Is the Airport Adequate?

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

Part III: Technical Appendix

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I. INTRODUCTION

This working paper provides an overview of the technical methods to be used in the MSP Adequacy Study.[1] It has two related purposes. First, it will help guide the joint work of the consultant team and the staff of the Metropolitan Council. Second, it will also serve to introduce the use of risk analysis to the members of the Metropolitan Council's Task Force and others interested in the future of aviation in the Twin Cities area. Indeed, the success of this process depends on a close interaction with the aviation community in the Twin Cities area, local civic leaders, and national experts. The ideas presented here will be further refined and updated periodically. Comments and questions are encouraged.

Public works are both long-lived and far reaching in their influence on a region's economic and social makeup. Decisions on major public investments are rarely straight-forward. Many risks are involved; some of these are technical and involve forecasts about the future, while others reflect value judgments about the most desirable economic and social makeup of the region and about the willingness to bear more noise pollution or increased airport delays.

One thing is certain -- virtually every important forecast will be wrong to some degree. Knowing this, how should decision-makers (and their technical advisors) size-up the pros and cons of their investment choices? For example, how can the Minneapolis-St.Paul region best compare the long run adequacy of existing facilities with the merit of major expansion or even a new airport given the multitude of uncertainties about future traffic, possible improvements to physical capacity, economic interactions, and environmental constraints?

Will air traffic at MSP International outstrip the airport system's ability to accommodate unconstrained growth? When is this likely to occur? What economic, industrial, or technical changes might affect the time when substantial increases in airport capacity might be required? What are the likely economic, social, and environmental consequences of limiting aviation activity? When and under what conditions should the region amass land for a new international airport? Or would such

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[1] The Study Team plans a series of Working Papers. Although labelled Working Paper Number 2, this paper is the first to be completed. Working Paper Number 1 will be finished shortly and provides general background on national and regional aviation trends and their possible influence on the Minneapolis-St. Paul region.

expenditures entail undue financial risk and community disruption in light of the existing system's long-term ability to handle new traffic?

The MSP Adequacy Study will recognize these uncertainties explicitly by using a family of techniques called risk assessment. 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. By attempting to measure the risks of each of the key factors that might influence a major investment decision the result will not be a single "take it or leave it" answer. Rather, the information necessary for an informed decision will be organized and presented in a systematic fashion.

A key objective of the study is to evaluate whether the value of a new airport -- or other substantial airport investment -- is justified by its development costs. In part, the study effort will assess the economic value to the MSP region of unconstrained traffic growth and the risk of foregoing that value if substantial new aviation investments (including a possible new airport) are not provided.

The next section explains the use of risk analysis and develops a detailed approach to guide the study team. The use of risk analysis will require inputs from experts outside the study team. This would help to form a consensus regarding the likelihood (probability) of various outcomes.

The criteria to guide the evaluation of alternative airport policies are developed in the last section. In addition, it discusses the critical issue of defining the "base" case -- the airport development approach against which other alternatives will be compared.

II. RISK ANALYSIS IN FORECASTING TRAFFIC AND CAPACITY

The decision of whether or not (and when) to build a new airport depends on the results of a series of analyses and a number of value judgments by the residents of the Minneapolis-St. Paul region. Some of these analyses are largely technical in nature: What level of aviation traffic (aircraft operations and passenger enplanements) can be expected? What capacity improvements to MSP are likely? What further expansion is possible at the current site? What financial options are available to support major capital investments?

Two key parts of the technical portion of the analysis--the expected amount of traffic and the effective capacity of the airport system -- require long-term forecasts of economic, social, technical, and political forces. In most long-term planning efforts these forces are rolled into a single discrete forecast, or perhaps a set of discrete forecasts. For discussion purposes, Figure 1 shows four alternative sets of such forecasts.

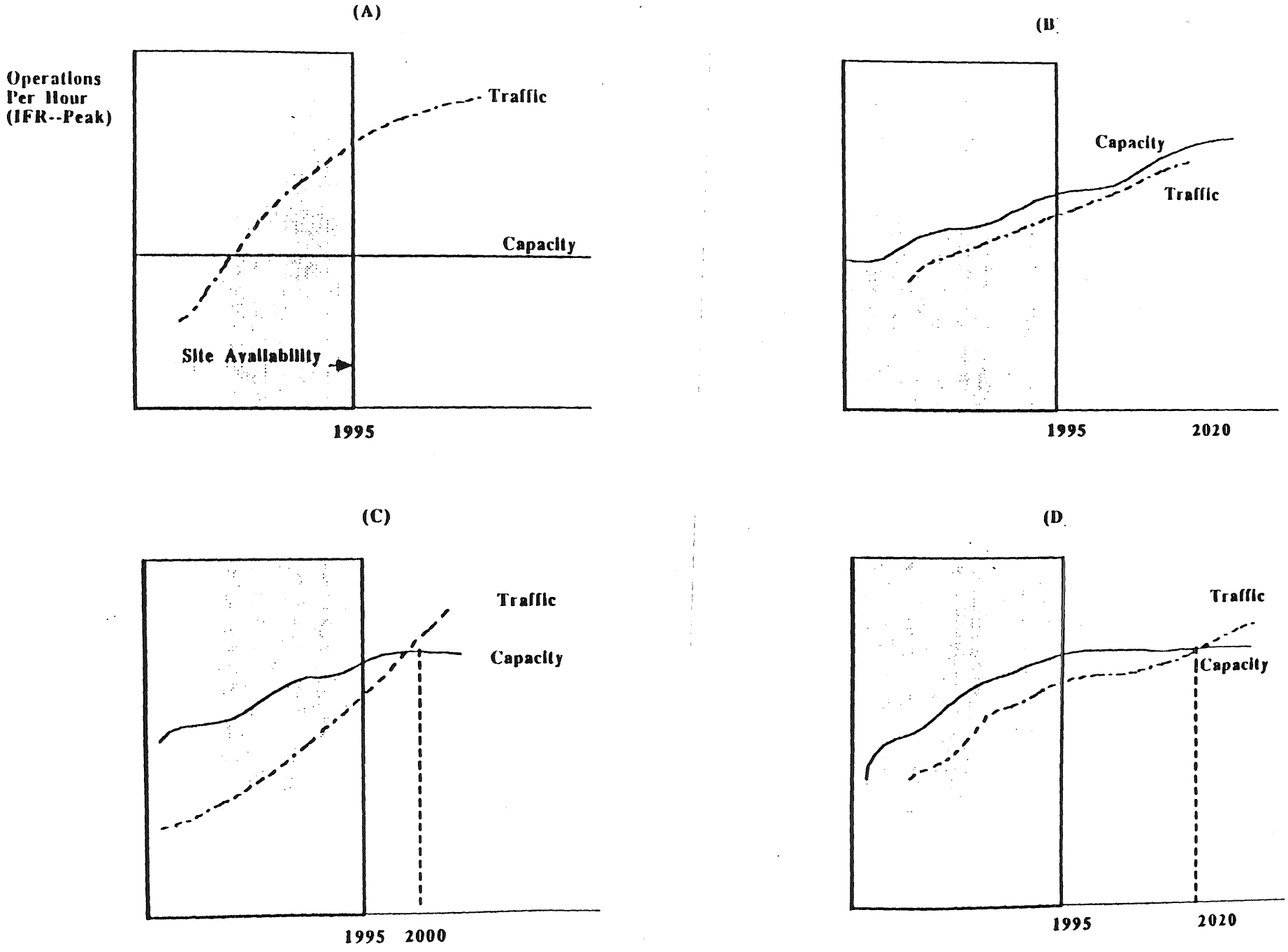
Each scenario shown in Figure 1 summarizes an alternative set of predictions about the future. Each results from a series of explicit and implicit decisions about the many variables that influence the forecast. Some are highly unlikely -- Figure 1a, for example, combines explosive traffic growth with no airport improvements.

For illustrative purposes, each example assumes that a suitable site for a new airport will be available at reasonable cost only through 1995 (the shaded area). Figure 1a, for example, shows a case in which no capacity improvements are made and traffic rapidly outstrips current capacity -- leaving ample time to procure a suitable site for a new airport.

On the other hand, Figure 1b depicts a case in which planned additions to the capacity of MSP will be able to cope with a more moderate growth in demand for the foreseeable future and investment in a new airport would not appear warranted. Figures 1c and 1d illustrate cases between these two extremes, with severe capacity problems deferred until the next century.

The forecaster's most probable or expected outcome (as shown by <u>one</u> of the cases in Figure 1) will help focus the decision making problem. It provides no guidance, however, regarding the likelihood of that outcome, thereby leaving the community and its elected decision-makers with an incomplete view of the future.

FIGURE 1: ALTERNATIVE OUTCOMES WITH NO KNOWLEDGE OF PROBABILITY



A typical variation on the single "expected outcome" is a "high" and "low" case based on high and low variations to the forecast's underlying assumptions. This approach adds little information for decision-making, however, since it gives no indication of how likely it is that these high and low cases will actually materialize.

An equally significant shortcoming of this 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. In reality, of course, the likelihood that all underlying factors shift in the same direction is quite remote.

The Concept of Probability: Towards a Measure of Risk

Probability provides a way around the forecasting conundrum outlined above. Probability measures the confidence or "odds" that an expected outcome will actually materialize. The shape depicted in Figure 2 is called a probability distribution and its mathematical description is called a "probability density function." The "mean" or average is synonymous with what we have termed the expected outcome. Figure 2 may be regarded as describing the confidence that an economic variable -- say, gross national product (GNP) -- will achieve a given growth rate in a future year (say, 1990).

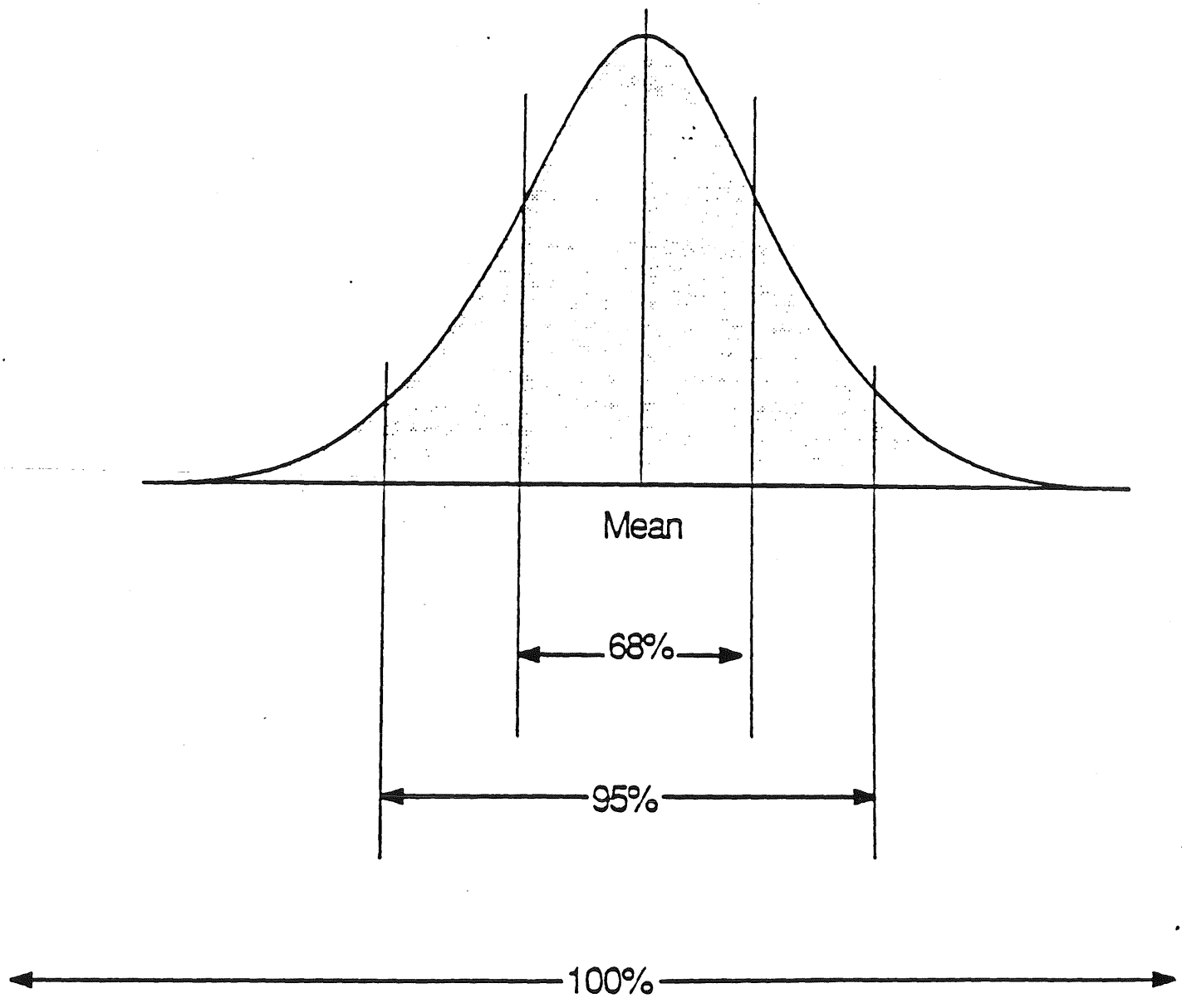
The lines marked "68%" and "95%" are called "standard deviations" and provide a measure of the dispersion of the actual answer. That is, they measure the likelihood of being wrong. The 95 percent "confidence range" means that the probability of economic growth being above or below these limits is only five percent.[2] The wider the 95 percent confidence range (the flatter the curve), the greater is the risk that the actual growth rate will deviate widely from its expected value.

Two important characteristics of probability distributions should be noted. First, standard deviations get wider as forecasts become more distant. For example, the probability distribution for a prediction of GNP in the year 2000 would have a much flatter shape, reflecting the much lower confidence with which we make more distant forecasts.

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[2] In this symmetrical case, the odds are 2.5 percent that actual growth will be higher than shown by the 95 percent line and 2.5 percent that growth will be lower.

