MAC's reliever airports) with excess airside capacity. All three approaches have the same end goal, however, to bridge the expected gap between capacity and peak-period demand. These options are by no means low cost, however, since adequate capacity may not be available at these airports and the increased traffic will also increase noise impacts on surrounding residents.

Because the traffic that is shifted are usually smaller aircraft, the remaining stream of aircraft will usually be more uniform in speed and size. This change in itself can permit an increase in the number of operations by reducing the variability in longitudinal separation as well as the absolute separation required.

All these options, however, create controversy (except among economists) and may be subject to political opposition and even lawsuits. Further, enforcing schedule changes among commercial air carriers may require local regulations -- a path that is bureaucratically cumbersome at best and may ultimately lead to violations of federal regulations. The baseline forecasts already assume that virtually all the current general aviation traffic will be shifted to other airports. In sum, these changes would make it possible to extend the current capacity for an additional three to five years, an important gain, but not an answer by itself.

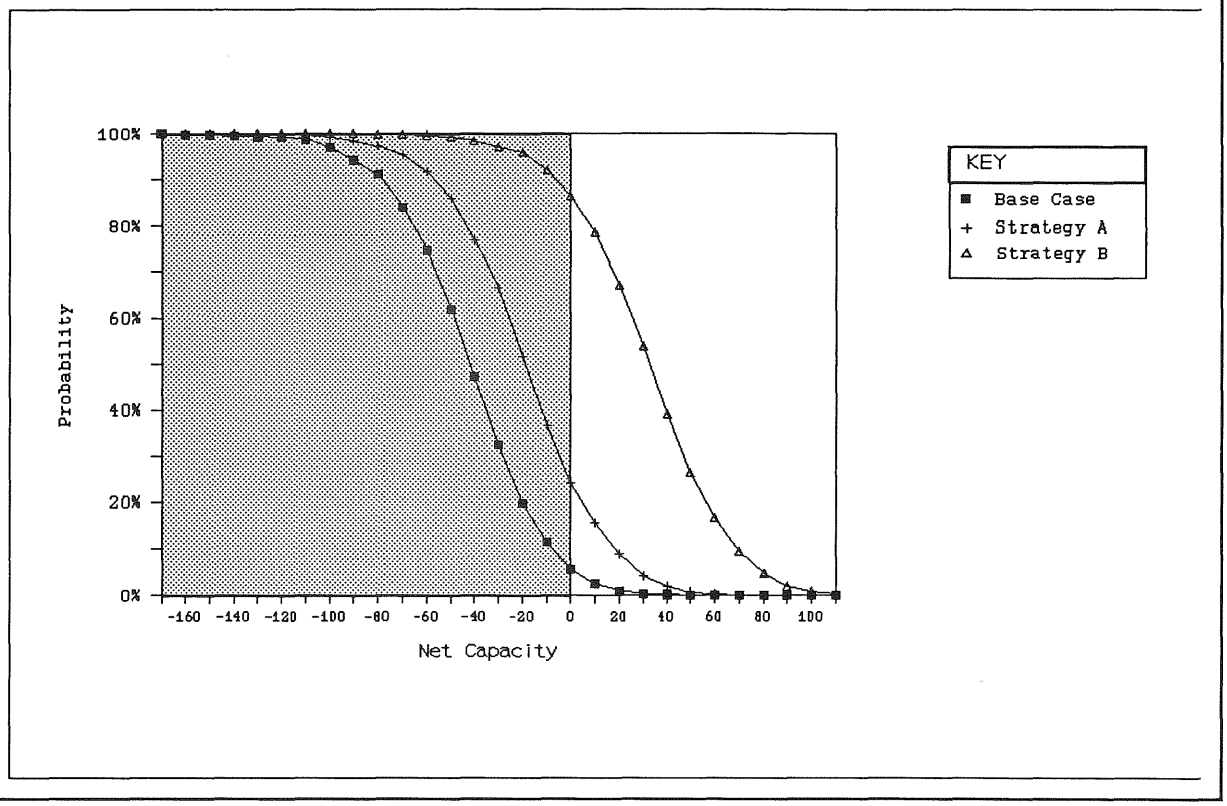
SUMMARY RESULTS

While there are different ways to measure the level of service, the approach used in this study uses the probability of being able to meet the expected future demand. A low probability will result in a low quality of service. A high probability, however, runs the risk of over-investing or building too soon in case demand does not materialize.

Traditional planning efforts implicitly assume only a 50 percent change of meeting expected demand, implying a 50 percent chance of having inadequate capacity. Providing a higher level of assurance will ensure a higher quality service to air travelers (fewer delays and shorter delays) but also require higher costs (financial as well as political) and is likely to increase environmental and other negative impacts on the surrounding community.[15]

Figure 9 combines the baseline forecasts already discussed with the capacity options discussed here.[16] That is, the numbers reflect not only each of the alternative runway layouts, but also

Figure 9. Net Capacity Probabilities at MSP International in 2008



[15]For example, "Forecast Methodology and Findings," prepared for the Metropolitan Council in May of 1988, describes the tradeoffs of setting an 80 percent chance of meeting demand versus a 50 percent chance.

[16] Mathematically, about forty separate demand and capacity variables were combined though some 10,000 separate simulations -- enough to enable the estimate of a complete probability distribution for each of the forecast years.

the likelihood of future air traffic control improvements and the full range of variables that affect future demand. While the chart uses expected IFR capacity estimates for each option, because the focus is on the year 2008, the difference between these estimates and the VFR capacity numbers shown in Table 9 above are quite small.

Net capacity is shown along the bottom. Negative numbers (those within the shaded area) show a shortfall in capacity. Positive numbers show capacity in excess of the expected demand. The vertical scale indicates the probability that expected demand will be less than the capacity shown -- that is that the airport will be large enough. For example, there is only about a five percent chance that the base case will provide adequate capacity in the year 2008.

In the year 2008, simulations show there is a 23 percent chance that Strategy A (adding a North-South runway) will be adequate and a more than 85 percent chance for Strategy B. By the year 2018, the choices are more limited. In that year, Strategy A offers little chance of being able to meet expected demand, while Strategy B shows an almost 45 percent probability of meeting demand. Our analysis further indicates that Strategy B represents close to the maximum operating capacity that can be achieved at the current site and within the Ring Road boundary.

NEW AIRPORT

Three questions are central to the consideration of new sites: the choice of planning horizon, capacity, and the general configuration of the facility.

Choice of Planning Horizon

As shown in the Table 10, it is possible to meet peak-load capacity demands through 2008 with capacity enhancements to the current site. The table shows that with the improvements defined by Strategy B (three independent runways), there is an 87 percent probability of meeting demand in 2008. In contrast, if no improvements are made, the current site has only a 1 percent probability of being adequate (Base Case).

As the planning horizon is extended toward the year 2020, the analysis indicates a high probability that the capacity of the current site will be insufficient to meet demand. Even the Strategy B option, the most extensive runway capacity available on the current site, yields only a 40 percent probability of sufficient capacity over the long term.

In choosing a planning horizon for the design of new airport concepts, the expert panel recommended the year 2008 for facilities and structures and the year 2018 for the acquisition of land. This

approach was considered prudent since it avoids the development of facilities in advance of need while at the same time allowing sufficient land to expand as longer term needs materialize. It is the latter that does not appear possible at the existing site.

Choice of Capacity

Given the planning horizon outline above, the prototypical capacity options for a new site was governed by two principles:

- Runways and terminal space need only be designed for the air traffic control anticipated for the year 2008; and,
- Land purchases should account for room to expand to meet demands of 2018.

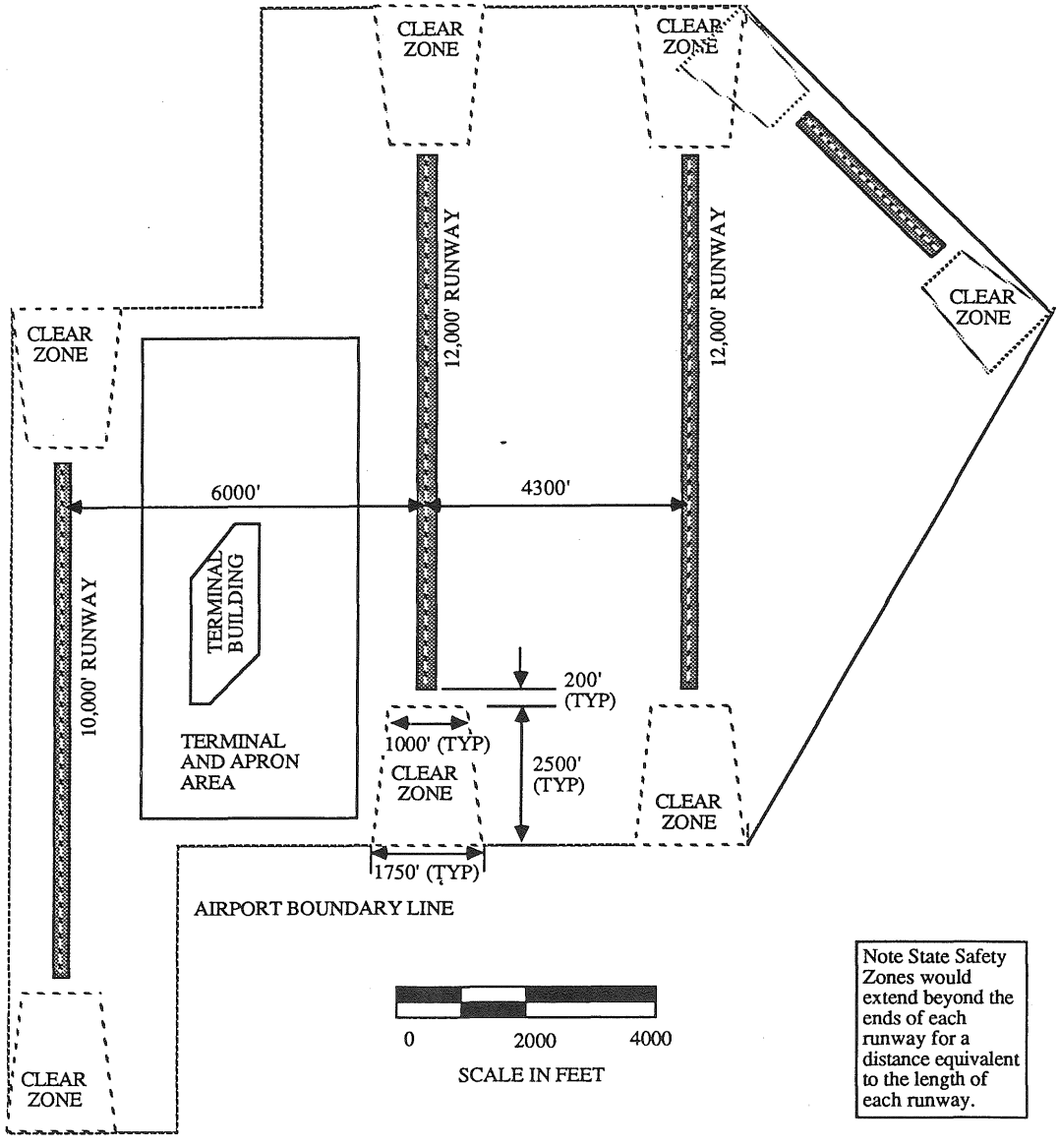
Table 10.
Probability of Adequacy in Meeting
Peak-Load Capacity Requirements (In percent)