FIGURE 2: PROBABILITY
A MEASURE OF CONFIDENCE/RISK



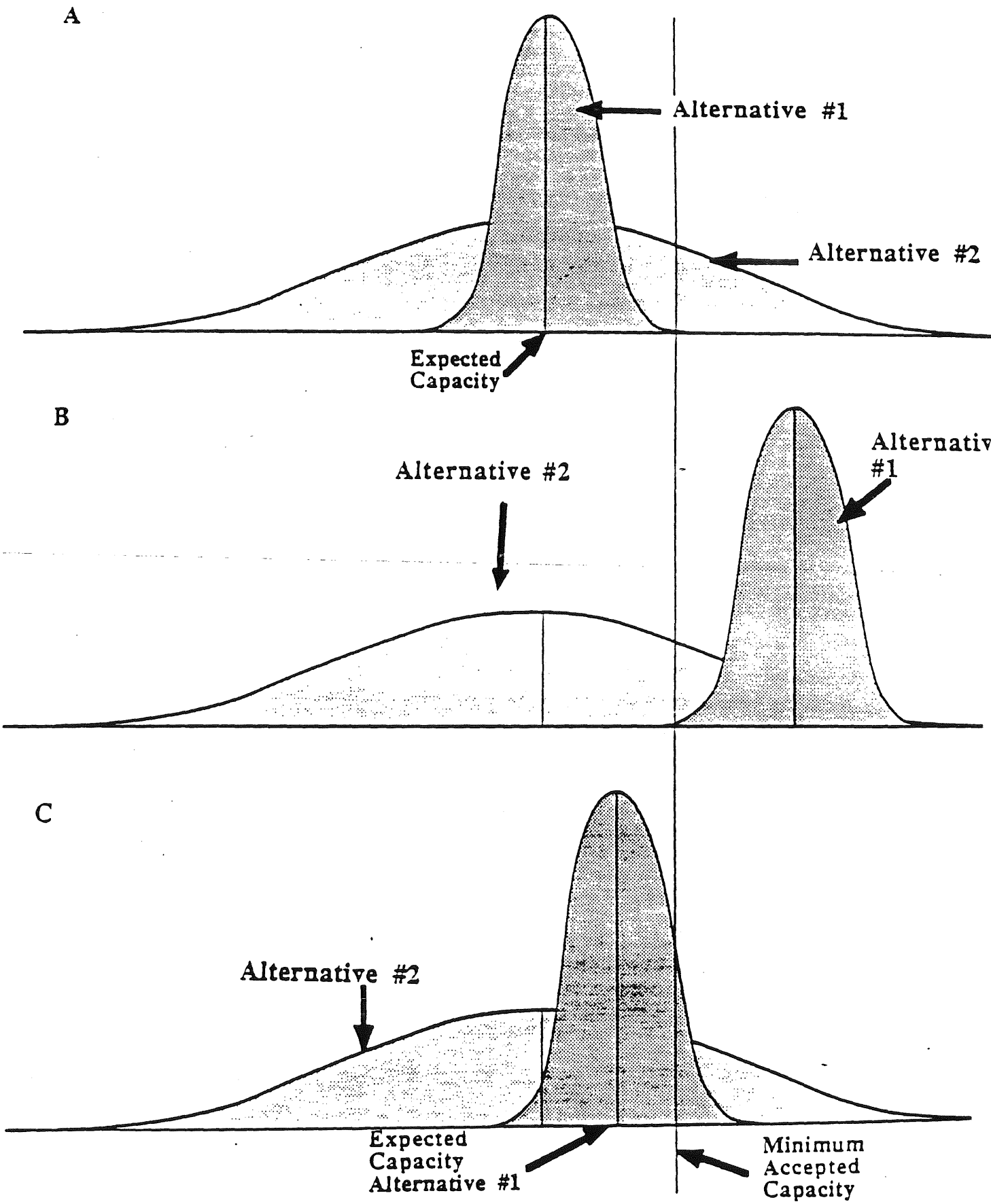
Second, probability distributions are not necessarily "symmetrical." The traditional "bell curve" shown in Figure 2 is symmetrical because the shape of the curve (the probabilities) are the same on either side of the mean -- there is an equal chance that the actual result will end up too high as too low. This is characteristic of some forecasts but not of others. Over the years, for example, economists have erred too high in their GNP projections with about the same magnitude and frequency as their underestimates (except for short-term forecasts, they have rarely been spot-on). In contrast, forecasters tend to overstate the magnitude of technology-driven cost savings more often than they understate them. The latter phenomenon is depicted by an asymmetrical probability distribution -- known in statistical jargon as a "skewed" distribution.

How does probability aid decision-making? Consider a simple example. Before the advent of powerful computers, weather forecasters would simply assert their mean expectations -- "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 few dollars -- not to mention good will and tempers-- were lost.

So it is with public investment. Figure 3 illustrates a few examples using the odds of running out of airport capacity in a particular year. Points to the right indicate more limited capacity, with the vertical line showing where capacity equals traffic. Both alternatives in Case A predict adequate capacity and thus could be represented by the same line in a chart such as those shown in Figure 1. Alternative #1 is much less risky however (the distribution is tall and narrow) than alternative #2 even though they both display the same expected outcome (the same mean). That is the risk of running short of capacity (the area to the right of the expected outcome) is greater under alternative #2.

In case B, the expected outcomes themselves are different. The first alternative requires an expected capacity that exceeds that of the second; however, there is less dispersion around the outcome of alternative #1 and thus a limited risk of winding up with radically too much capacity if MSP were expanded.

FIGURE 3: RISK AND RETURN
THE NEED TO EXAMINE PROBABILITY



In case C, the second alternative provides greater assurance of not exceeding the minimum level of capacity but also creates a greater risk of over-investment. Once risk and confidence are properly understood (and summarized in terms of overall costs and benefits) it should be easier for the community and its elected officials to forge a consensus on ways to proceed.

Applying Risk Analysis to the MSP Adequacy Study

The master planning process conducted by the Metropolitan Airports Commission (MAC) leads to traffic and capacity projections that will be treated as the baseline forecasts for this study. Given these forecasts, the risk analysis will proceed in five steps:

1. Identify all factors (and corresponding numerical assumptions) used in the baseline (MAC) forecast for each year over the forecast period;

   - o For traffic forecasts;
   - o For environmental capacity forecasts;
   - o For physical capacity forecasts.

2. Identify factors not taken explicitly into account in the base forecast;[3]

   - o For traffic forecasts;
   - o For environmental capacity forecasts;
   - o For physical capacity forecasts.

3. In consultation with expert groups, develop probability distributions for each forecast factor and assumption identified in steps 1 and 2.

4. Combine the series of individual probabilities into a unified assessment of the community's risk of having inadequate airport capacity. That is, instead of developing a single point estimate, we will apply a form of risk analysis known in the jargon as "Monte-Carlo Simulation."[4]

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[3] For example, the forecast may not deal explicitly or quantitatively with possible capacity enhancements from microwave landing systems (MLS) and collision avoidance systems (TCAS).

[4] Using a Monte Carlo Simulation merely means that instead of using a "single-line" prediction of the future, the probability distribution for each factor that influences future traffic and capacity will be estimated. The result is a forecast

5. Present results in a form that is useful for public consultation.

Steps 1 and 2: Identify Individual Forecast Factors. Three formal lists will be developed that describe the individual factors that affect each forecast.[5] These will include variables explicitly used in the MAC forecasts plus others that could influence the long-term outcome. For each factor, the value (or values) used by existing forecasts will be recorded.

LIST #1: TRAFFIC FORECAST FACTORS

IN BASELINE FORECAST	NOT IN BASELINE FORECAST
Gross National Product (average annual growth)	Airline Hubbing Decisions
GNP Elasticity	.
Average Aircraft Size	.
.	.
.	.

LIST #2: ENVIRONMENTAL CAPACITY FORECAST FACTORS

IN BASELINE FORECAST	NOT IN BASELINE FORECAST
Per Aircraft Noise Index	.
.	.
.	.

LIST #3: PHYSICAL CAPACITY FORECAST FACTORS

IN BASELINE FORECAST	NOT IN BASELINE FORECAST
Runway Extension Plans	ATC Procedures
Reliever Airport Capacity	Simultaneous Operations
.	.
.	.

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that describes the most likely case together with a probability distribution of alternatives.

[5] Drafts of these lists will be developed in Working Papers 3 and 7 on traffic and capacity forecasts. They will be further refined in Working Papers 4 and 8.

Once complete, these lists and the corresponding values for each factor will contain the key influences that could bear on the adequacy of MSP. Each list will be refined and modified as the study progresses and provide a central record of the factors being taken into account in the analytic process. The analysis will identify those factors that are most influential in determining future traffic growth or capacity at MSP.

Step 3: Develop Probability Distributions. This involves three distinct stages:

- First, record the baseline assumptions for each forecast factor in a probability recording chart;
- Second, define an initial probability distribution for each entry in the charts; and
- Third, consult with groups of outside experts and revise initial distributions.

Figures 4, 5, 6, and 7 display the format of the recording chart that will be used to organize the process. These charts are illustrative only and the actual values and probability distributions used in the study are likely to be quite different. The "x" in the charts represent the assumptions made by the baseline or most likely forecast.

The curves represent the probability distributions that will be combined during the Monte Carlo simulation as part of the risk assessment process. In the case of gross national product (GNP) -- top chart in Figure 4 -- the distributions will probably be symmetrical but will widen significantly for more distant forecasts. For the elasticity of air travel with respect to GNP[6] -- bottom chart in Figure 4 -- the distribution may be "skewed left," reflecting the belief that downward changes from the current elasticity are more likely than increases. This would occur if the demand for air transport matures so that growing incomes will continue to lead to increased travel, but at a decreasing rate.

Figures 5, 6, and 7 show hypothetical charts for aircraft size, aircraft noise, and the impact of MLS on runway capacity. Figure 5 on aircraft size shows a rapid increase in the number of seats per aircraft. The distributions are skewed left, meaning that actual aircraft capacity is much more likely to fall short of such rapid growth than it is to exceed it. In combination

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[6] This elasticity measures the percentage change in air traffic for each one percent change in GNP. Thus, an elasticity of 1.2 means that a six percent increase in GNP should result in a 7.2 percent increase in traffic (6 times 1.2).

FIGURE 4: FORECASTING DEMAND: IMPACT OF ECONOMIC GROWTH

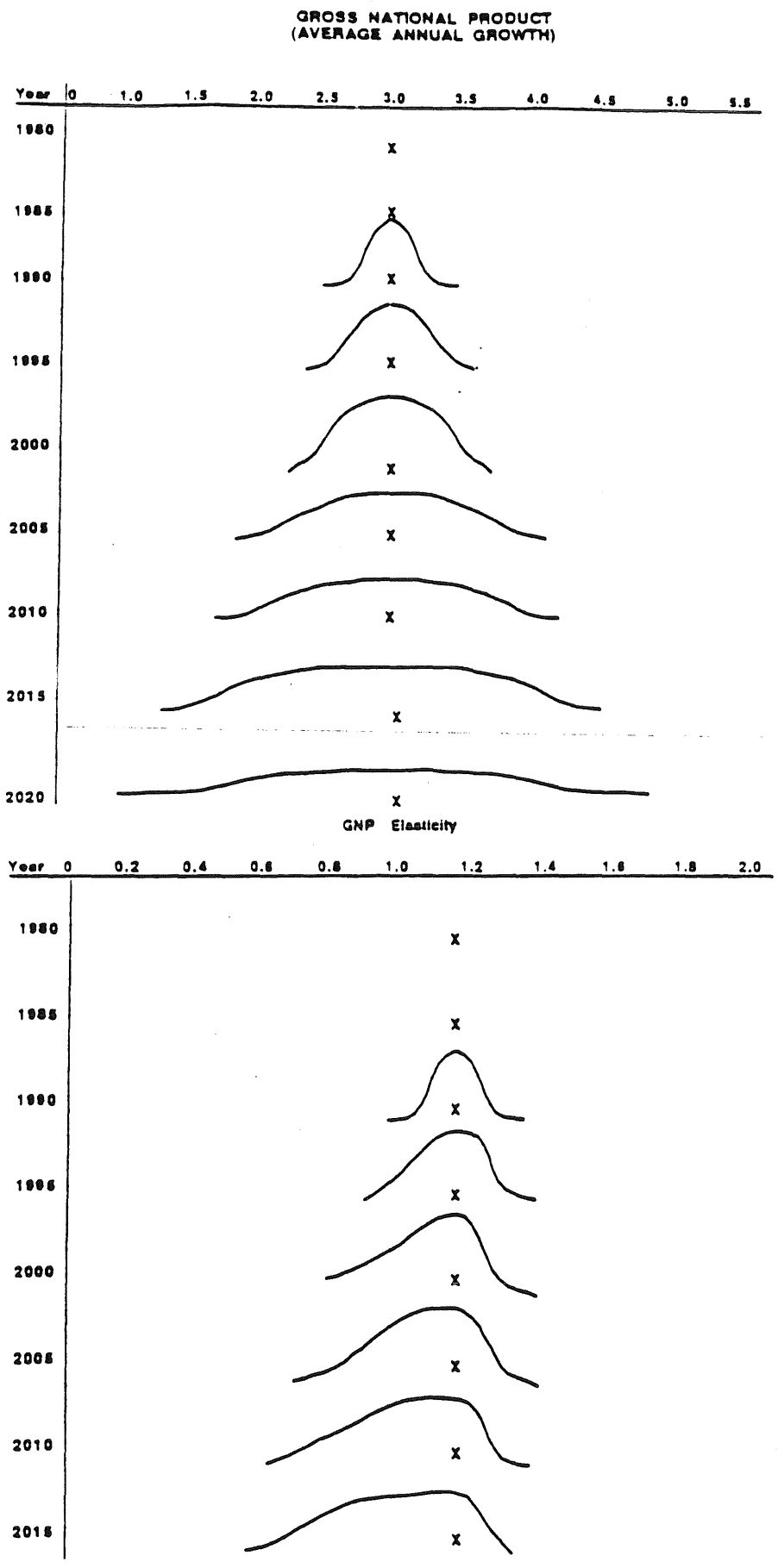


FIGURE 5: FORECASTING AIRCRAFT SIZE

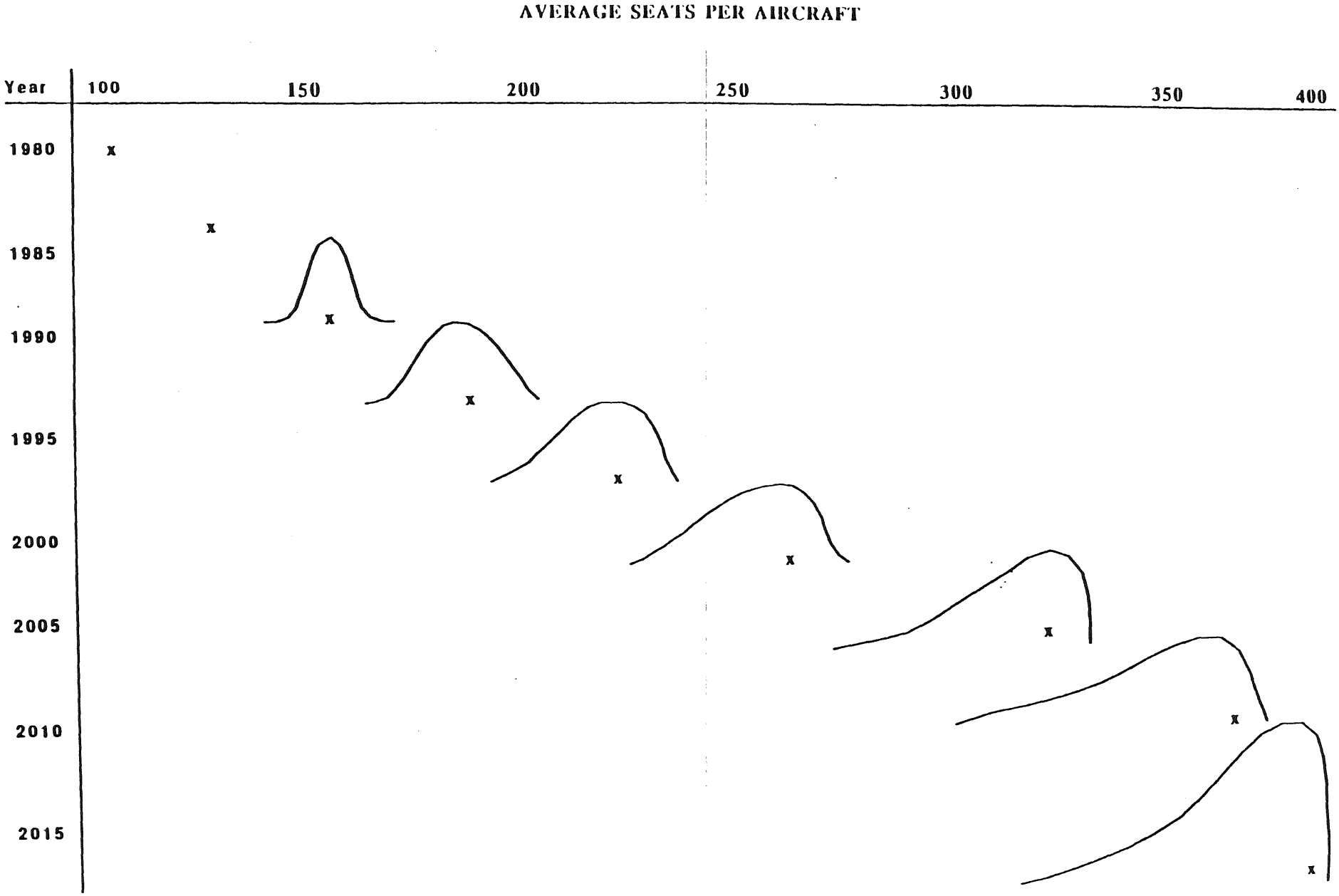


FIGURE 6: FORECASTING ENVIRONMENTAL CAPACITY: IMPACT OF NOISE

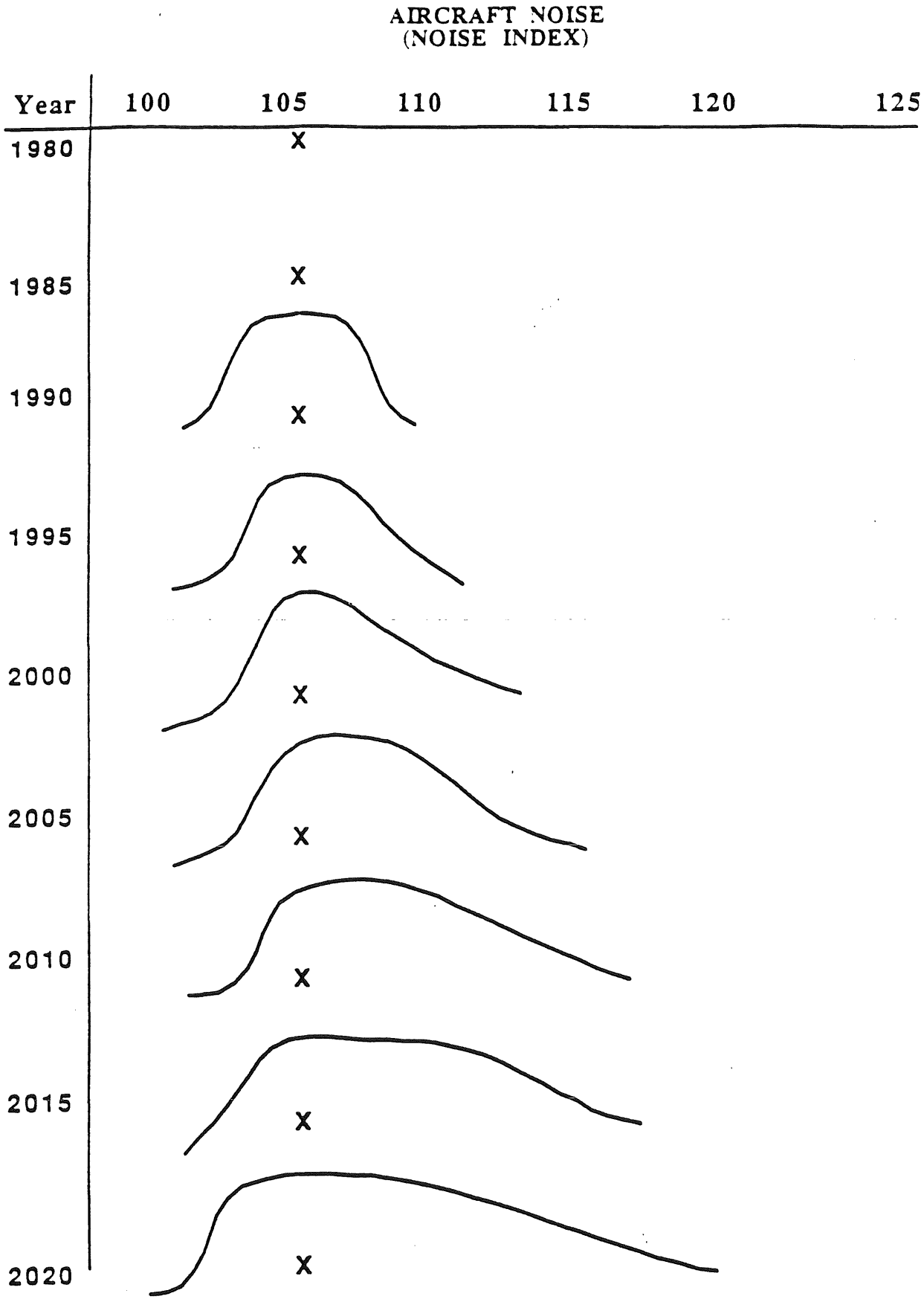
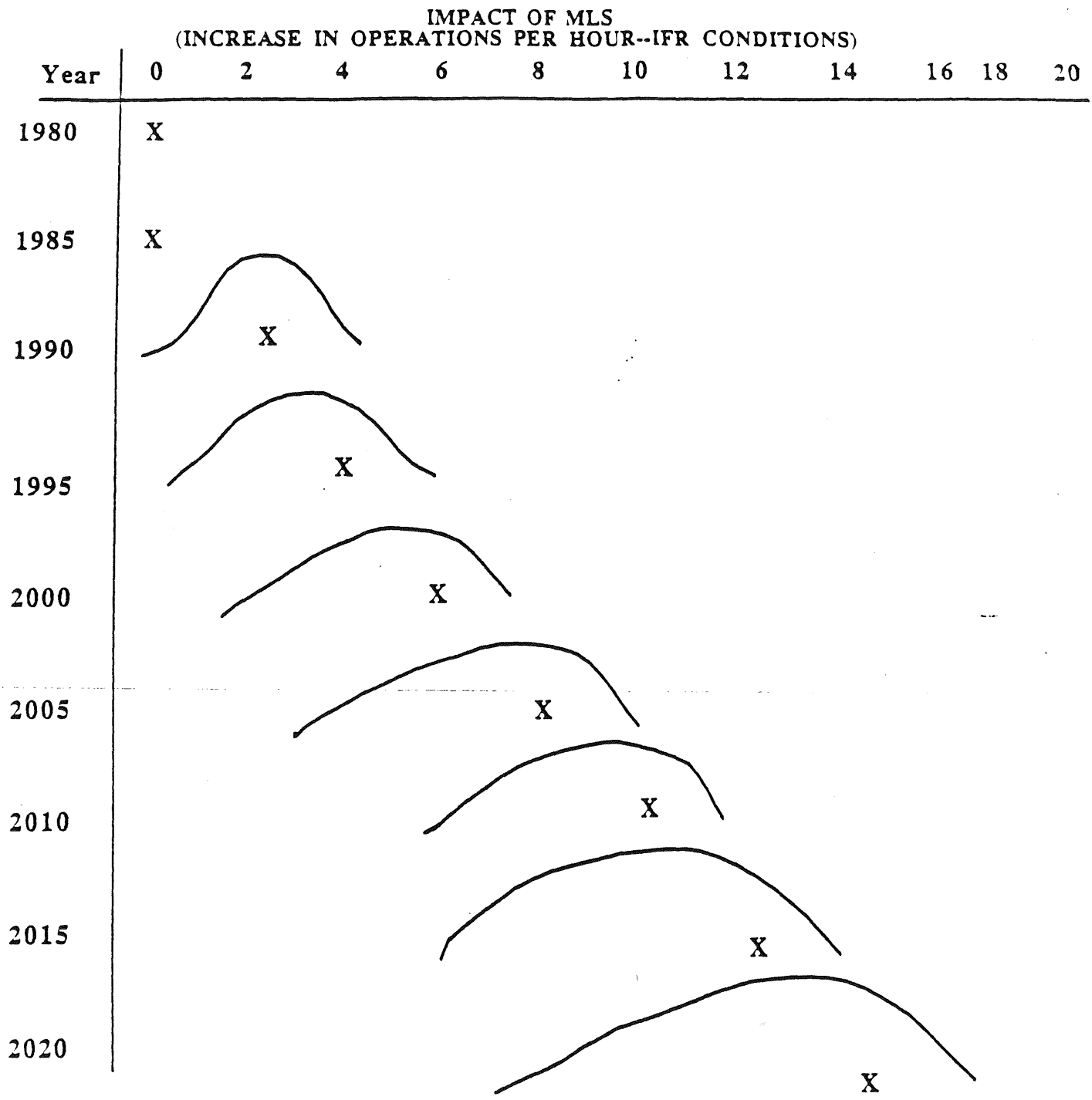


FIGURE 7: FORECASTING PHYSICAL CAPACITY:
IMPACT OF MLS



with a chart of projected load factors, assumptions about future aircraft size will make it possible to convert between forecasts of enplanements and forecasts of aircraft operations.

Figure 6 assumes that noise impacts will be converted to a noise index. This distribution is skewed to the right, indicating that given the steady growth in air traffic, forecasts of future noise are more likely to represent under-estimates.

In the case of Figure 7, the distributions are skewed to the left, indicating that the capacity gains from MLS are more likely to fall short of projected success (or be delayed in time) than they are to exceed it. This may occur for technical as well as social and political reasons. For example, the angled approaches that MLS permits require neighborhood consultation due to changed noise patterns and thus could delay full exploitation of MLS.

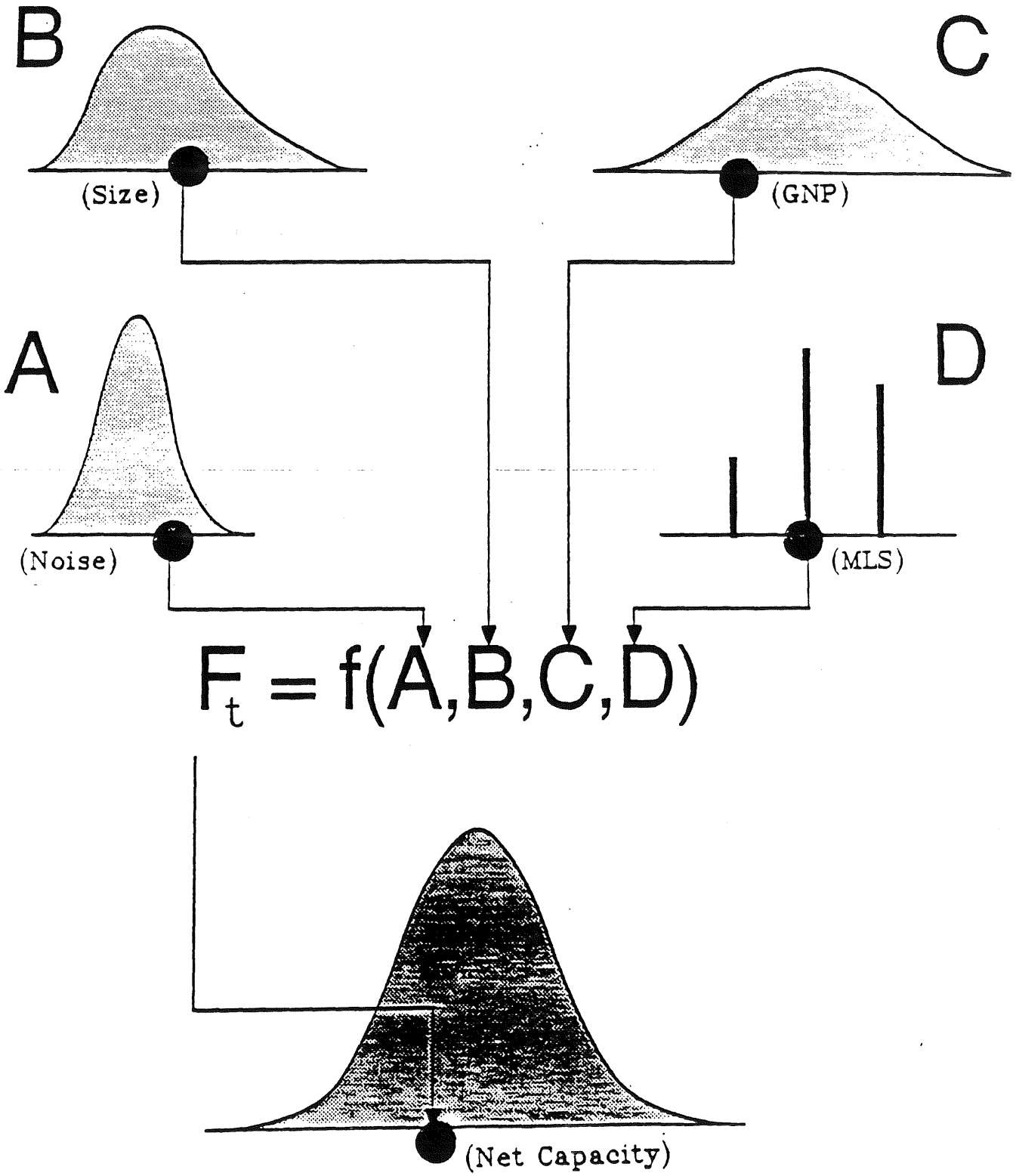
As part of the third stage, two review groups will be formed, one with traffic forecast experts and one with capacity experts. Membership will be drawn from local and national perspectives (including representatives of other localities). Each group will be limited to six members other than members of the Study Team and representatives from MAC. MAC and Study Team staff will present baseline forecasts and the initial distributions developed by the Study Team. Following the consultative process, a final set of "consensus probability distributions" will be developed.