OPTION	YEAR		
	1998	2008	2018
Base Case	10	5	1
Strategy A	67	18	9
Strategy B	92	87	40

Panel deliberation lead to the selection of four runway options and a fifth for a remote terminal. The preferred option (number 4) is illustrated in the Figure 10 on the following page:

1) Twin dual runways;
2) Three independent runways;
3) Three runways with crosswind runways;
4) Three independent runways with one crosswind runway; and
5) A remote terminal retained at the existing site connected to any of the above four options by a rail line.

Figure 10. Preferred Runway Option, New Airport



Land Requirements

Although it would be possible to begin construction of a new facility with as little as 3,000 acres, the optimal configuration would consist of 13,000. This would allow continued expansion to accommodate demand beyond the year 2008.

COMBINING OPTIONS INTO STRATEGIES

The physical options described above were combined into six alternative strategies, including estimates of likely timing requirements:

Base Case — Continue MSP with existing runway system and implement current capital improvement including the 4-22 runway extension (the base case program is assumed in all subsequent strategies),

Strategy A — Enhance MSP by building a new North-South Runway, operational in 1997;

Strategy B — Enhance MSP to its maximum potential (within the ringroad highway system) by building a new North-South Runway, operational in 1997 and by building a new Far Parallel Runway, operational in 2008.

Strategy C — Enhance MSP short-term and land bank for a new replacement airport long-term.

Strategy C1 — Enhance MSP by building a North-South Runway, operational in 1997; secure a land bank for a potential new airport, land under control by 1990 or 1991 if possible and by 1996-1997 at latest; and build and open a new airport in 2008 if justified by contingency planning process.

Strategy C2 — Enhance MSP by building a new North-South Runway, operational in 1997; secure a land bank for a potential new airport, land under control by 1990 or 1991 if possible and by 1996-1997 at latest; and build and open a new airport in 2015 if justified by contingency planning process.

Strategy D — Use demand management techniques to alter the schedule of the air carriers and regional commuters to maximize the capacity of MSP;

Strategy E Site and build a new airport, open it by 1999.

Under the base case set of assumptions, demand for service though MSP quickly outstrips the capacity of the system -- even with significant air traffic control improvements included in the calculations. For example, by the year 2008, the Base Case offers only a five percent chance of being adequate to meet expected demand -- that is, a ninety five percent chance of falling short of expected demand. As demonstrated earlier, however, Strategy A, however, would improve this probability to about 20 percent, while Strategy B offers a more than 80 percent assurance of meeting demand in the year 2008.

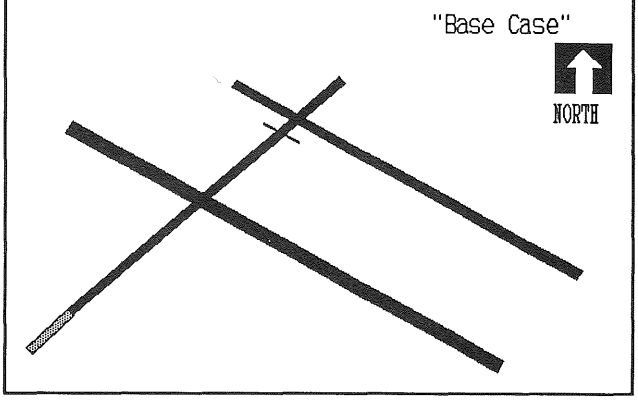
Strategy B probably represents the maximum feasible development of the current site. This option requires taking part of Fort Snelling Park and would mean that the Air Force and Air National Guard operations would have to be moved. Further, if current MinnDOT rules for safety zones at the end of new runways were followed, parts of the South Minneapolis neighborhood would have to be purchased.

DETAIL ON OPTIONS

Runway Options: Base Case

Description. The base case does not, as in the typical analysis, mean do nothing. Instead, it includes the existing runway and taxiway network at MSP, airfield improvements already approved for the period 1988 to 1994, as well as normal maintenance and rehabilitation in the future (Figure 11). All of these planned changes are detailed in the Capital Improvement Plans for the 1988 to 1994 period (See Table 11). Of those projects already identified, the vast majority (92 percent) will be undertaken at MSP International, the remainder being dedicated to reliever airports. In addition, the Base Case includes estimates of potential air traffic control improvements over the forecast period.

Figure 11.



At present, MSP operates three runways, each of which has (or soon will have) instrument landing systems (ILS) on both ends. Two of the three runways, 11L-29R and 11R-29L, are parallel, separated by 3,380 feet. These runways are 8,200 feet and 10,000 feet long, respectively. The third, Runway 4-22, is a 7,256 foot crosswind runway[17] whose operating thresholds also intersect both parallel runways, creating a convergent runway system when it is operated in conjunction with one or both of the parallels.

Current policy calls for maximizing the use of Runway 4-22 (called the preferential runway system or PRS) as a means of shifting some noise impacts to other neighborhoods. Typical operations under PRS include segregating landings and departures on one or the other of the converging runways. This is done either by directing landings on runway 4 and departures on 11L and 11R, or shifting landings to 29L and 29R and departures to 22. At present, 4-22 is used as much as 5 to 6 hours daily, but usually not during peak hours. Because of FAA safety rules concerning

[17] The full physical length of this runway is 1,000 longer, but because of limits imposed by the nearby VA hospital, the current operating threshold has been shifted toward the Southwest. This additional length might be available under special and infrequent circumstances.

convergent runways, it can only be used in conjunction with one of the parallel runways during VFR conditions. Projected traffic growth is likely to force increased reliance on the parallels, at the expense of 4-22.

Table 11
Projected Capital Outlays for MSP Airports
One, Two, and Five-Year Plans
($000s)

Facility	1988	1989	1990-94
MSP International			
- Field and Runways	$ 5,150	$39,950	$34,950
- Self-Liquidating	45,000	16,000	--
- Landside	59,150	8,400	12,350
- Environmental	7,300	--	--
Subtotal, MSP	116,600	64,350	47,300
Reliever Airports	9,875	1,800	6,350
Total, All Facilities	$126,475	$66,150	$53,650

Source: "1990-1994 Capital Improvement Plan," Memorandum to Planning and Physical Development Committee, Finney, Nigel D., October 15, 1987.

Impacts on Capacity. The roughly 3,400 foot distance between the two parallel runways is more than the 700 foot separation required by the FAA for independent operations during VFR (Visual Flight Rules) but less than the 4,300 foot difference now required by the FAA for independent operations during IFR (Instrument Flight Rules). As a result, the IFR capacity at MSP is substantially less than the VFR capacity -- 78 operations per hour under IFR versus 103 per hour under VFR, both assuming a 50-50 mix between arrivals and departures. Actual operating levels could be lower depending on the mix of different size aircraft and specific local circumstances. Indeed, the FAA estimates the IFR capacity for the parallels at about 72 operations per hour in mixed arrivals and departures.[18]

[18] FAA, Airport Capacity Program Office, Airport Capacity Enhancement Plan, 1987, page 3-12.

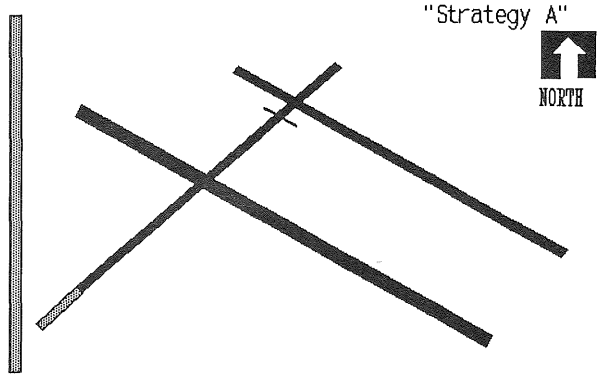
While the use of 4-22 as a preferential system, helps distribute aircraft noise more equitably, airport capacity is reduced by about 40 percent during VFR conditions relative to what can be achieved using the two parallels. Safety concerns because of the converging runways are a major factor behind this reduced capacity. Thus, use is generally limited to non-peak periods except when crosswind operations are required (about five percent of the time). The extension of 4-22 does not increase the airport's overall capacity.