Step 4: Apply Risk Analysis. Monte Carlo simulation is simply a way of combining probabilities. In this simple example the net capacity of MSP ("F") in any year "t" -- and the associated probability distribution -- is determined by GNP, aircraft size, MLS, and all the other factors detailed in the lists and enumerated in the recording charts (Figure 8). 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.

A number of key analytic decisions will be taken in developing the algorithms. For example, will planning peaks be defined on an annual, daily, or hourly basis? The computer programs however will be "open" in the sense that these assumptions can be changed by the user. The program will be "user friendly," requiring no programming knowledge and permitting all assumptions to be changed in order to make

FIGURE 8: MONTE-CARLO SIMULATION:
A WAY TO COMBINE PROBABILITIES



sensitivity tests. The program will be written in "C", a computer language designed to build simulations. Graphics will be generated from packaged software.

Step 5: Presentation of Results. Figures 9, 10, 11, and 12 illustrate alternative modes of presentation. It should be noted that the graphics software will be flexible and should accommodate the various presentational requirements and ideas that emerge over the course of the study.

To illustrate the possibilities, the shaded areas shown in Figure 9 depict a selected probability range. The lesson learned from Figure 9 (top) is that a substantial risk exists that traffic will exceed capacity prior to the "break-even" year under official forecast assumptions. Figure 9 (bottom) translates the results into dollar terms and thus quantifies the value of foregone traffic under various risk conditions (that is, "there is a 40 percent chance of losing $3 billion of local economic value if new airport capacity is not in place by the year 2005; there is a 75 percent chance of losing $4 billion of local economic value if new airport capacity is not in place by the year 2009").

Figures 10 and 11 depict the latter statements in numbers rather than charts. This form of presentation has been used successfully in presenting the results of risk analysis to Members of Congress.[7]

Figure 12 shows a presentational option (top) and its analytic basis (bottom). The line marked "0" denotes a balance of traffic and capacity. The are above the line denotes inadequate capacity; area below the line denotes adequate capacity. The chart (top) depicts a case where the mean forecast indicates sufficient capacity throughout the forecast period but a substantial risk of inadequate capacity emerging early in the period. The bottom chart simply shows the unified probability distribution in each year from which the top chart draws. Referring back to Figure 1, it is clear how the various possible outcomes depicted there are properly reconciled with the risk framework emerging in Figure 12.

Having assessed the economic value of unconstrained traffic growth, and the risk of foregoing that value without new airport development, it is necessary to evaluate whether the costs of a new airport appear justified -- whether the economic value of a new airport exceeds the costs of land acquisition and airport construction, minus the economic value of the existing site.

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[7] Congressional Budget Office, Improving the Air Traffic Control System: An Assessment of the National Airspace System Plan, (August 1983).

FIGURE 9: TRAFFIC AND CAPACITY
UNDER UNCERTAINTY

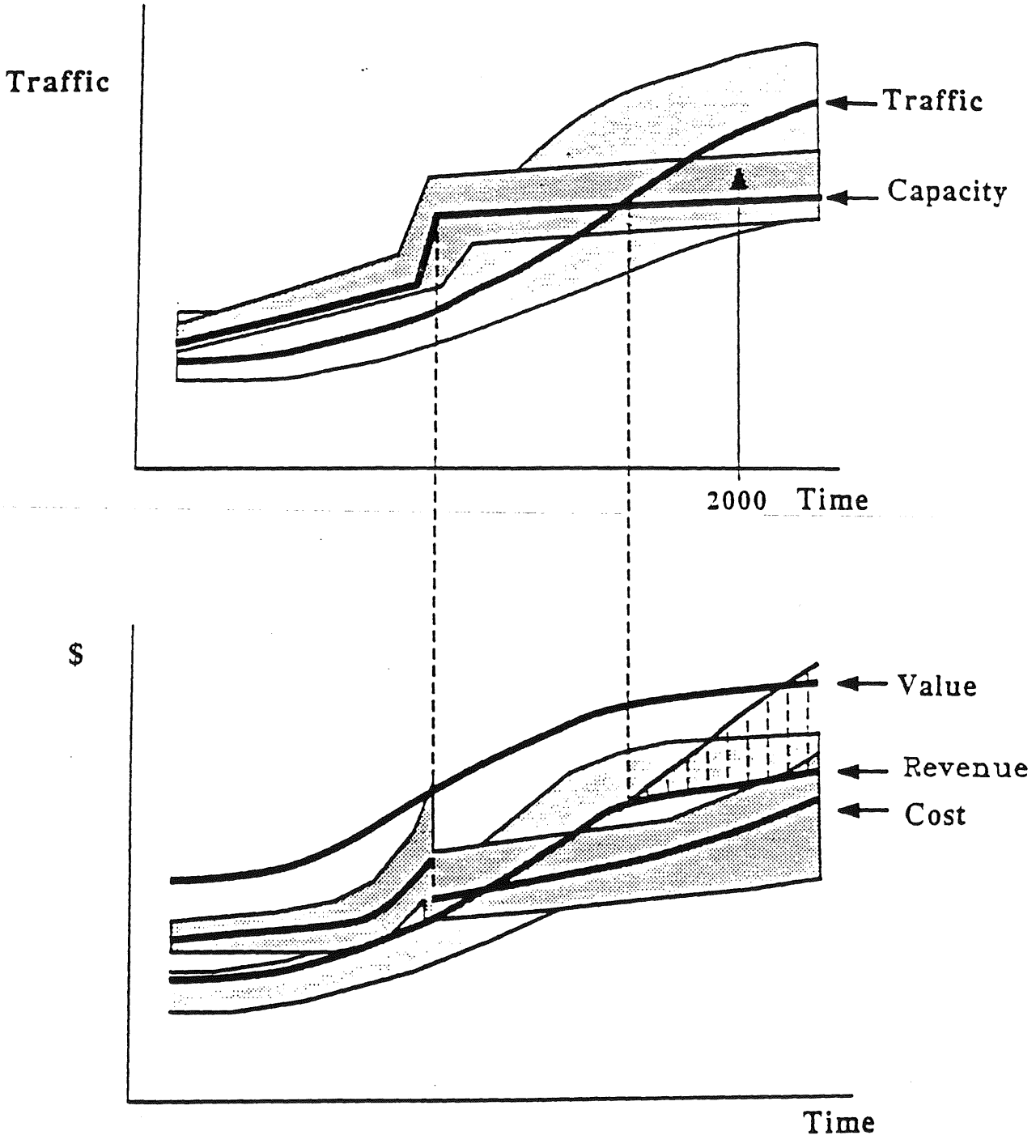


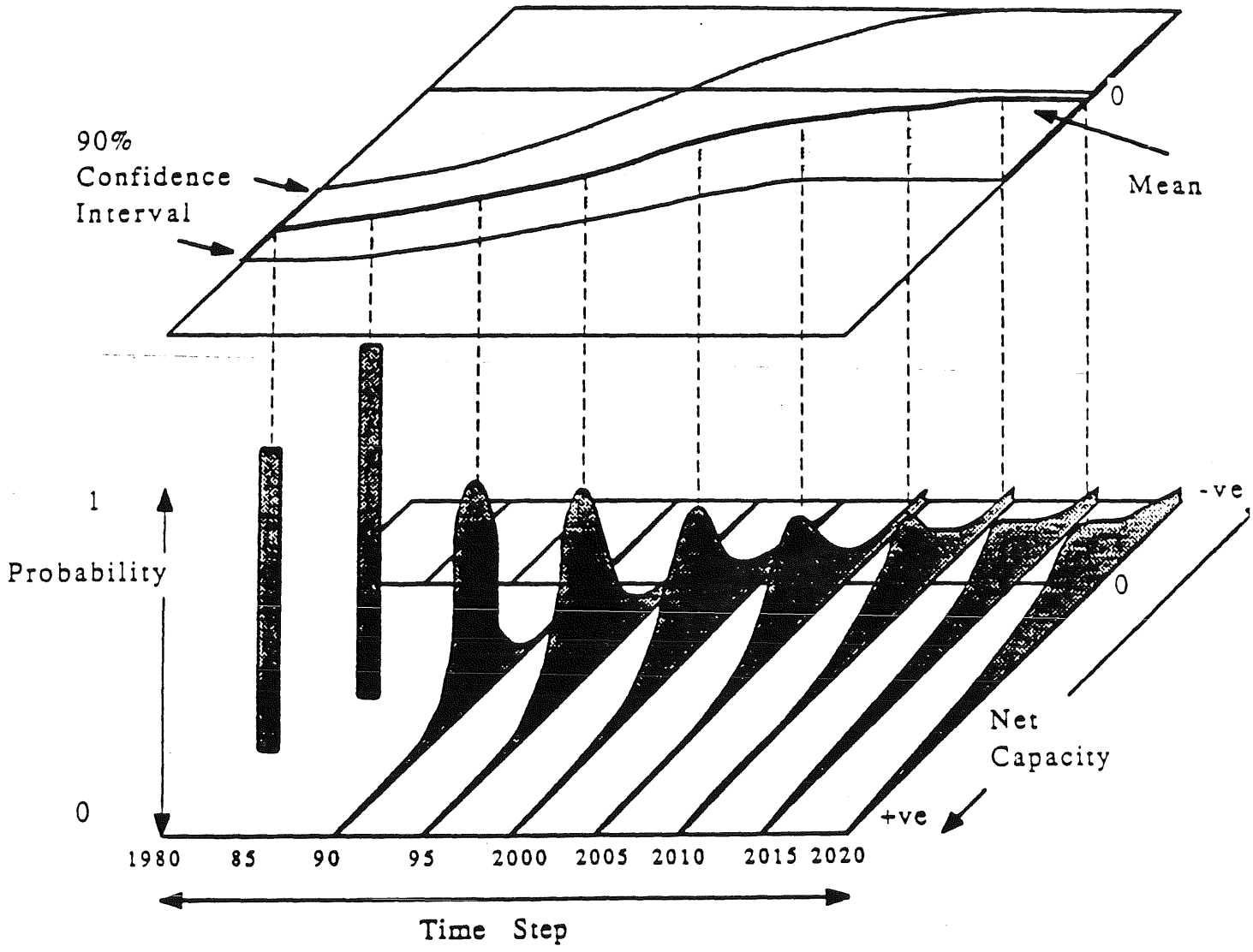
FIGURE 10: RISK ANALYSIS OF CAPACITY

Year	Probability that Capacity will be Insufficient in Year at Left
1980	0
1985	0
1990	5
1995	40
2000	75
2005	88
2010	90
2015	93
2020	95
Mean	2010
Standard Deviation	11 years

FIGURE 11: RISK ANALYSIS OF CAPACITY

Year	Probability that Capacity will be Insufficient in Year at Left
1980	0
1985	0
1990	10
1995	15
2000	20
2005	40
2010	80
2015	90
2020	95
Mean	2010
Standard Deviation	3 years

FIGURE 12:
Presentation of Final Results



III. EVALUATION FRAMEWORK

The Metropolitan Council faces a series of options to improve airport and terminal airspace capacity. These range from revised operational procedures to major capital investments, including a possible future new airport. In some cases, these options are limited by FAA regulations or concerns for safety as with the ability to handle simultaneous aircraft operations on the parallel runways. Other choices, such as extending the parallel runways or adding new runways may be constrained by concerns for noise pollution or by the limited size of the current airport site. The possibility of a major new airport depends on the level of demand for air travel at MSP and how much of this demand the citizens wish to meet, the ease with which such a large undertaking could be financed, and on the availability of large blocks of land at moderate cost and reasonable distance from current business centers.

At present, we foresee the evaluation focusing on four key options, as follows:

- Base case (current programmed improvement);
- Enhanced existing (ten-year perspective);
- Maximize existing (ultimate development); and
- New replacement airport.

Each alternative includes the range of possible assumptions regarding demand management techniques and options for reliever airport development.

It is important to note that the case for a new airport would need to be made against a "baseline" that included the most realistic and productive use of the existing site. (In other words, this should not be compared against a base case that includes no improvements to the existing airport.)

This workplan presents a framework to help the Metropolitan Council and the citizens of Minneapolis-St. Paul evaluate these alternative futures for MSP. The framework described here will summarize the risk assessment analysis and add the evaluation measures necessary for a comprehensive, impartial, and consistent review of the options faced by MSP.

Any decision regarding long-term changes at MSP and the timing of those changes requires five types of evaluation measures:

- o benefit cost: whether the economic value of new airport development -- measured as the avoidance of delay and lost traffic -- is likely to exceed the costs of land acquisition and construction, minus the disposal value of any redundant airport assets;

- o system performance: how well will air transportation services be provided given expected growth in passengers and operations;

- o economic concerns including demand for air transport, its link to regional economic growth, and the local opportunity cost of capital invested in aviation;

- o social concerns such as community and environmental impacts; and

- o financial concerns which assess the capital and operating costs of various alternatives and possible sources of funds.

Some of the measures listed above actively encompass some of the others -- a hierarchy of indicators. The higher level criteria will become central to the debate. The benefit-cost ratio is the key example of a high level indicator. It encompasses many of the measures of the remaining four categories and these can thus become supporting criteria.