Runway Options: Strategy A

Description. This case includes the extension of Runway 4-22, taxiway improvements, and a new north-south runway on the west side of the airport parallel to Cedar Avenue (Figure 12). This runway, to be operational by 1999, is assumed to be at least 8,000 feet in length with operations limited to the Southern end. In spite of this operational limitation, the runway will have an instrument landing system on each ends (for safety). Construction of this runway would require the acquisition of homes along Cedar Avenue and the potential closure of the golf course. Technically, not all this land would be required for the new runway, but they would be important both as noise buffers and as possible sites for airport-related activities such as cargo facilities.

Effect on Capacity. The new runway would increase both VFR and IFR capacity. These benefits, however, would by restricted by the practical need to use the runway only as an "in-out" runway. This would limit use to south departures and arrivals from the south. Departures to the north or arrivals from the north create converging flight paths with aircraft operations on the parallel runways.

Figure 12.



In addition, wind conditions would limit the ability to use the north-south runway in conjunction with the parallels to 75 to 85 percent of the time. Even with this limit, VFR capacity would be increased by about 32 operations an hour to 135. Without additional changes in air traffic control procedures, the gain in IFR is more limited because of aircraft spacing requirements associated with the potential for missed approaches involving the parallel runways.

Uncertainties. The provision of a new north-south runway provides an opportunity to distribute aircraft noise to other

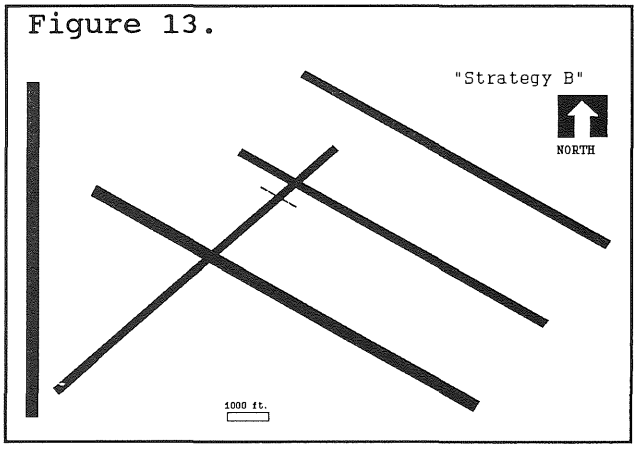
communities, thus expanding on the intent of the existing preferential runway system. This would, of course, increase noise exposure to residents to who had not previously been affected by aircraft overflights.

Implementation - Timing. Construction of a north-south runway present environmental impact requirements that must precede any construction. In addition, the required land use changes and noise impacts are likely to create public debate over this option, limiting the ability to implement it quickly.

Runway Options: Strategy B

Description. Strategy B (Figure 13) includes a Runway 4-22 extension, taxiway improvements, a new north-south runway, and a parallel 8,000-foot runway (with instrument landing systems on each end) 2,000 feet north of existing Runway 11L-29R (renamed 11C-29C). (To achieve the IFR gains from independent parallel, it must be at least 920 feet from 11L-29R.

Figure 13.



This "far" parallel requires use of land in Fort Snelling State Park. While the most important historical buildings could be saved, important financial and other considerations must be resolved. Clearly, this effort would be justified only if the public gains from reduced delays and higher traffic due to improved capacity are quite large. In addition, the government operations north of existing Runway 11L-29R would need to be consolidated and/or relocated elsewhere at MSP or some other site or some combination.

Effect on Capacity. Under this scenario, independent IFR operations would be possible even if current FAA rules, which require a 4,300 foot separation, are not relaxed since the two outboard runways would have a lateral separation of about 5,380 feet. Given that the possible timing for these rule changes is speculative, this runway provides good insurance and represents one of the most assured ways for a significant improvement to IFR capacity. Further, during VFR (and to a limited extent during IFR), Center Runway 11-29 could be used to augment arrivals or departures.

Construction of a far parallel runway also offers an important advantage by permitting the development of parallel taxiways to the

north of the main terminal. This should reduce overall runway occupancy times, thus making it feasible to handle 182 operations per hour. Under IFR conditions, the outboard parallels would be operated independently and each could accommodate 60 operations per hour.

This option also provides an additional capacity benefit because it eliminates any intersection between Runways 4-22 and the new 11L-29R. This would be one of the few ways to improve the IFR capacity of the PRS without depending on new rules for the use of converging runways. Because the PRS must be used during off-peak hours, this gain in capacity is not a key factor in meeting peak-period demand.

Implementation/Timing. Because of the extensive land that must be required, early implementation of this option is clearly unlikely. Further, its choice as a public option depends on its ability to significantly reduce delays and stimulate additional economic activity. As a result, the ideal time to implement this option might be as capacity problems begin to impose significant negative economic impacts.

V. TRANSPORTATION COSTS AND BENEFITS

A family of economic tools grouped under the term of benefit cost analyses are well-suited to evaluating the relative attractiveness of alternative investments. These tools require a comparison of the direct costs and benefits attributed to each option. Because they involve calculations of benefits and costs that can be measured in terms of dollars, they are usually limited to those impacts that can quantified in a consistent manner. For the MSP Adequacy Study, this restricts their use to analyzing the transportation costs and benefits. Other important consideration -- noise effects, impacts on regional economic growth, and financial considerations -- must be weighed as well. These effects are analyzed in the next chapter. Any conclusions, about the relative attractiveness of different strategies, however, depends on considering the results of both chapters.

COSTS OF DEVELOPMENT

The direct costs of each of the strategies includes the capital costs to construct the runways, terminals, and ground access needed as well as the costs to purchase the land required for siting these facilities (See Table 12). Each option involves higher operating costs as well.

While not discussed in detail, there is also the potential need to add additional safety zones at the end of the existing runways. MSP is currently "grandfathered" from this requirement. All costs and benefits have been converted into constant 1988 dollars. Other non-economic costs -- most importantly noise impacts -- are discussed on Chapter VI.

BENEFITS OF DEVELOPMENT

The transportation benefits from adding capacity all derive from reduced delays. These benefits are of two types:

- savings to airlines from reduced fuel use and lower aircraft and crew costs; and
- savings to travelers from reduced waiting for delayed aircraft.

In the analysis presented below, estimates are made using total transportation benefits and then using only airline benefits. Focusing on aircraft benefits alone is clearly the more conservative approach and is done in part because of uncertainty in assigning a value to travel time savings.

Estimates of future costs and benefits clearly involve a series of estimates about what the level of future aviation service and assumptions about key variables (the value of traveler's time, for example. These key assumptions are summarized in the box below.

Figure 14. Key Assumptions of Cost-Benefit Analysis

- Discount rate is 10 percent in real terms (8 1/4 percent cost of capital plus an allowance for risk)
- Airline operating costs in 1988 were $1,125 per hour.
- Real oil price will decline by 2 percent per annum through 1989; by 1 percent per annum through 1991; and will increase by 1 percent per annum thereafter.
- Real airline labor costs will remain constant over the period 1988 - 2020.
- Passenger time savings are valued at $35.00 per hour.
- The probability range for the dollar value of time is skewed to one-third the expected value ($11.66 per hour) to reflect in-flight productivity.

Estimates of delay under each strategy use a detailed airport simulation model -- called ADSIM -- that was developed by the FAA for use in their airport capacity studies. This model "tracks" each aircraft that uses MSP from the time it enters the glide path until it reaches a gate and can unload. This detailed simulation provides estimates of total aircraft hours of travel delay under present and future conditions. Simulations were performed for the base case and for each strategy for 1998, 2008 and 2018; for IFR and VFR conditions and under several different schedules. Figure 15 shows the estimated total delay for each strategy. A key conclusion is that without significant additions to capacity (as shown by the successive implementation of Strategies A, B and C) the travel delays at MSP quickly escalate to intolerable levels.

Table 12.
Summary of Potential Development Costs
(Millions of 1988 Dollars)

(1) Direct Development Costs

COST CATEGORY	STRATEGY A	STRATEGY B	STRATEGY C1	STRATEGY C2
PROPERTY ACQUISITION & PREP.:				
NATIONAL GUARD	N/A	205.5	(1)	(1)
AIR FORCE	N/A	142.5	(1)	(1)
WEST-SIDE RESIDENTIAL	40.0	40.0	40.0	40.0
OTHER	N/A	37.5	(1)	(1)
TOTAL	40.0	425.5	460.6(2)	460.6(2)
ADD'L ZONES (NEW RUNWAYS)				
CLEAR ZONE (6)	27.5	102.5	27.5	27.5
SAFETY ZONE A	169.1	255.5	169.1(3)	169.1(3)
SAFETY ZONE B	88.8	171.9	88.8(3)	88.8(3)
HOV LANES	0.0	27.7	N/A	N/A
AIRFIELD DEVELOPMENT	34.4	63.4	260.7(4)	260.7(4)
TERMINAL FACILITIES	192.0	192.0	737.4(5)	737.4(5)
SUBTOTAL	551.8	1,238.5	1,784.1	1,784.1