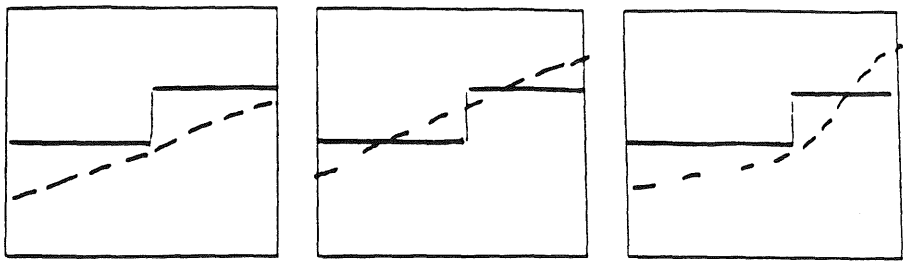
The remainder of the categories are broad and cannot be evaluated on the basis of any one criteria. For example, social factors extend beyond community growth goals, to include noise and air pollution, land use and availability, and the political climate. Thus, for each broad category, a range of sub-categories must be examined in order to assess the overall impact of each airport development option.

Nonetheless, for each alternative or scenario a summary measure will be developed to quantify many of the individual evaluation measures. For example, many of the economic impact and system performance indicators (delay, for example), can be combined in terms of net present value or overall ratio of costs to benefits. These measures will not represent a single answer for each option, but rather will help to summarize a diverse number of individual indicators. Of course, the individual values will be presented as well. Combined, this "report card" summary of measures will provide a comprehensive base upon which the Council and the people of the region can assess the long-term tradeoffs involved in the various airport configurations.

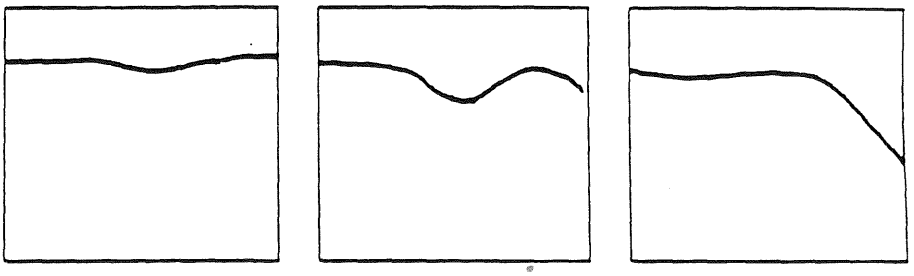
Figure 13 provides a "mock-up" of a summary report card for a particular investment option. Each column represents an

Airport Development Option "X"
"Report Card" Under Different Forecasts

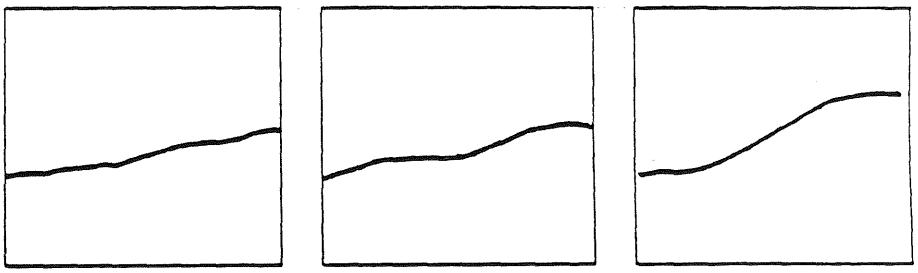
Traffic Forecast vs. Capacity



Performance (% not delayed)



Economic Value (jobs)



Social/ Environmental: Verbal description; Population within noise contours

Financial: Dollars needed; Possible resources

Summary Measures: Verbal Summary:
Key decision points (changes in probabilities);
Net present value where appropriate

alternative estimate of future traffic demand. Each row provides one or more evaluation measures. Some measures can be presented graphically or numerically; others require written descriptions. Of course, behind each report card there will be considerable detail on each evaluation measure.

Where possible, numerical estimates will be used, although various assumptions must necessarily be built into these values. Moreover, timing is an important factor which must be considered. For example, it may be less costly to build a new airport now than in 20 years due to land availability, available financing, etc.

Not all outcomes are easy or suitable to be quantified, however. For example, many of the broader societal impacts will be estimated and discussed qualitatively. The following section outlines the values to be included in this "report card" as well as their importance to the decision-making process.

Performance Measures

Performance indicators measure the quantity, quality and cost effectiveness of air transportation services provided by the MSP airport. Together, they describe how well a given airport development alternative provides air service. A series of performance indicators will be evaluated for each development alternative:

- o Capacity measures the potential airport service in terms of feasible take-offs and landings or available seats. These numbers depend on assumptions about aircraft mix, plane size, and average load factors.

- o Times delays measures the quality of the services provided by the airport and its airlines -- it is closely related to the relative level of demand and airport capacity and, in turn, affects the economic value of the airport;

- o Type of Service including the degree of hubbing or the percent of non-stop flights also measures the quality of services provided by the airport; and

- o Cost-effectiveness measures spending per unit output: capital and operating costs per take-off or landing, per enplaned passenger, for example. A more complete picture of cost effectiveness would combine the cost of delays with the direct "out of pocket" costs of airport service.

Economic Factors

The link between economic growth and airport capacity is very strong. Airport development will have both short-run and long-run economic impacts. In the short term, spending on a new airport or capital additions to the old airport will create construction jobs. Moreover, this spending will be recycled throughout the local economy in a "multiplier effect" further increasing income and creating jobs well beyond construction. The magnitude of the initial spending will dictate the magnitude of the total impact.

In the long run, airport capacity will affect the quantity and quality of air service between MSP and other cities. This, in turn, will help determine the ability of Minneapolis-St. Paul to attract new business. Further, decisions regarding the existing airport site (if a new airport is built) can also play a role in inducing economic growth.

Social and Environmental

Social impacts of adequacy include community and environmental considerations. Providing increased airport capacity will probably result in an increased growth population and economic development for the Minneapolis-St. Paul area. In the long run, this may be substantial enough to change the nature of the community from one where limited aviation capacity constrained growth. Thus, within this category four areas must be considered: community growth, community character, demographic changes and their interaction with air transport demand, noise pollution, and air pollution. Some of these areas will be easier to quantify than others. The economic and noise impacts are conceptually easier to measure and represent areas where considerable analysis is already underway.

Financial

Finance translates the costs of each planning option into what can actually be achieved. There is no fixed financial cost for any given airport configuration. Rather, costs will be affected by the nature of the tax-exempt bond market, short- and long-term interest rates, and airport credit ratings. They will further depend on possible uses of the old airport, timing, expected federal, state and local assistance, the ability to identify and use innovative financing techniques, the type of cost-sharing agreement between MAC and the airlines, and the willingness of the airlines (most importantly, Northwest) to modify these agreements for a new airport or other major capital project.

Probability of Outcome

Included in each "report card" will be an estimated probability that the set of impacts will be realized. As described above, these probabilities will be based on demand and capacity forecasts.

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

Background Material
for Expert Panel Review

Prepared By:
APOGEE RESEARCH
Thompson-Hickling
CH2M HILL
Enviroscience

POGEE
RESEARCH
INC.

February 11, 1988

Dear Panelist,

Thank you for agreeing to participate in our expert-panel session on traffic forecasting in the Minneapolis-St.Paul region. The panels include individuals from many different backgrounds, including the aviation industry, forecasting, economics and business. While no one is expected to offer expertise in all areas of interest, together, the panels will offer the collective wisdom we need to offer MSP the best possible advice regarding the adequacy of its airport facilities.

This package contains the materials to be used during the session, as follows:

- A "primer," or explanation of the methodology and your role in the process (see also "Working Paper No. 2" provided under separate cover);
- Diagrams of the forecasting models used to establish the "baseline" forecasts. Although we will not be discussing models per se, these diagrams will help panelists put each forecast variable into context;
- The forecast variables for discussion are included in a separate attachment containing:
  1. Cover sheets describing the variables and the issues and uncertainties associated with developing forecasts of their future growth or decline;
  2. Data sheets giving, as an example, the consulting team's initial estimate of the range (probability distribution) associated with each variable; and
  3. Blank data sheets for panelists to use in making their own judgments about each variable. Panelists will be asked to fill these in during the sessions in MSP.

ECONOMICS
FINANCE &
ENGINEERING

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As noted above, you should have received Working Paper II: Analytical Framework directly from the Metropolitan Council. This working paper provides detailed discussion of the methodology used in this analysis.

The session will be conducted as follows. We will begin with an introduction and review of the process by the consulting team. The rest of the session will be devoted to a systematic discussion of each forecast variable and the associated uncertainty. Based upon the discussion of each factor, we will draw together the panel's collective views and then move on to the next forecast variable. Although we will use the materials in the packets to represent these views, we stress that no one is expected to be a statistician. What we are seeking is input based upon your own particular expertise. The tables and charts will simply provide a convenient framework for recording the results of our deliberations.

Again, thank you for your help. This is a challenging process and we look forward to an interesting and productive session.

Yours sincerely,

Richard Mudge
President
Apogee Research Inc.

David Lewis
Vice President
Thompson-Hickling Aviation Inc.

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ATTACHMENTS

- Technical Description of Variables
- Sample Data Sheet
- Blank Data Sheet

Introduction and Overview

Public works are both long-lived and far reaching in their influence on a region's economic and social makeup. Decisions on major public investments are rarely straight-forward. Many risks are involved; some of these are technical and involve forecasts about the future, while others reflect value judgments about the most desirable economic and social makeup of the region and about the willingness to bear more noise pollution or increased airport delays.

One thing is certain -- virtually every important forecast will be wrong to some degree. Knowing this, how should decision-makers (and their technical advisors) size-up the pros and cons of their investment choices? For example, how can the Minneapolis-St.Paul region best compare the long run adequacy of existing facilities with the merit of major expansion or even a new airport given the multitude of uncertainties about future traffic, possible improvements to physical capacity, economic interactions, and environmental constraints?

The MSP Adequacy Study recognizes these uncertainties explicitly by using a family of techniques called risk assessment. By attempting to measure the risks of each of the key factors that might influence a major investment decision the result will not be a single "take it or leave it" answer. Rather, the information necessary for an informed decision will be organized and presented in a systematic fashion.

For example, two key parts of the technical portion of the analysis -- the expected amount of traffic and the effective capacity of the airport system -- require long-term forecasts of economic, social, technical, and political forces. In most long-term planning efforts these forces are rolled into a single discrete forecast, or perhaps a set of discrete forecasts. Each of these forecasts result from a series of explicit and implicit decisions about the many variables that influence the forecast. Some are highly unlikely, for example, explosive traffic growth with no airport improvements.

Although this methodology of probable or expected outcome helps focus the decision making problem, it provides no guidance regarding the likelihood of that outcome, thereby leaving the community and its elected decision-makers with an incomplete view of the future.

A typical variation on the single "expected outcome" is a "high" and "low" case based on high and low variations to the forecast's underlying assumptions. This approach adds little information for decision-making, however, since it gives no indication of how likely it is that these high and low cases will actually materialize.

An equally significant shortcoming of this 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. In reality, of course, the likelihood that all underlying factors shift in the same direction is quite remote.

Probability provides a way around the forecasting conundrum outlined above. Probability measures the confidence or "odds" that an expected outcome will actually materialize. To understand how probability aids decision-making, consider a simple example. Before the advent of powerful computers, weather forecasters would simply assert their mean expectations -- "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 few dollars -- not to mention good will and tempers-- were lost.

It is clear that this style of risk assessment will greatly assist the MSP Region in the decision making process. The success of this analysis, however, hinges on defining accurate probability distributions. This involves three steps:

- o First, record the baseline assumptions for each forecast factor in a probability recording chart;
- o Second, define an initial probability distribution for each entry in the charts; and
- o Third, consult with groups of outside experts and revise initial distributions.

The first two steps have already been completed by the working group. The purpose of this technical memorandum is to consult with expert groups to develop "consensus probability distributions" for each forecast variable identified. In this manner, the working group expects to develop the most accurate probability statistics.

The panel of experts assembled have extensive experience in a range of fields including: economics, aviation technology, forecasting, decision making, etc. Although the individual expert may not fully understand all variables or confidently predict values for these variables, as a group, you can provide

the most accurate estimates for these distributions. For any variables that you might not fully understand, please begin to think of questions that should be addressed at the panel meeting in order to clarify these variables for you and other panel members.

The Need for Expert Opinion

You, the expert, are best qualified to provide the qualitative information necessary to complete our analysis. Your training, experience, and knowledge of the relevant facts and issues provide a database and analytical process which would be impossible to model. While individually you may not be able to fully predict future airport utilization, collectively your opinions will enable us to estimate the probabilities associated with expected outcomes.

Attached are data sheets that ask for information concerning a number of factors that will influence the adequacy of the MSP airport in future years. A detailed explanation of how to complete these forms follows below.

Completing the Expert Opinion Survey

When you predict a number, whether it be a football score or an economic parameter, there are two important pieces of information which describe that forecast:

- What you think the number will be, and
- How sure you are that you will be right.

If you think the odds are that your team will win, you may place a bet, but the size of the bet will be partially determined by your certainty. Similarly, airport planning depends on the probable future values of parameters affecting capacity.

In general, the potential values of a forecast will display a central tendency around a particular value, with greater or lesser values of the parameter having a relatively lower chance of occurring. Your predictions can be adequately conveyed to us through the following three numbers:

- Central Value - where your feeling is that the actual value of the parameter has an equal chance of being above or below this value.
- Upper Limit - where your feeling is that the actual value of the parameter has less than a 10 percent chance of being above this value.

- o Lower Limit - where your feeling is that the actual value of the parameter has less than a 10 percent chance of being below this value.

Please note that the upper and lower limits are not measures of your confidence in your central value prediction, but rather are your feelings about the uncertainty inherent in the prediction of the parameter. Typically, the lower and upper limits will diverge in successive years because forecasting further into the future is always less precise. To assist you in making your predictions, official forecasts of the central values have been included for comparison purposes.

The following example may help to clarify your role in our survey. The official forecast for average number of seats in an aircraft in the year 1993 is 96. However, you feel, as a result of your direct knowledge (or findings from the panel discussions) of the probable long term impact of deregulation, that this number is a little two low. You think the number is closer to 98 and thus set your central value to 98. Moreover, you feel that the average number of seats is more likely to be higher than this value than the potential for the number to be relatively lower. For this reason you set the upper limit to 107 and the lower limit to 93, with the result that your estimates are "stretched" towards higher values.