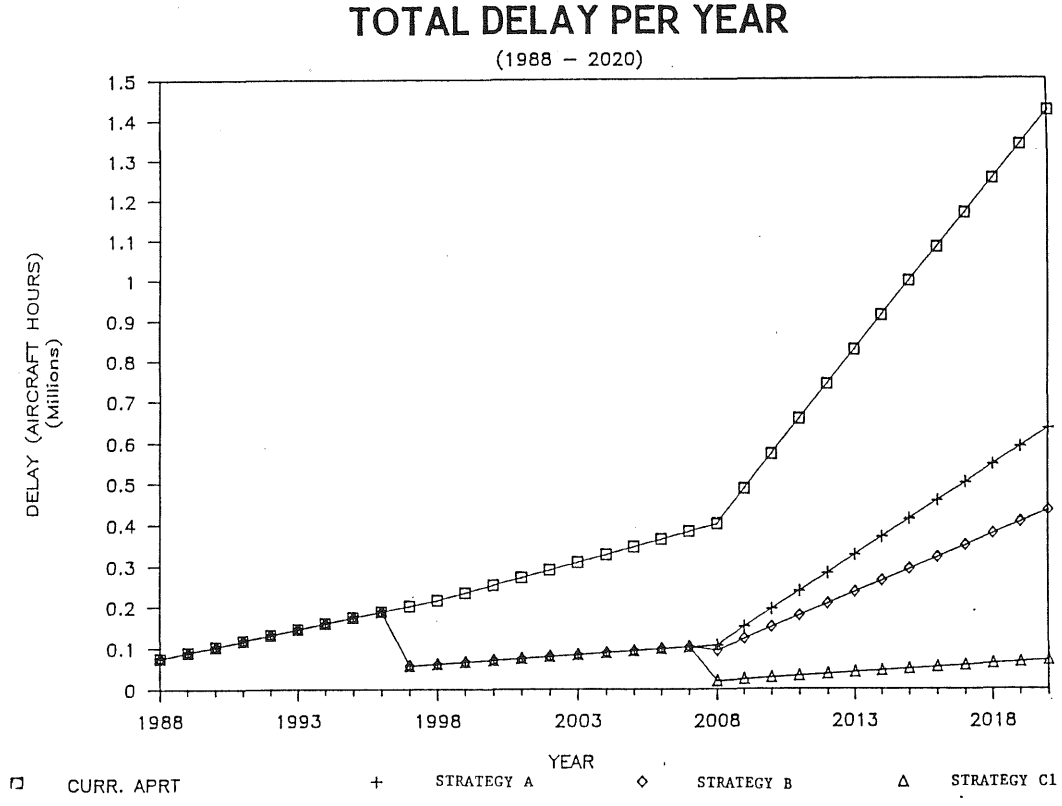
(2) INDIRECT AND POTENTIAL DEVELOPMENT COSTS

COST CATEGORY				
ADD'L ZONES (EXISTING RUNWAYS)				
CLEAR ZONE (FAA)	0.0	0.0	0.0	0.0
SAFETY ZONE A (MINNDOT)	286.6	286.6	286.6	286.6
SAFETY ZONE B (MINNDOT)	539.1	539.1	539.1	539.1
SUBTOTAL	825.7	825.7	825.7	825.7
TOTAL	1,377.5	2,064.2	2,609.8	2,609.8

NOTES:

1) Anticipated Costs are not estimated.
2) Includes new airport property acquisition ($48.9) and site preparation ($371.7),and Strategy A ($40).
3) For construction of new airport safety zones and clear zones included under land construction.
4) For new airport, general aviation ($3.5) and support facilities ($92.5), and Strategy A ($34.4).
5) For new airport, ground transportation ($194.4) and federal facilities ($31.0),and Strategy A ($34.4).
6) Final Costs depend on exact orientation of runway.

Figure 15. Total Delay Per Year



EVALUATION MEASURES

The economic evaluation measures used in this study can be divided into two groups: those concerned with the overall worth of the investment, and those that focus on the proper timing of the investment. Each set of measures tells a different story. (the following table summarizes how each is calculated).

Figure 16. Key Measures of Cost-Benefit

MEASURES OF WORTH	DEFINITION	INTERPRETATION
Net Present Value (NPV)	Present-day value of benefits minus present day value of costs.	NPV greater than zero means project is worthwhile. Projects are ranked according to NPV.
Rate of Return	The discount rate at which NVP = 0	Rate of return should exceed pre-set hurdle rate (10%) to qualify for consideration.
Benefit-Cost Ratio	Present value of benefits divided by present value of costs.	A ratio of greater than one means project is worthwhile.
MEASURES OF TIMING		
First-Year Benefit	Benefits in the first year after construction divided by construction costs (including interest paid during construction period), expressed as a percent.	A ratio equal to or in excess of the hurdle rate (10%) means project is well timed. A ratio below hurdle rate means project is premature.
Pay-Back Period	Number of years until capital re-couped through the flow of benefis.	A short pay-back period means less risk.

In terms of ranking the different strategies, net present value (the discounted value of benefits minus the discounted value of total costs) is the best single measure. Rate of return measures and benefit cost ratios are useful as setting minimum hurdles that must be exceeded to make projects worthwhile -- typically, a rate for return in excess of ten percent year and a benefit-cost ratio of one or greater are required to nominate a project for consideration. The rate of return measure also offers a comparison with the type of criteria often examined in private business.

The first year benefit is a good measure of project timing. If the benefits in the first year of operation are more than ten percent (the hurdle rate) of the total construction costs, than the project can "pay for itself" from year one and is well-timed. Moreover, if the first year benefit rate is substantially more than the hurdle rate, this may indicate that the project may be overdue.

RESULTS

The results of the cost-benefit analysis are summarized in Table 13 and Figures 17 and 18. The table compares the major development options in terms of net present value, rate of return and first-year benefits. Separate calculations are shown for total benefits and for just aircraft benefits alone. This second set of calculations is more conservative.

In terms of net present value, all of the options perform well, with Strategy C1 (a North South Runway followed by a new airport in 2008) showing the highest value when total benefits are used. All strategies (except E) show rates of return in the mid-40s -- another indication or worthwhile investments,a nd the return for E is well above most minimum rates of return..

Based on total benefits, the ratio of first year benefits is well in excess of ten percent for each option, indicating that these options could be implemented even sooner. Indeed, this test indicates that the MSP region is already foregoing large **net** benefits in every year that capacity is not expanded. For the community as a whole, the first-year benefit ratio exceeds the hurdle rate of ten percent for each strategy under consideration and the pay-back period is less than four years in every case. In the case of airline returns, the first-year benefit for strategies B and C1 lie below 10 percent; however, a one year delay in the start of these projects is all that is required to bring the ratio above the ten percent level.

What are the risks of failure? Figures 17 and 18 show the probability of achieving different levels of net present values. In all cases, there is virtually no chance that the net present value of these investments (whether based on total benefits or just airline benefits) will fall to zero. Both charts indicate the

Table 13. Summary of Cost/Benefit Analysis of Airport Development Strategies

ALL TRANSPORTATION BENEFITS			
Strategy	Net Present Value ($ Millions)	Rate of Return (Percent)	1st Year Benefit (Percent)
A	3,229	47	75.0
B	3,332	46	14.3
C1	3,705	44	19.0[a]
C2	3,527	47	80.2[a]
E	3,283	24	42.8

AIRCRAFT BENEFITS			
Strategy	Net Present Value ($ Millions)	Rate of Return (Percent)	1st Year Benefit (Percent)
A	956	26	26.0
B	861	23	4.9
C1	811	21	4.8[a]
C2	931	25	62.9[a]
E	335	12	15.2

[a] Incremental return for new airports only.

Figure 17. All Benefits, Direct Costs

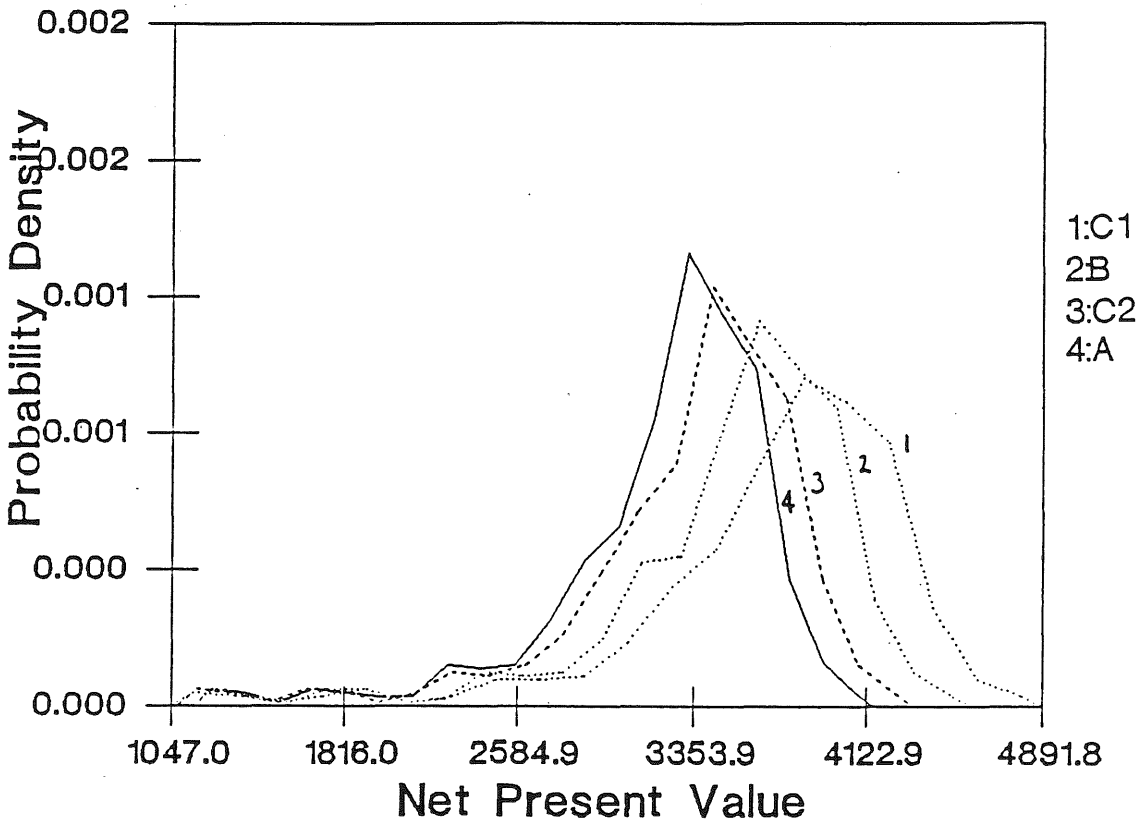
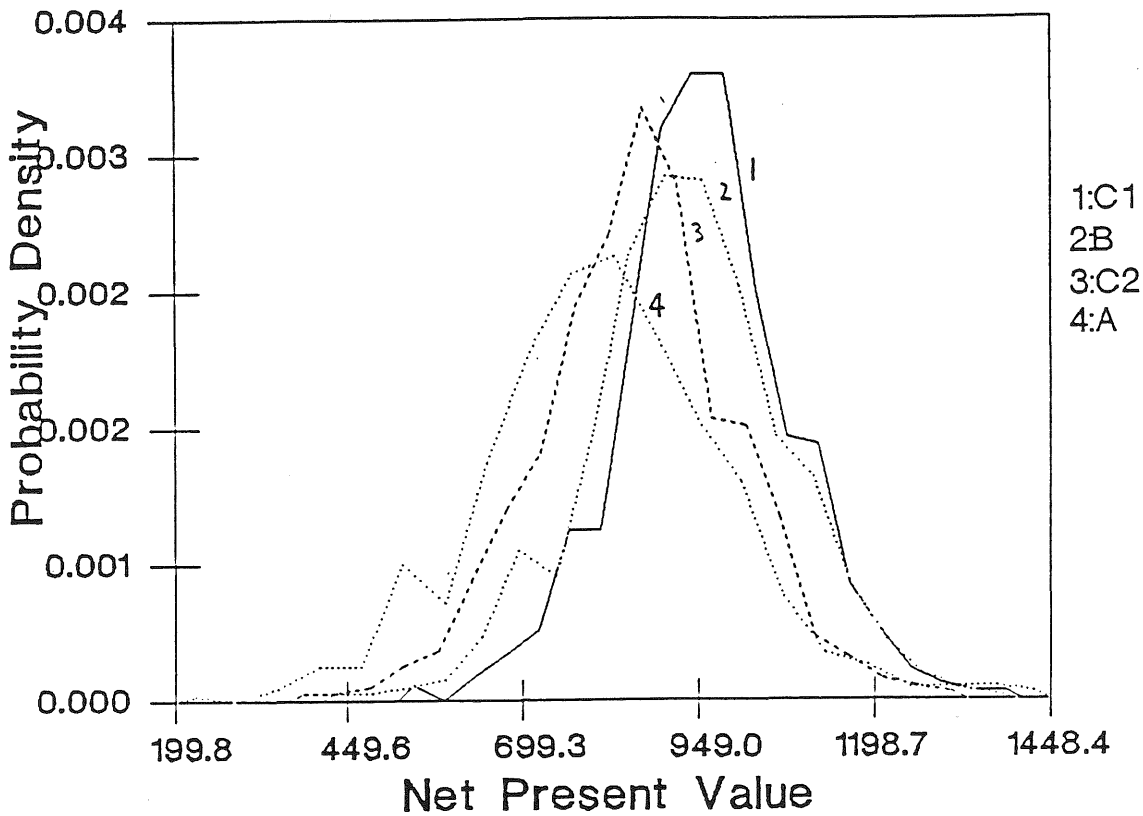