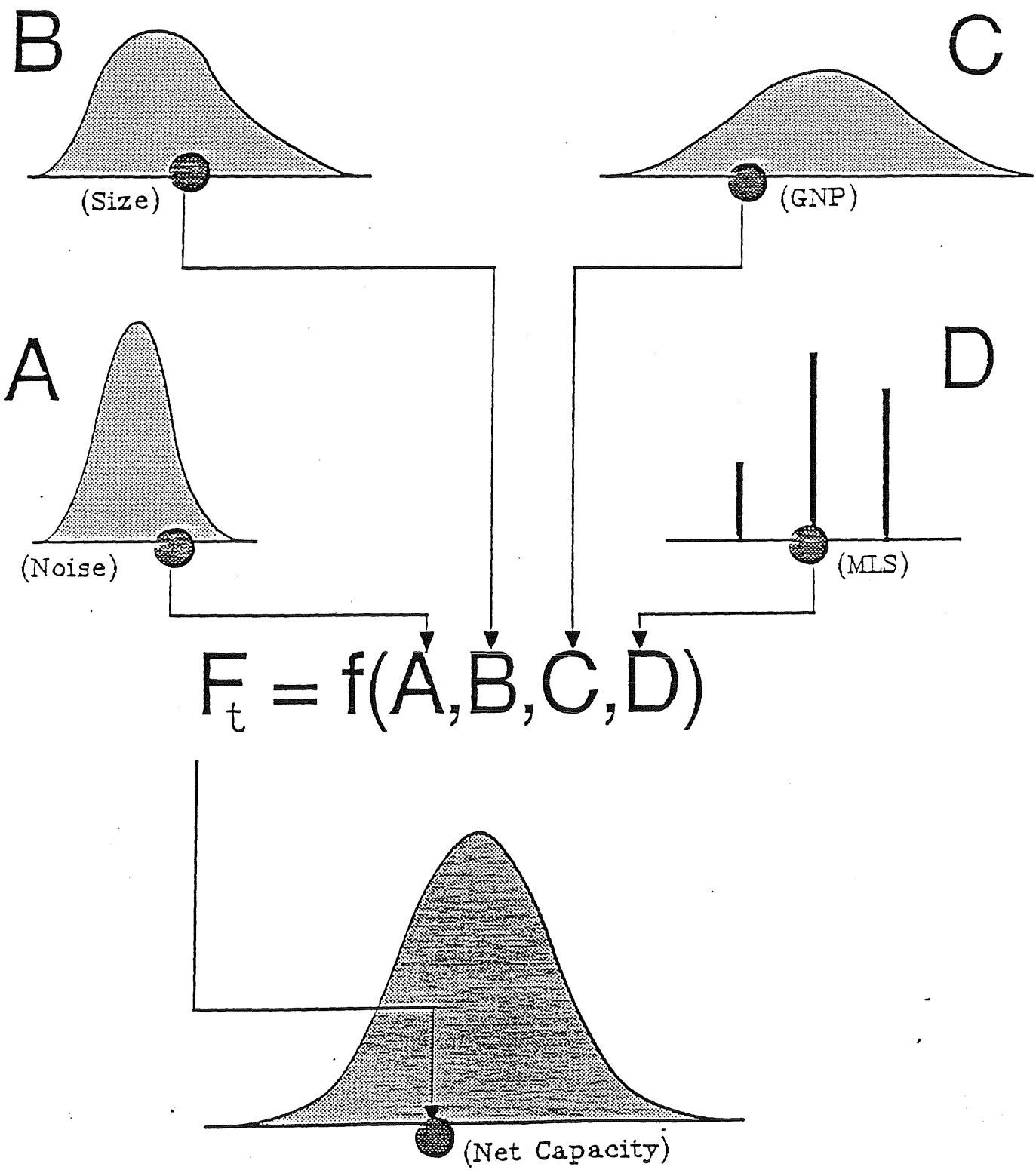
Statistical Interpretation of the Expert Opinion Survey

The role you are being asked to play is defined by the attached Figure 8 from Working Paper II. A forecasting model consists of input values (Size, GNP, Noise, MLS), output values (net capacity), and a model stating a precise relationship between input and output values (Net Capacity = f{Size, GNP, Noise, MLS}). The future values of the inputs must be projected before the model can make a projection of the output. A basic projection takes the single most likely future input values (the black dots) and produces a single number indicating the most likely output value (net capacity). However, under this method there is no indication of the degree of uncertainty associated with the forecast.

To obtain a measure of the degree of uncertainty, panelists will be asked to assess the uncertainty associated with the forecast of input values (the grey areas around the black dots). Your assessment of the input values will be combined with the model developed by Howard Needles Tammen & Bergendoff to produce an estimate of the uncertainty of the output values.

The technique by which you are providing information is firmly grounded in statistical theory. This appendix details the concept behind probability and its relationship to the expert

FIGURE 1: MONTE-CARLO SIMULATION:
A WAY TO COMBINE PROBABILITIES



opinion survey.

The well known, bell shaped, probability density function for the normal distribution is illustrated in Figure 1. Values of the parameter of interest are indicated along the horizontal axis. The probability of an occurrence between any two values is given by the area under the curve. For example, the probability of a value between -1.28 and 1.28 is 80 percent. This is commonly referred to as the 80 percent confidence interval.

The normal distribution is fully described by two parameters; one indicating the center of the distribution and the other indicating the amount of dispersion about the center. There are three ways of measuring central tendency:

- o **Mean** - the average of all possible values, weighted according to probability.
- o **Mode** - the value with the highest probability (the peak of the probability density function).
- o **Median** - the value which bisects the area under the probability density function such that there is an equal probability of higher and lower values occurring.

In the special case of the normal distribution, the mean, mode, and median are equal. As we will see later, this is not necessarily true for all distributions.

"Dispersion" describes the width of the range of probable values. There are two ways of measuring dispersion about the center:

- o **Variance** - is equal to the sum of the squared deviations form the mean divided by one less than the number of observations.
- o **Standard Deviation** - is equal to the square root of the variance.

In a standard normal distribution the mean, mode, and median are all equal to zero and the standard deviation is equal to one. Because a great deal is known about the behavior of the standard deviation of a normal distribution, it is a very useful distribution for analysis. Normal distributions with different means and standard deviations can, for example, be easily transformed into a standard normal distribution for analytical purposes.

A variation on the probability density function (PDF) in Figure 2 is the cumulative density function (CDF) of Figure 3. Mathematically the CDF is the integral of the PDF, and the PDF is the derivative of the CDF. This means that a point on the CDF curve represents the area under the PDF curve from negative infinity to that value of the parameter. In other words, the CDF gives the probability of values occurring which is less than or equal to the specified value.

Often probability distributions are assumed to be normal, when they are considered at all. This is partially because the normal distribution does describe a wide range of events, but mostly because the distribution is well understood and easy to apply. In this study we have avoided the assumption of normality because we feel that it is not appropriate for many parameters.

Distributions which are not normal, as shown in Figure 4, are described by two parameters in addition to the measure of central tendency and dispersion. These are:

- o **Skewness** - Measure of the asymmetry of the density function. A high skew indicates that one side is larger than the other.

- o **Kurtosis** - Measure of the shape of the density function. A high kurtosis indicates a relatively thin density function with heavy tails.

A normal function has a skewness parameter equal to zero and a kurtosis parameter of approximately three.

In distributions which are skewed, the mean, mode, and median are not equal. Therefore, the measure chosen to describe a particular distribution is somewhat arbitrary. For the purposes of the MSP Adequacy study we have asked you to provide estimates of the median in the attached survey, as this measure is best suited to our needs.

FIGURE 2. NORMAL PROBABILITY DENSITY FUNCTION (PDF)

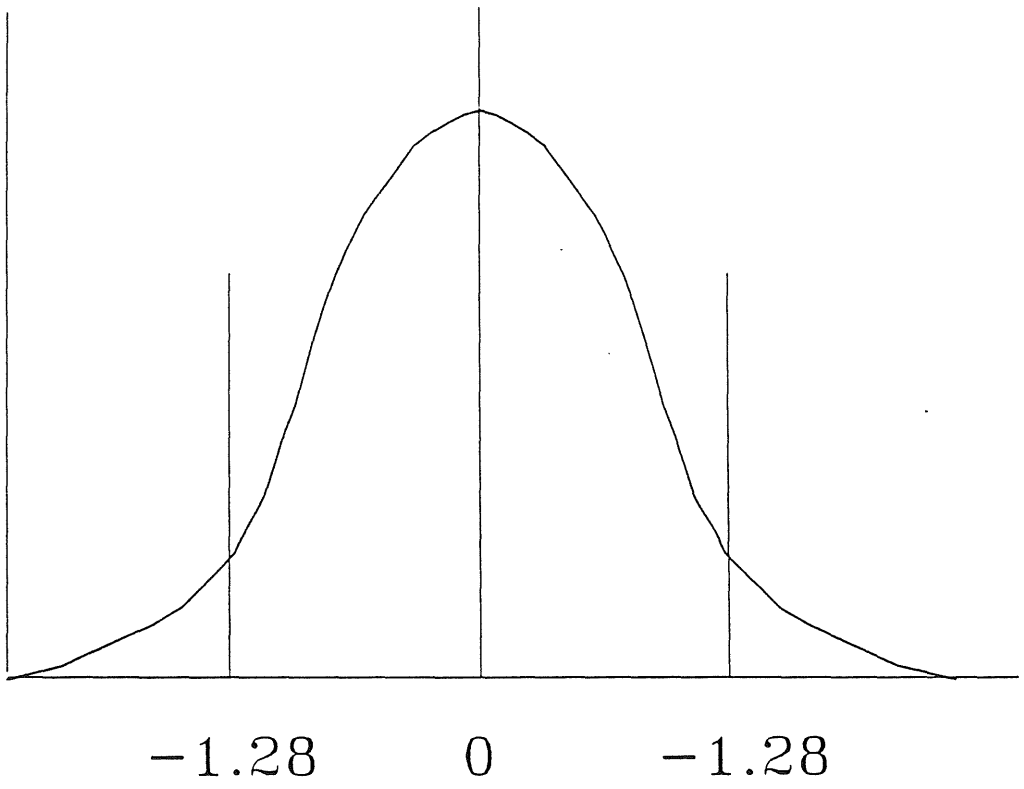


FIGURE 3. NORMAL CUMULATIVE DENSITY FUNCTION (CDF)

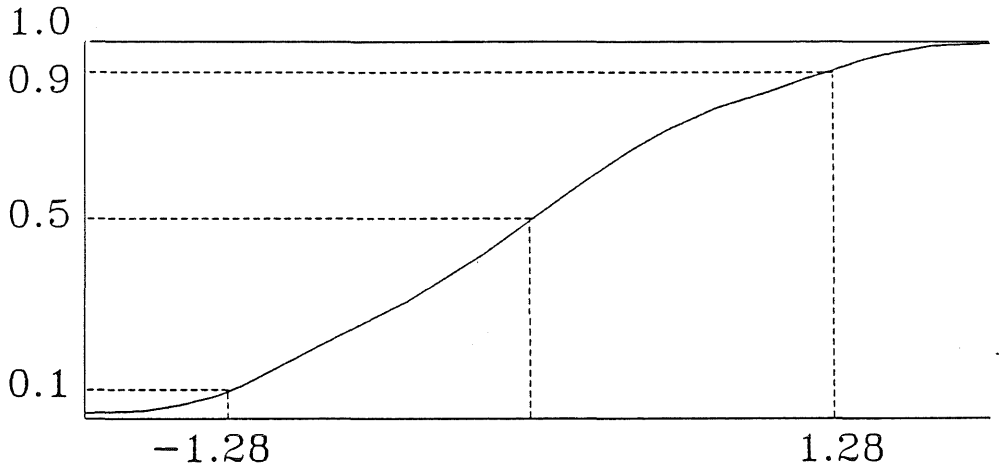
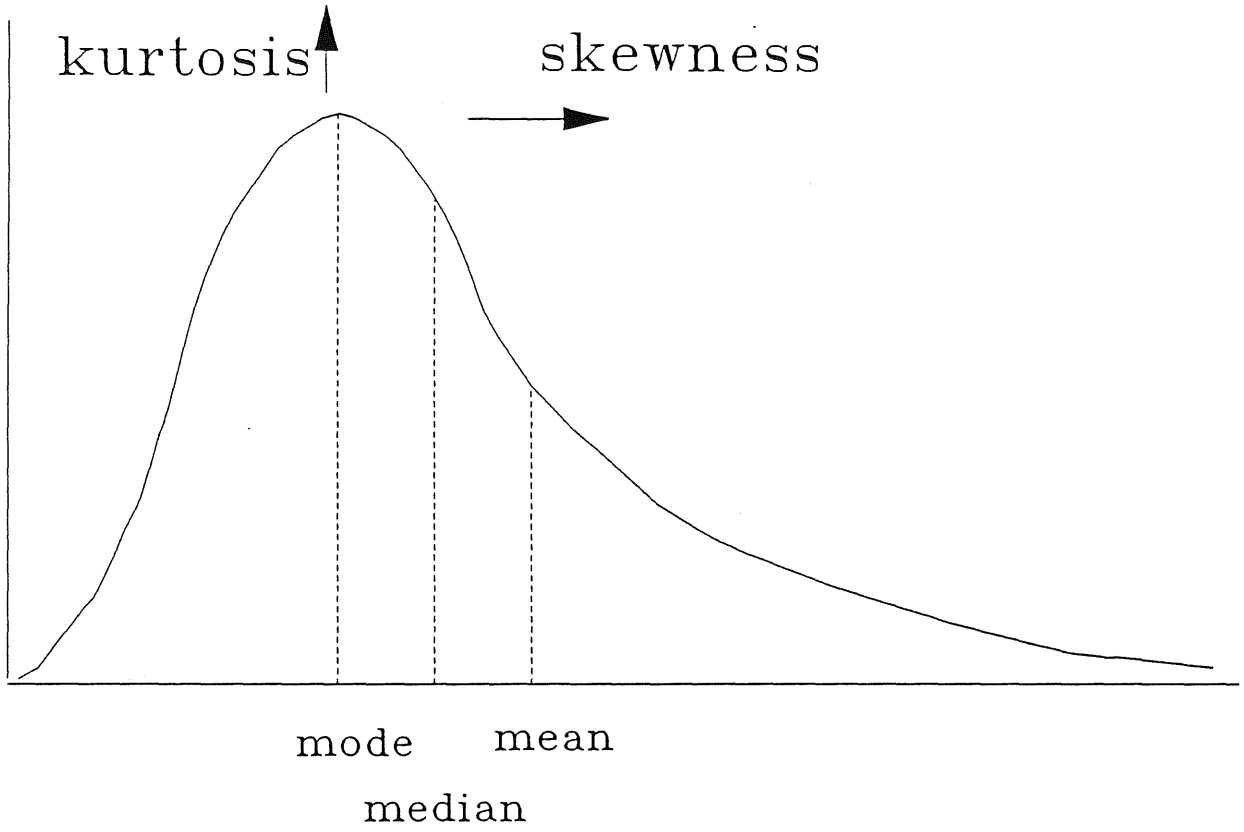


FIGURE 4. NON-NORMAL DISTRIBUTION



Panelists will be able to influence skewness in their choice of the 10% upper and lower limits. A larger upper limit will flatten out the upper side of the distribution, skewing the distribution to the lower end. Panelists familiar with statistics should note that because we are using the median for a central value rather than the mean, the probability of the forecast value falling below the central value is always 50%, regardless of the skew.

The choices panelists make will not influence kurtosis.

Use of the Expert Opinion Survey

The information which you will provide in this survey will allow us to develop an appropriate non-normal PDF and CDF for each parameter in each year. This will be done by plotting your information and fitting a CDF curve to it. A PDF curve can then be developed from the CDF curve. The CDF function will allow uniformly distributed random numbers (which are easily generated by a computer program) to be transformed into random numbers distributed according to the distribution which you have defined for parameters in this survey. These distributions will be used as input to the Monte Carlo analysis described in Working Paper II.

Forecast Factors and Logic Models of the Howard Needles Tammen and Ergendoff Forecast

A major step in the process of forecasting air traffic at the Minneapolis-Saint Paul International Airport is to quantify the base case and probability function for each of the forecast factors. In the MSP Airport Master Plan Update separate forecasts were made for air carrier, regional carrier, cargo, general aviation and military, each with their own independent variables. As the relationships are quite complicated and lengthy, we have developed structure and logic diagrams that will help panelists put each factor in context. On the following pages a structure and logic diagram and a table are provided for each major category of traffic.

The table considers four aspects of the forecast. First, it lists the input factors used such as MSA population, MSA employment and average airline revenue per passenger. Next, it presents the output resulting from the input factors. Some examples of outputs are air carrier originations, enplanements and aircraft operations. Any assumptions that were made about the behavior of the input factors or the model are described in the next column. Assumptions were often made about growth rates,

load factors, and North Western Airlines' activity. Finally, any other factors that were believed to also have an effect on the outputs were also listed.

From the table it can be seen that outputs from one step of the forecast often become inputs for the next. The purpose of the logic and structure diagrams is to illustrate more clearly how the different factors (inputs, outputs, assumptions and other factors) integrate with one another and into the forecast model itself.

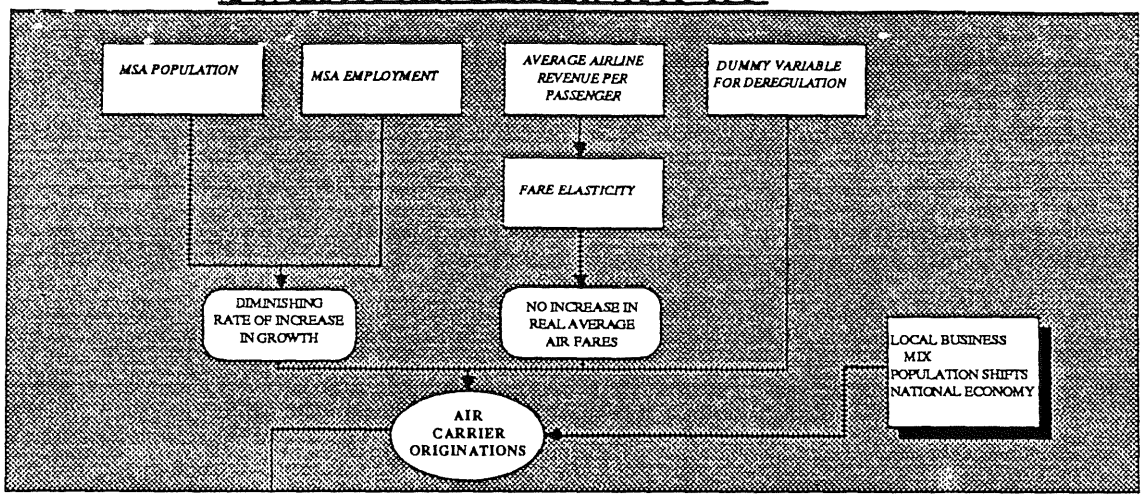
The models may be broken into two sections. The first represents the econometric model, a statistical relationship between historical traffic and variables thought to affect traffic growth. The second is called accounting-type factors. This section illustrates the factors which are multipliers used to adjust outputs to future levels.

FORECASTS FOR DOMESTIC AIR CARRIERS

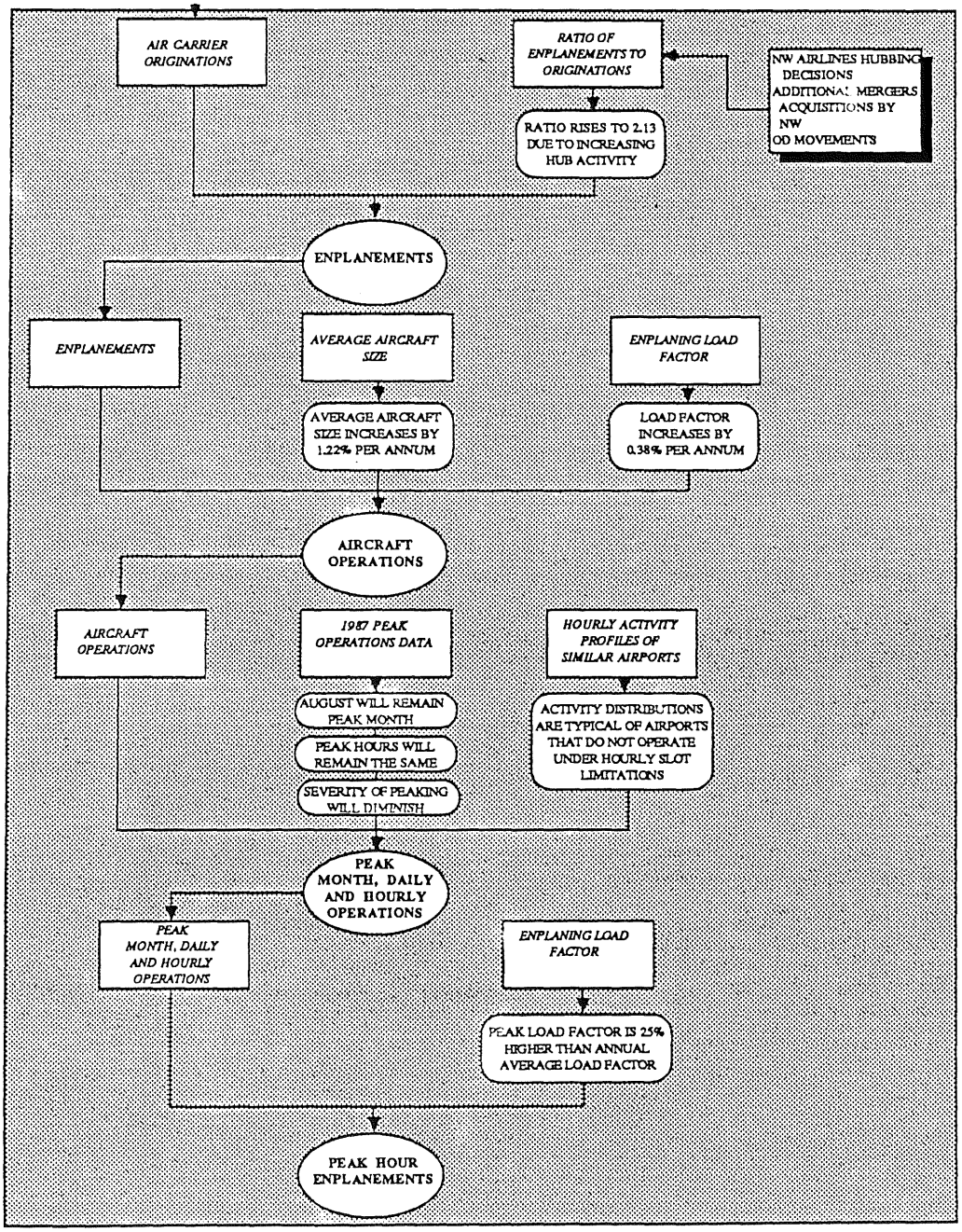
INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
MSA population MSA employment Average airline revenue per passenger ($1972) Dummy variable for deregulation	Air carrier originations	Economic/demographic projections assume continuous growth but at a diminishing rate of increase. No increase occurs in the 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.

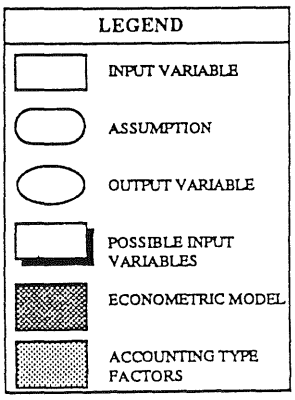
LOGIC MODEL FOR HNTB FORECASTING MODEL (DOMESTIC AIR CARRIER ACTIVITY)



ECONOMETRIC MODEL



ACCOUNTING TYPE FACTORS

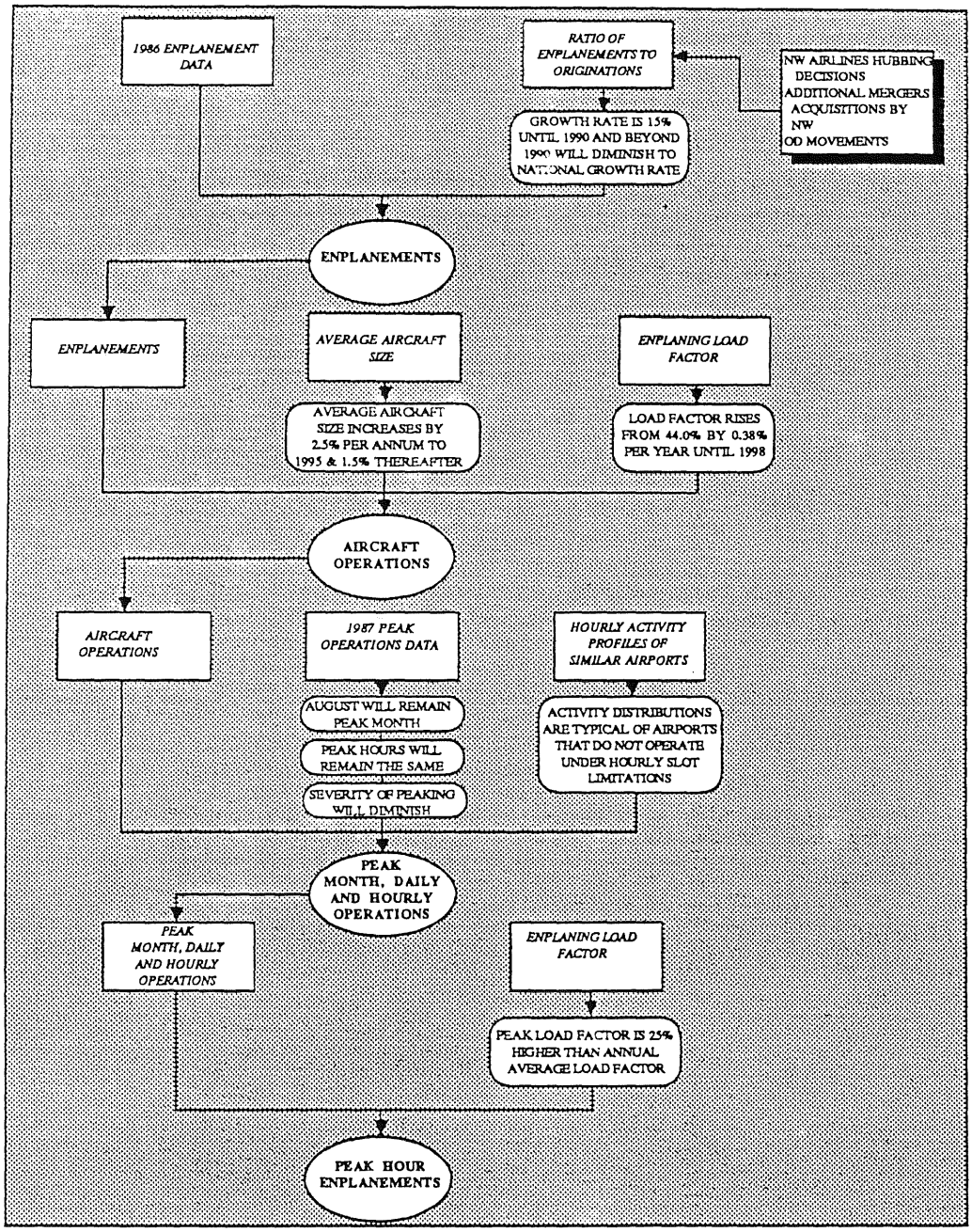


FORECASTS FOR REGIONAL CARRIER ACTIVITY

INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
1986 enplanement data Growth rates	Regional Air Carrier Enplanements	Enplanements would continue to grow at 15% per year through 1990. Beyond 1990 the growth rate will diminish to the national growth rate forecasted by the FAA.	OD movements Local business mix Population shifts National economy
Enplaning load factor Average aircraft size	Enplanements per departure	Enplaning load factor rises from 44.0% (1985 historical rate) by 0.38% per year until 1998. Average MSP turboprop aircraft will increase its size by 2.5% annually through 1995. Beyond 1995 growth rate is lower at 1.5% per year.	
Enplanements per departure Regional Carrier Enplanements	Departures		
Annual departures 1987 data on peak operations	Peak month, daily and hourly operations	August will be the peak month with 9.74% of the annual operations. August peak will decline to 9.06% of annual operations. In projecting future houlrly activity, the severity of the existing hourly fluctuations was reduced in an attempt to develop a pattern of regional carrier activity that would correspond to that of the air carriers.	
ak houly operations nplaning 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, Feruary 1988 prepared by Howard Needles Tammen & Bergendoff.
MSA defines the Minneapolis-Saint Paul metropolitan statistical area.