Figure 18. Aircraft Benefits, Direct Costs



greatest assurance with Strategy A, adding just a North-South runway. This is not surprising, since this is the least cost investment option considered and the fastest one to generate benefits.

An important implication of Strategy C1 is the closure of a new north-south runway in or around the year 2008 as a new MSP is opened. Since pavement structures last a great deal longer than that, such a policy means abandonment of a useful facility prior to the end of its useful life. Whether such a policy is sensible depends upon whether the benefits that accrue up until closure are sufficient to cover the construction costs, including the opportunity cost of the capital foregone.

The statistics reported above address this question in terms of the community at large and the airlines in particular. If only direct costs are considered, "early" closure of the north-south runway would still result in net benefits of $1.7 billion overall and $372 million to the airline operators. This is because the pay-back period for the new runway is only 1.2 years for the community at large and 3.5 years for the airlines. Thus, as long as the runway is commissioned during the 1990's, the pay-off will be positive even if it is closed before 2005. Since the project is actually overdue from the stand-point of benefits over costs (ie the community and the airlines are already foregoing net benefits for every year of delay) the sooner the project begins the better.

VI. NON-TRANSPORTATION AIRPORT IMPACTS

The previous chapter focussed on those impacts of additional airport capacity that are easier to convert to dollars -- the costs to build and operate and the benefits from reduced aircraft costs and shorter delays. Regional investments of the scale considered in this study must consider other factors as well. This chapter reviews the likely noise impacts of each strategy, the regional economic development implications of each and the ability to finance required capital costs.

NOISE IMPACTS

Analyzing Aircraft Noise

Noise affects people in a number of different -- usually detrimental -- ways. Exposure to a single event, such as a low flying aircraft, is something all of us have experienced at one time or another. Repetitive occurrences over the course of a day is something fewer people experience directly but is obviously a potential source of irritation.

Many methodologies have been developed to measure aircraft noise, the most common being the Day-Night Average Sound Level (Ldn). Ldn combines the single-event sound exposure level and the number of occurrences of those events and represents the total noise over a 24-hour period (with a 10 decibel penalty for noise between 10 p.m. and 7 a.m. Expressed on maps in the form of contour lines (lines linking geographic areas of equal Ldn exposure), Ldn is now the standard used by the Federal Aviation Administration and virtually all major airports to depict the exposure to noise in different parts of an airport's hinterland.

While the mathematics of the Ldn formula are complicated[19], its fundamental characteristics are easily understood. Ldn can change in value for three reasons, a change in the noise intensity of single events, the number of events or both. As an example of the effect of event-intensity alone on Ldn, consider the following situations. Suppose there are two cases with 100 events each, but having sound exposure levels of 80 decibels and 90 decibels respectively. From the formula for Ldn, case number one would have an Ldn level of 50.6 decibels and case number two 60.6 decibels. Thus, the Ldn changes by 10 decibels because of the 10 decibel change in the single-event intensity.

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[19] For a good outline of Ldn and other measures of aircraft noise, see **Aircraft Noise Primer,** The Parry Co., October 1979 (Available from the Metropolitan Council of the Twin Cities).

However, Ldn also depends upon the number of events. This means that a change in the number of flights overhead (operations) will also shift Ldn as shown in Table 14:

Table 14. Relationship of Ldn to Number of Events

NUMBER OF EVENTS	CHANGE IN Ldn
10	10
100	20
1,000	30
10,000	40

From the table it is clear that in order to change Ldn by 10 decibels, the frequency of operations change by a factor ten (from 100 to 1,000, for example). For this reason, an increase in the number of flights can be balanced by a reduction in aircraft engine noise resulting in the same reading on the Ldn scale.

The Affect of Noise on People

Noise can interfere with human activity and good health (both physical and mental). Although the particular effects of noise vary sharply from individual to individual, for planning purposes it is possible to identify general impacts.

It has been known for many years, for example, that the percent of a community highly annoyed by noise is strongly linked to the Ldn level. At Ldn 50, for example, surveys indicate that only about 15 percent of the affected community is highly annoyed; as Ldn rises, however, the fraction who are highly annoyed increases as well, so that at Ldn 65, about 25 percent are highly annoyed and at Ldn 75 the percentage rises to some 60 percent.[20]

Annoyance occurs for many reasons, including sleep disturbance, interference with entertainment activities, and even fear. Studies by the U.S. Environmental Protection Agency show a strong relationship between Ldn level and speech interference (an increase in Ldn from 65 to 75 may increase speech interference by 90 percent).

While difficult to measure with precision, noise impacts may be severe enough to depress real estate values and to encourage people to move to other neighborhoods.

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[20] Figures based on survey reported in The Parry Company, ibid.

Problems with Ldn

Although noise-related stress and the Ldn level are closely correlated, the Ldn metric alone is not sufficient to explain how different aspects of noise might affect people's degree of stress and annoyance. As explained above, a very large increase in the volume of flights over an area is needed in order to change the Ldn level even marginally. Indeed, the Ldn level will not necessarily increase at all, even with a sharp increase in flights, if the noise-intensity of each overflight is reduced at the same time. But is it reasonable to assume that an increase in the number of arriving or departing aircraft over an area by, say, 100 flights a day, will have no impact on people's level of annoyance simply because the noise volume of each flight is reduced somewhat through the introduction of quieter engines?

Some would answer that an increase in the number of flights would create additional stress and annoyance even if aircraft were quieter than before and that a "no-change" in the Ldn level may provide a misleading guide for the purposes of assessing the implications of alternative policies. In effect, what the public labels as an aircraft "noise" problem may also reflect other problems due to nearby aircraft, including vibration and fear.

A Statistical Approach

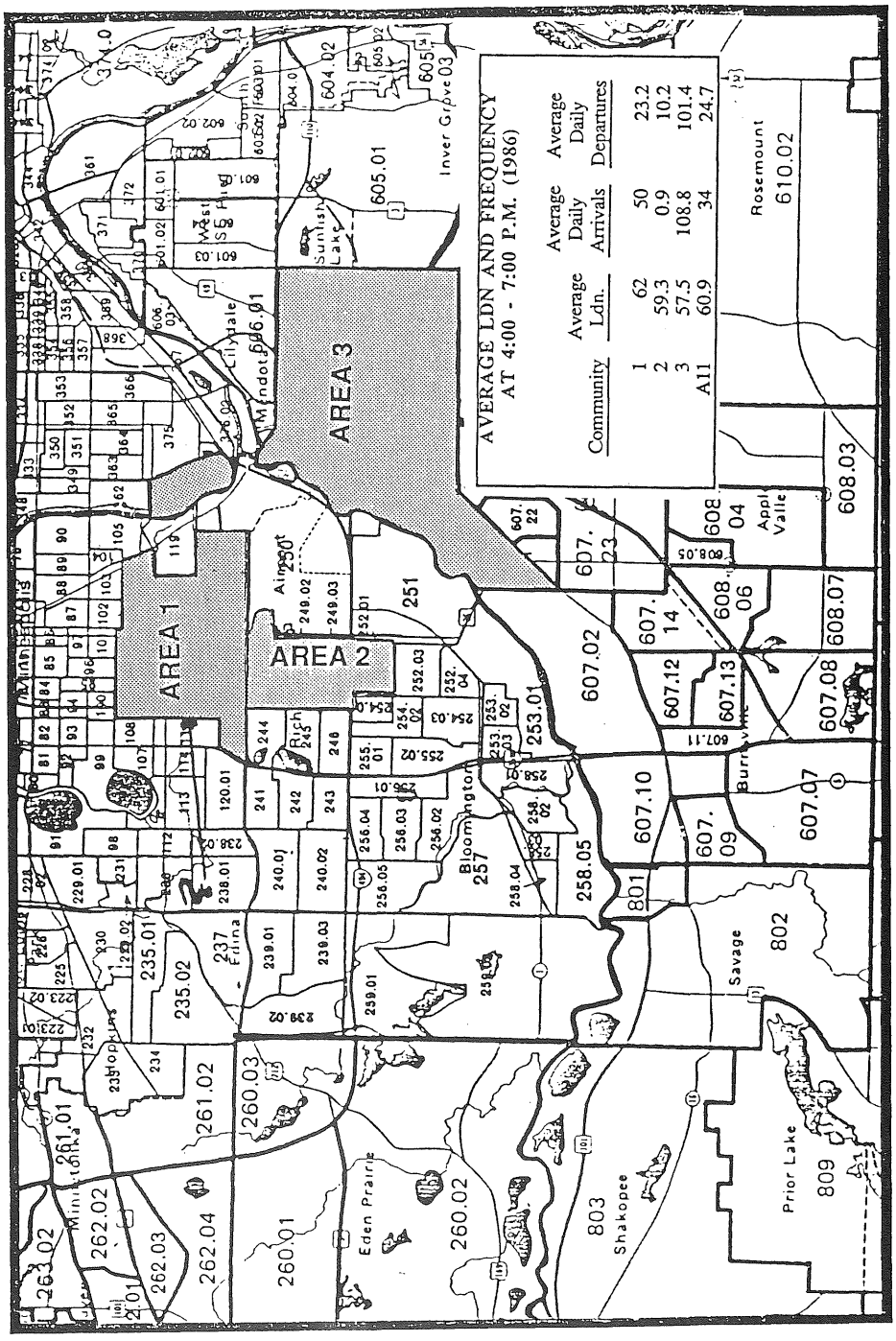
The task of understanding the separate influence of Ldn and the frequency of overflights on noise-related stress requires the application of statistics. Using a 1986 survey of noise-related annoyance among 1,025 MSP residents[3], the study team used multiple linear regression analysis to quantify the independent effects of Ldn and frequency on people's reactions to noise at different times of day and during different seasons of the year. The survey (commissioned by MAC) asked respondents to rate their degree of annoyance on a scale of 1 to 5, with 1 denoting no annoyance and 5 a high degree of annoyance. We have termed this scale the Community Noise-Related Stress Index (CNSI) for the MSP region.

The analysis regressed the CNSI as the dependent variable against the estimated Ldn level and the number of overflights associated with the census tract to each survey respondent. Separate regressions were estimated for three broad geographic areas (Figure 19) within the region in order to reduce statistical variability due to the very different orientations of these sub-regions in relation to the airport and the corresponding differences in the volume of overflights. Separate regressions

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[3] Citizen Attitudes About Noise from the Minneapolis-St. Paul International Airport, prepared by Paul Riedesel and Julie Frank, Mid-Continent Research.

Figure 19. Areas Used for Regression



were also estimated for five different times of day and for each season. In all, 27 separate regressions were estimated.

To compare the relative influence of Ldn and flight frequency on the CNSI, the regression coefficients were translated into "elasticities." An elasticity is simply the percentage change in the CNSI that corresponds to a one percent change in either Ldn or flight frequency. Thus, the larger the Ldn elasticity, the greater the influence of Ldn on noise-related stress, and likewise for flight frequency. The elasticity measure provides a consistent basis for comparing the relative influence of Ldn and flight frequency on noise-related stress.

The results of the statistical analysis are reported in a set of 18 tables (available from the Metropolitan Council). The tables are reported in pairs; the first table of each pair reports the detailed statistical results for a period of day or season while the second table reports the associated elasticities. Tables 15 and 16 depict these data for the 4:00 p.m. - 7:00 p.m. period.

Results

The results indicate that Ldn and flight frequency each have an independent and statistically significant effect on noise-related stress, although the impacts vary greatly depending upon time of day and season. While goodness of fit tests (R-squares) appear relatively low compared to values typically observed in time series regression analysis, this is to be expected for large ungrouped cross-sectional analysis like that presented here;[4] moreover, related F-tests indicate a high degree of statistical significance in the explained variance. Multicolinearity between Ldn and the frequency of arriving and departing aircraft was lower than 0.4 in each case, indicating a low correlation between these two independent variables and thus an absence of statistical bias in the estimated regression coefficient.

The strongest impacts occur between 4:00 p.m. to 7:00 p.m and during the summer. The statistical analysis also indicates that in communities that already experience a comparatively high level of overflights, the elasticity of noise-related stress with respect to further increases in operations exceeds the elasticity with respect to increased Ldn. For example, a one percent increase in overflights in Community 3 leads to a 5.8 percent increase in noise-related stress; a one percent increase in Ldn level, on the other hand, leads to a 1.77 percent increase in stress. Community 3 has the highest average level of overflights of the three

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[4] See, I Friend and C. Lieberman, **Short-Run Asset Effects on Household Saving And Consumption: The Cross-Section Evidence,** The American Economic Review, September 1975, page 628.

TABLE 15: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE 4:00P.M. - 7:00P.M. TIME PERIOD

	Dependent Variables		
Independent Variable	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-1.85 (3.26)	1.25 (1.42)	-26.19 (3.33)
Ldn	0.08 (8.27)	0.03 (2.11)	0.10 (2.27)
Departures	0.06 (1.78)	-3.40 (1.92)	1.74 (4.90)
Arrivals	0.15 (3.68)	0.52 (2.60)	0.74 (2.32)
Statistical Measures			
R^2	0.19	0.04	0.25
F Value	48.96	4.57	10.54

Notes: a) Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

b) T-Ratios are given in parenthesis

TABLE 16: ESTIMATED MEAN ELASTICITIES FOR THE 4:00P.M. - 7:00P.M. TIME PERIOD

	Community 1	Community 2	Community 3
Ldn Elasticity	1.35	0.58	1.77
Departrs Elasticity	0.07	0.12	1.81
Arrivals Elasticity	0.08	-0.08	5.81

Notes: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.). All figures shown are statistically significant at the 95% level or greater.

sub-regions considered. A plausible reason for this pattern is that an increase in flights when the existing frequency is already high means a great deal more additional activity overhead than would the same percentage increase when flights are quite low to begin with.

CNSI Contour Analysis

The results reported above indicate that quieter aircraft engines will not necessarily off-set the impact of higher traffic levels on the amount of noise-related stress and annoyance in the community. To understand how the CNSI levels might change under the various strategies considered in this report, contour maps were developed that contain areas of approximately equal CNSI levels. Maps were first developed for the current year. For future years, the regression models were used to forecast CNSI levels in each census tract based upon the traffic forecasts presented earlier in the report and Ldn forecasts that incorporated the steady introduction of quieter "stage three" aircraft. Flight tracks were projected in relation to each runway configuration under consideration so that contours could be developed for each strategy under review.

The results indicate that the increased frequency of overflights will more than off-set the impact of quieter engines causing noise-related stress in the community to increase sharply as traffic grows (see Figures 20 and 21). By the year 2008, this means that virtually all neighborhoods covered in the 1986 survey will rate noise-related annoyance at the highest possible level and that lower but significant levels of stress will spill into the area beyond. The addition of new runways at the existing site shifts the noise-related stress among various neighborhoods but does not diminish the overall increase in annoyance.

Policy Implications

If the Metropolitan Region wishes to accommodate growth in aviation traffic at the existing airport site, there seems little doubt that a sharp increase in noise-related annoyance will follow. Quieter engines will help, but not enough to offset the effect of traffic growth on people's perception of the noise problem.

If, on the other hand, a new airport were to be constructed in a non-or-low populated area with a large enough land area to contain most noise on site, growth could be accommodated with only limited noise costs. Whether the benefits of reduced or eliminated noise costs exceed the additional costs of developing a new airport must be considered as part of the overall cost-benefit equation. However, since the transportation benefits of a new airport have already been shown to exceed its costs, the additional benefits of greatly reduced noise exposure only reinforces the case for developing a new airport.

Figure 20. Contour Map of Community Noise Related Stress Index (4:00 p.m. - 7:00 p.m.) Under Strategy A (2008)

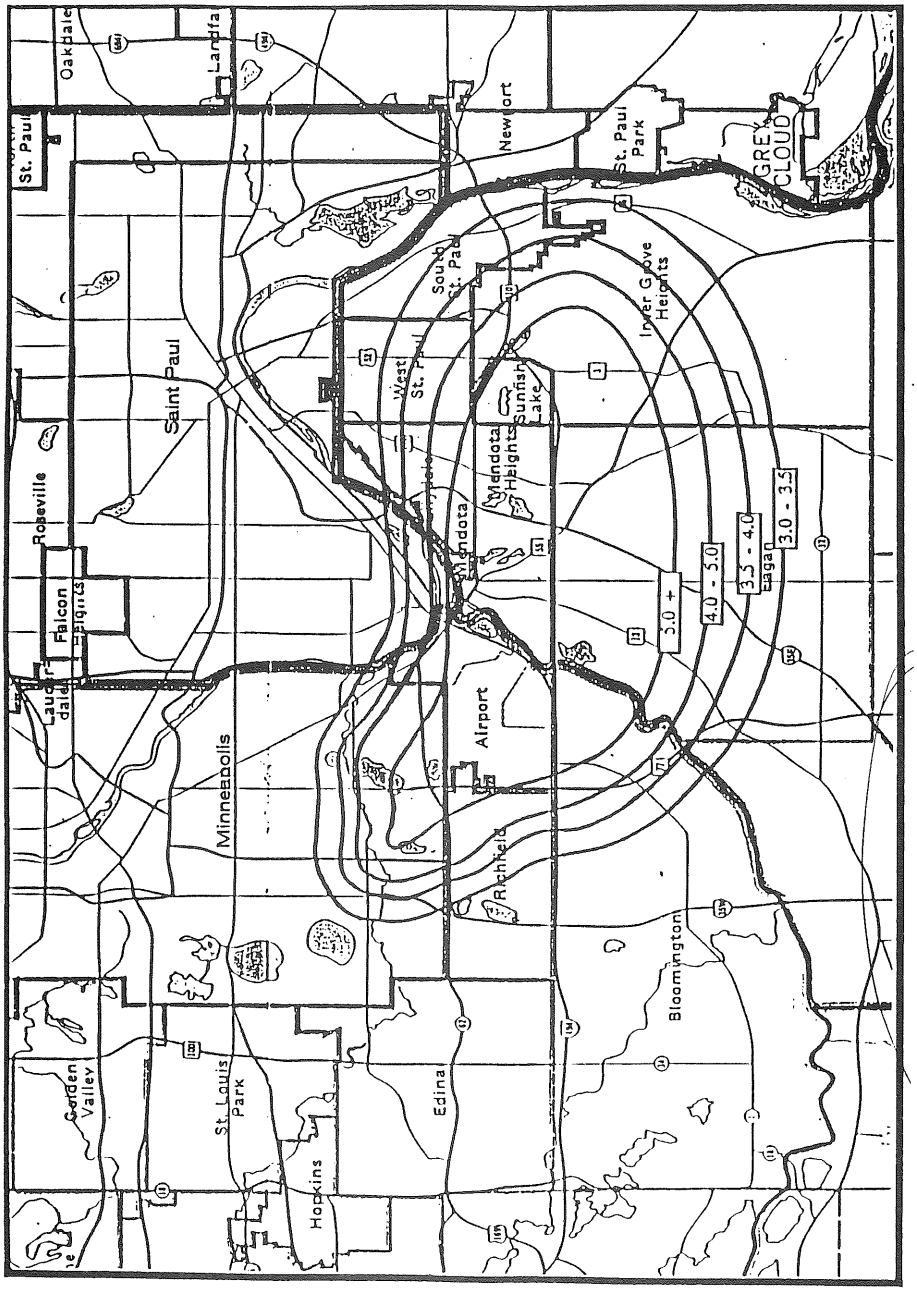
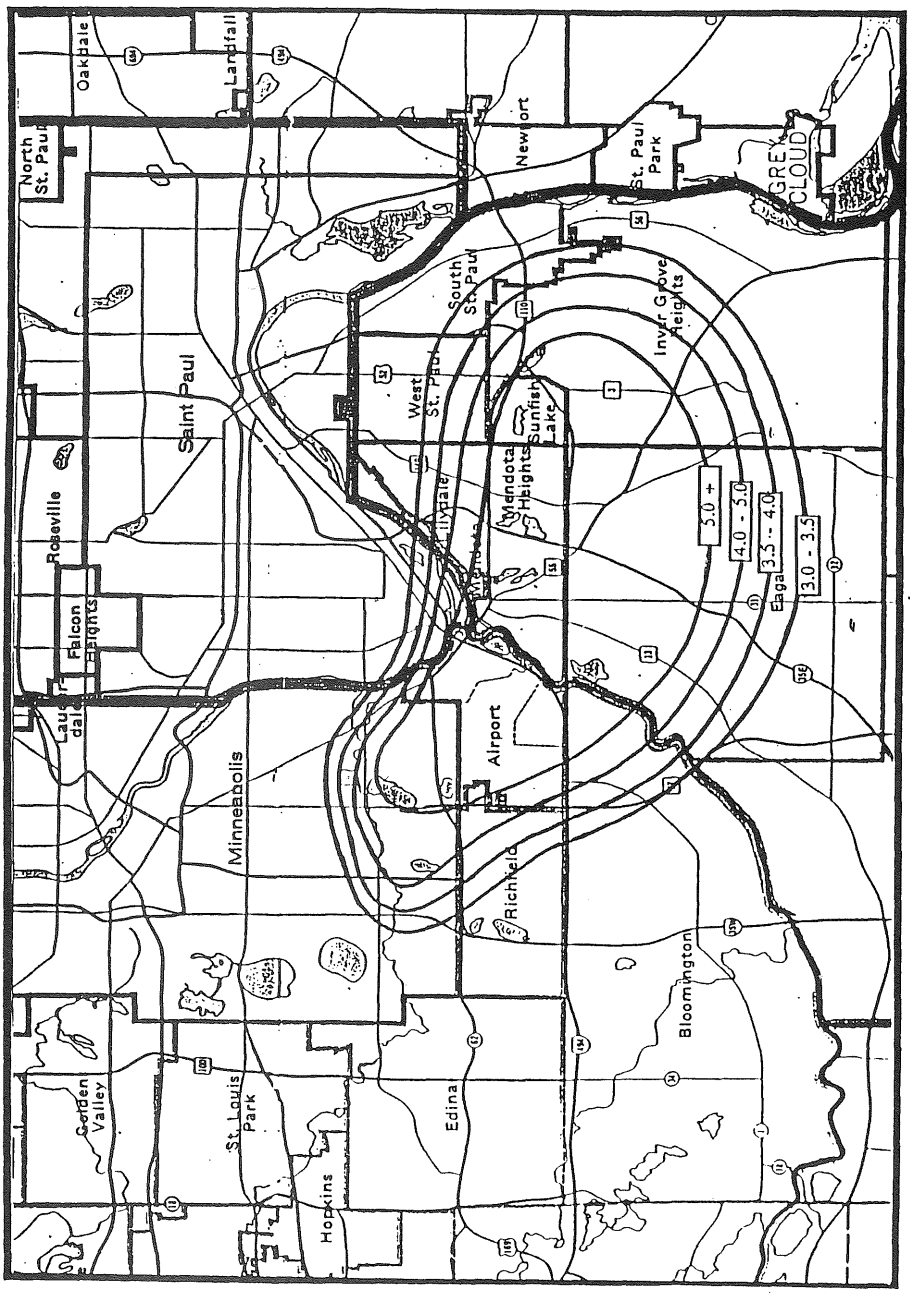


Figure 21. Contour Map of Community Noise Related Stress Index (4:00 p.m. - 7:00 p.m.) Under Strategy B (2008)



ECONOMIC IMPACTS

Airports play a key role in attracting new business or encouraging existing businesses to expand. This motivation to encourage economic growth played a large part in the decision to build a new Dallas Airport in the early 1970s and the current move to build a new airport in Denver.

Airport economic impacts are of two types -- direct impacts due to handling and servicing aircraft, their passengers and cargo, and the indirect effects as these streams of activity move through the economy. The summary numbers presented in this section combine both types of impacts. A third effect is important but impossible to measure. This relates to the general perception of how open or receptive a community is to encouraging economic development. As with many other public services (education and highways are examples), a community's ability to offer better service than other, competing regions plays a role in its attractiveness to business and residents alike.

The potential regional economic gains that could be achieved from increasing capacity in line with expected demand are quite large. MSP currently contributes more than $2 billion a year to the region's economy.[5] Based on the airport economic model developed earlier this year for the Minneapolis Chamber of Commerce, the baseline forecast of enplanements and aircraft operations means that this impact could increase to about $3.5 billion over the next two decades.

However, if a significant increase in capacity is not achieved, the severe capacity constraints found under the Base Case imply annual losses of $1 billion or more by the year 2008 -- a thirty percent loss (see Figure 22). This estimate assumes that the overall level of activity though MSP will drop in line with the expected higher delays -- that is, rather than impose huge delays on air travelers, by early in the next century, the airlines will have shifted activity to other airports. Estimating the precise magnitude of such a loss is clearly somewhat speculative.

In addition to the value of economic activity, an airport also brings new jobs. One that is capacity constrained, on the other hand, will limit growth below its potential. As demonstrated in the Figure 23, for example, the change in service implied by increased delays can only result in lost opportunities for growth. Here, the greater delays and diverted flights under the Base Case results in thousands fewer jobs for the region.

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[5] See Martin O'Connell Associates, The Economic Impact of The Minneapolis/St. Paul Airport, prepared for the Greater Minneapolis Chamber of Commerce, January 1988.

Figure 22. Range of Potential Economic Impacts at MSP International

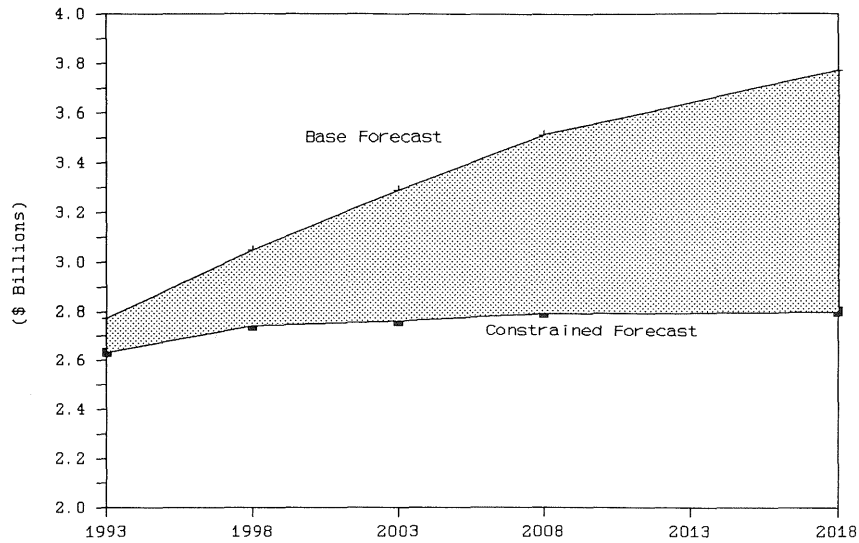
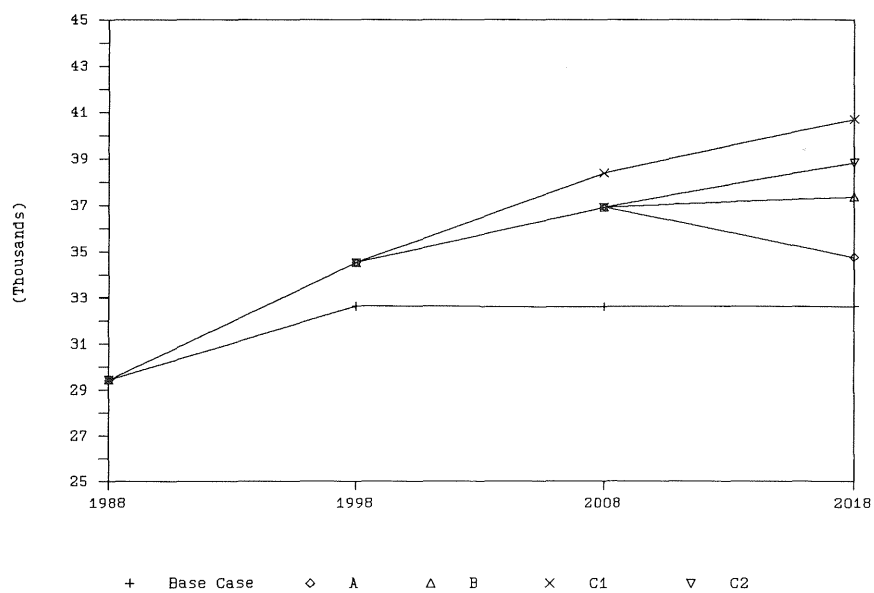


Figure 23. Implied Changes in Employment Due to Delays



These estimates are based on changes that either restrict capacity to well below current demand or that allow capacity to grow roughly in line with expected demand. Yet even the high end of the range of potential impacts may understate the potential growth additional capacity since by offering a higher level of service, an airport with "excess" capacity can act as a "growth pole." The job estimate figure reflects this potential by showing slightly higher estimates for those options that involve building a new airport -- Strategies C1, C2, and E.

In terms of economic impact, Strategy C1 appears to stand out because of its strong commitment to increasing capacity at a fast but practical pace. This is one way to assure strong access to national and world markets.

The economic impact of different airport developments depends on the baseline used. For example, the analysis presented here focuses on comparisons with what would happen under the Base Case. This Base Case assumption itself is a moving target however. Thus, even without significant capacity improvements at MSP, airport activity would still increase regional income and add new jobs. However, while the regional economy would not shrink if significant capacity additions were not made, future growth would be much more limited (see the lower line in attached figures).

The distribution of airport-related economic impacts across the region is not uniform. No detailed data are available for MSP, but a disproportionate share of direct aviation benefits are likely to occur in the immediate surrounding area (Bloomington for example) while the indirect effects are likely to be more widely spread depending on where airport employees live and on the location of business in general. This also means that any additional economic gains from increased airport capacity will also be unevenly spread. The gains from adding capacity at the current site will benefit those communities that receive most benefits today.

Conversely, construction of a new airport will redistribute these benefits. The degree to which this happens depends on the location selected for a new airport, the amount of advance notice for the move, on the type of redevelopment that occurs at the current site, and how fast that development takes place. Two ways exist, however, to minimize any negative economic impact in the immediate area: redevelop the current airport site as rapidly as possible, or explore the idea of using a remote terminal with a high-speed transportation between the current site and the new airport site. With a longer time horizon, the economic activity on the immediate area that full redevelopment of the current MSP site could generate, might equal or exceed that of the airport. A key policy question is whether or not to use financial aid to help bridge the difference in timing between closing the current airport and redevelopment of the current site.

FINANCE

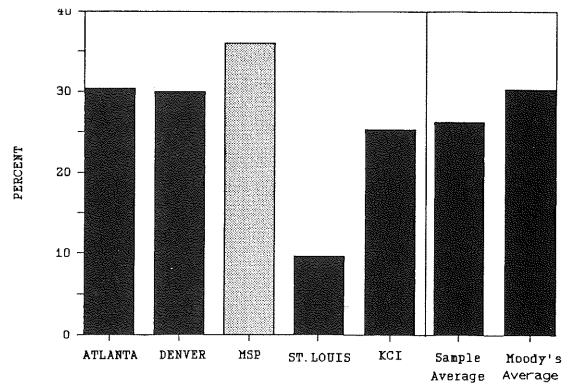
In addition to the many complex planning and political questions that are part of adding airport capacity, the Twin Cities must also consider (1) whether or not specific development options are financially feasible, and, (2) if so, what sources are available? The first question has already been answered. Based on the cost-benefit analysis, for example, the airlines alone stand to realize enough savings from aircraft operations (due to crew and fuel savings) under either Strategy A, B, C, or E to justify the additional expense of any of the implied investments.[6]

Further, the financial standing of the Minneapolis-St. Paul International Airport is strong. In terms of historical performance, for example, the MAC operating ratio (operating costs as a percent of operating revenues) has consistently out-ranked that of other airports while also displaying a trend of continued improvement (falling from 85 percent in 1980 to 76 percent in 1987). Today, debt obligations of the MAC hold the highest bond rating possible (AAA), and debt security as measured by the Debt Service Coverage Ratio is actually the highest among similarly positioned hub airports (Figure 24).

Sources

The answer to the second question is not as clearcut, but encouraging nonetheless. Two categories of sources exist: traditional and non-traditional. Traditional sources include Federal Aviation Administration (FAA) grants and MAC long-term tax-exempt bond issues. Given the findings of the cost-benefit analysis, bonded indebtedness should not be difficult to secure.

Figure 24. Debt Service Coverage Ratio of Selected Hubs



However, a new airport implies considerable capital in the early stages of development -- a constraint to the ability of either of grants or bonds to cover all costs. This should not prove limiting. For example, aside from the traditional sources of funding for new airport development, the Twin Cities area is positioned to take advantage of a unique resource -- the existing site. MSP International is

[6]Further analysis and discussion of the costs and benefits of specific development alternatives is included in the Transportation Costs and Benefits section.

centrally located and includes considerable acreage. Drawing on this fact, the expert panel focusing on possible re-use options for the existing site identified alternatives that could generate adequate funds to finance a large portion of a new airport.

Thus, the answer to the question of financial feasibility is that due to the sound current financial status of the Metropolitan Airports Commission (MAC), the long-term growth potential of the region, and the geographic positioning of the existing site, virtually all development options are sound and feasible.

VII. CONCLUSIONS

The key conclusion of our analysis is the strong need to do something, and do something relatively large in scale. Without significant additions to MSP's capacity, the economic costs to the Metropolitan Region will continue to escalate both in terms of increased travel delays and in terms of job and income losses relative to what could be achieved with increased capacity.

Because of the political and planning uncertainties that surround any given option, a strategy to pursue more than a single option appears desirable. Strategies C1 and C2 represent such "dual" options. Thus, for example, if it appeared that construction of a North-South runway was infeasible, the region would not have ruled out the possibility of a new airport. If these choices are pursued, it would appear to be wise to incorporate a set of criteria that could be used to evaluate the need for any mid-course corrections.

Until a definitive decision has been reached on the region's preferred long-range airport plan, land banking for a new airport stands out as a low-cost, low-risk action. If land banking is delayed until the mid-1990s (or later), however, the region runs the real risk of missing the chance of finding suitable land relatively close to the economic centers of the Twin Cities. Thus, lack of action now might make it difficult -- and perhaps impossible -- to implement a new airport later.

Although the analysis indicates that all options for capacity expansion rank highly in terms of cost-effectiveness, Strategy C1 stands out for several reasons:

- It has the highest transportation-related net present value of all options considered;
- Strategy C1 minimizes long-term environmental costs by shifting noise to a site that could contain most (or perhaps all) of the significant noise effects sometime early in the next century. Because of the importance of increased operations in generating noise stress, these negative impacts are likely to continue to escalate even with continued growth in quieter aircraft;
- By making significant increases to long-term capacity, it presents the option of making maximum use of the airport as a tool of economic development;
- Through land-banking and construction of a new north-south runway, Strategy C1 preserves the choice of delaying the new airport decision until late in the 1990s while still sustaining growth in air traffic and related

employment and other regional economic impacts. Since the new runway would pay-off quickly, there is no risk that its closure after a decade of use would be wasteful;

A disadvantage of Strategy C1 is that some airport-dependent economic activities would shift (in whole or in part) from near the current airport to the site of a new airport, causing economic disruption in the immediate area. At the same time, however, **overall** economic impacts for the MSP region would be maximized since a new airport would create maximum potential for new airport-related economic benefits. Effective options exist to offset these potential losses, including re-use of the existing site, careful land-use planning activities in the early part of the next century; the use of remote terminal to serve the new site during a transition period; and finally, the use of funds to help bridge the gap between closing the old airport and redevelopment of the site.

The final selection of any of the strategies discussed in this report clearly involves more than simply adding up the summary numbers. The decision will require considerable debate by the residents of the Twin Cities. Personal value judgments are required to make tradeoffs among key factors such as the potential direct savings in travel costs, noise impacts, and economic growth opportunities. A key consideration must involve the type of community that residents wish for the Metropolitan region over the next few decades.

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