LOGIC MODEL FOR HNTB FORECASTING MODEL (REGIONAL CARRIER ACTIVITY)



FORECASTS FOR NON-SCHEDULED ACTIVITY

INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
Average enplanements for 1981-1986 (50,549) Growth rate	Non-sceduled enplanements	Average enplanements grows at an annual rate of 2% throughout the study period.	
Enplanements Average enplanements per departure (111)	Operations	Average enplanements per departure grows at 1.5%	

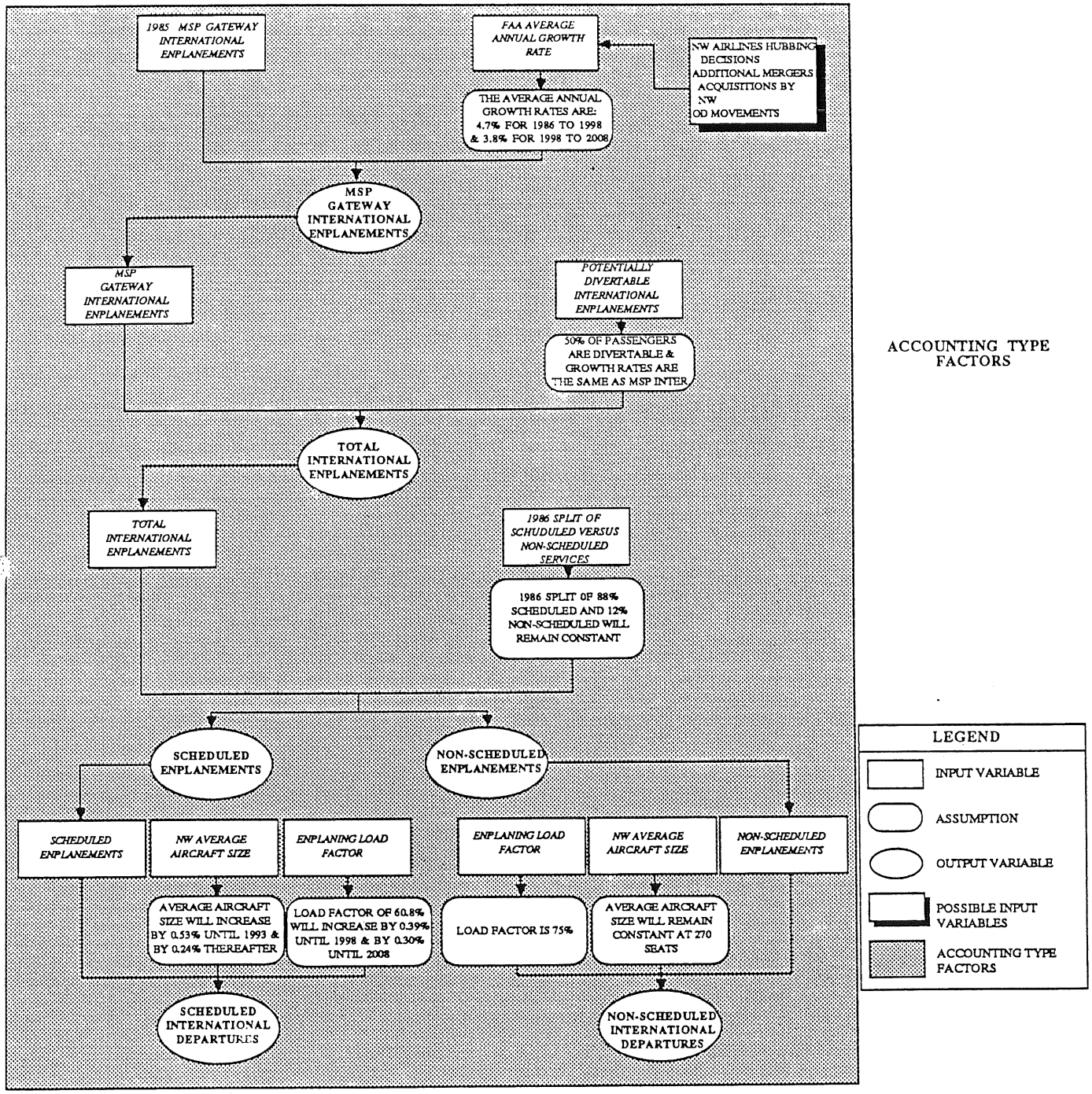
NOTES: The forecast methodology is from the Minneapolis-Saint Paul International Airport Master Plan Update, February 1988 prepared by Howard Needles Tammen & Bergendoff.
MSA defines the Minneapolis-Saint Paul metropolitan statistical area.

FORECASTS FOR INTERNATIONAL ACTIVITY

INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
1985 MSP gateway international enplanements FAA estimates of of average annual growth	MSP gateway international enplanements	The average annual growth rates are: 4.7% for 1986 to 1993, 4.7% for 1993 to 1998, 3.8% for 1998 to 2008. The higher growth rates in international enplanements compared with domestic, is consistent the assumption that NW will develop more domestic feed to MSP as an international gateway hub for its Pacific and/or North Atlantic routes.	
Potentially divertable international enplanements from other gateway cities MSP international enplanements	Total international enplanements	50% of the passengers using other North American gateways are potentially divertable to MSP. Potentially divertable passengers grows at the same rate as MSP international enplanements. NW actually diverts an increasing share of these passengers to MSP.	
Total international enplanements 1986 split of scheduled vs. non-scheduled services	Scheduled enplanements versus non-scheduled enplanements	1986 split of 88% scheduled and 12% non-scheduled will remain constant in the future.	
NW average aircraft size 1986 enplaning load factor	Enplanements per departure for scheduled enplanements	Because of NW's dominance of scheduled services, scheduled enplanements are converted into departures using NW operational factors. NW 1986 load factor of 60.8% will increase by 0.39% for 1986 to 1998 and by 0.30% for 1998 to 2008. Average aircraft size of 395 (1986) will increase by 0.53% for 1986 to 1993 and by 0.24% thereafter.	
Enplanements per departure for scheduled enplanements Scheduled enplanements	Scheduled international departures		
Non-scheduled international Average Aircraft Size Enplaning load factor	Non-scheduled international departures	Non-scheduled departures are estimated using the equivalent of a D10 aircraft (270 seats) operating at a 75% enplaning 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.

LOGIC MODEL FOR HNTB FORECASTING MODEL (INTERNATIONAL ACTIVITY)

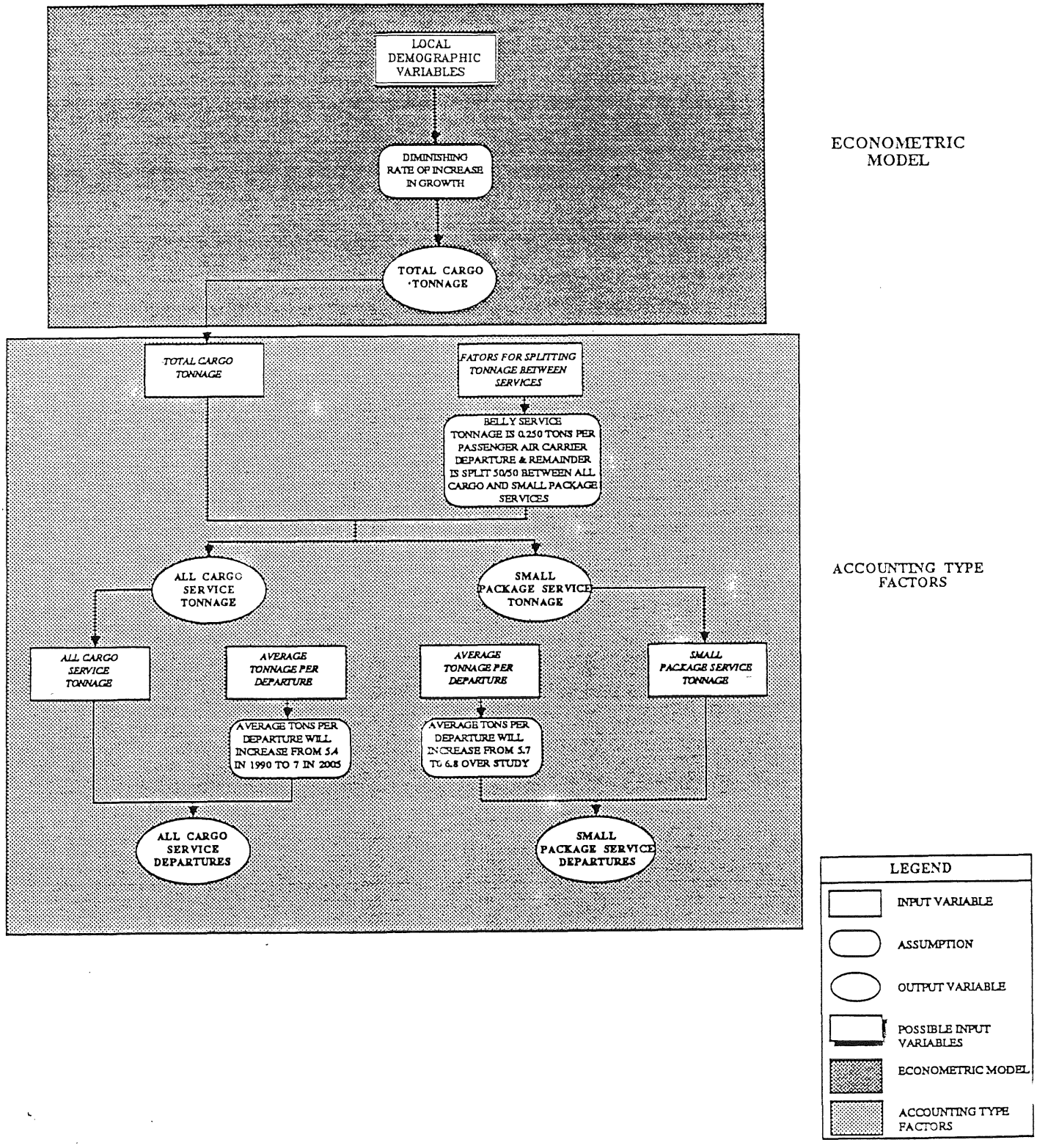


FORECASTS FOR CARGO AND MAIL ACTIVITY

INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
Local area demographic variables	Total cargo tonnage	Economic/demographic projections assume continuous growth but at a diminishing rate of increase.	
Total cargo tonnage Factors for splitting tonnage between services	Belly service tonnage All cargo service tonnage Small package service tonnage	A factor of 0.250 tons per passenger air carrier departures was used to estimate tonnage attributable to belly service Remainder of tonnage was allocated 50/50 between all-cargo and small package services	
All cargo service tonnage Average ton per departure	Departures associated with all cargo sevice	Since the tonnage attributable to passenger air carrier activity and mail will move in the belly of passenger flights there will be no additional departures associated with air carrier tonnage Average tons per departure will increase from 5.4 in 1990 to 7 in 2005 to reflect the use 727-200's & 727-100's	
Small package service tonnage Average ton per departure	Departures associated with small package service	Average tons per departure is increased from 5.7 to 6.8 over the study period	

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.

LOGIC MODEL FOR HNTB FORECASTING MODEL
(AIR CARGO ACTIVITY)

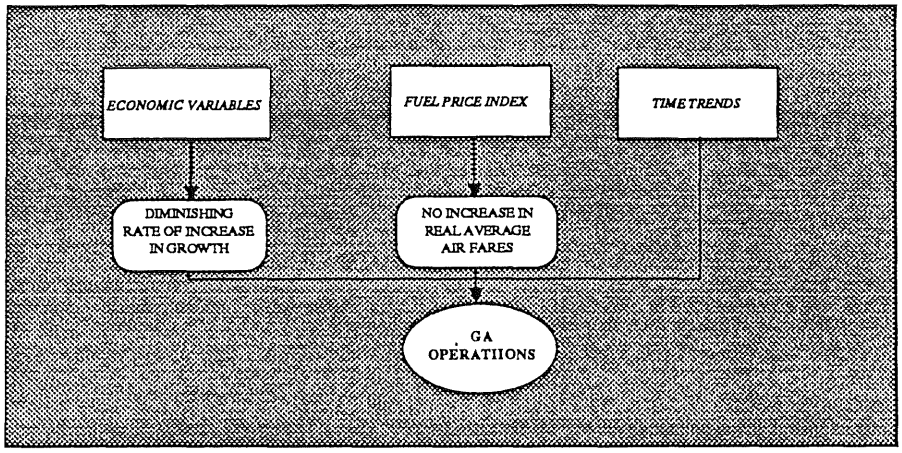


FORECASTS FOR GENERAL AVIATION ACTIVITY

INPUTS USED	OUTPUTS	ASSUMPTIONS	OTHER FACTORS
Economic variables Fuel price index Time trend analysis	GA operations	Economic/demographic projections assume continuous growth but at a diminishing rate of increase. No change in the real price of fuel Airport's policy of encouraging GA users to relocate to other airports will continue	

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.

LOGIC MODEL FOR HNTB FORECASTING MODEL (GENERAL AVIATION ACTIVITY)



ECONOMETRIC MODEL

LEGEND

- INPUT VARIABLE
- ASSUMPTION
- OUTPUT VARIABLE
- POSSIBLE INPUT VARIABLES
- ECONOMETRIC MODEL

TECHNICAL DESCRIPTION OF VARIABLES

SAMPLE DATA SHEETS

BLANK DATA SHEETS

EXPLANATION OF VARIABLES AND SAMPLE DISTRIBUTIONS FOR PANELISTS

For each variable that panelists are being asked to consider, we have attached a description and examples of 10 percent limits. The description is broken into the following headings:

- Description
- How the Variable Affects Traffic
  An explanation of how the variable fits into the air traffic forecasting model developed by Howard Needles Tammen & Bergendoff (HNTB).
- Baseline Assumptions
  The assumptions upon which HNTB based their projections of this variable.
- Major Uncertainties
  Some suggested considerations for panelists in revising forecast values and setting the 10 percent limits. Note that these are only suggestions for initiating discussion. Panelists are encouraged to follow their own thought and experience.
- Upper and Lower 10% Limits
  An indication of how the example 10 percent limits (as demonstrated in the sample data sheets) were derived.

It must be stressed that the example 10 percent limits are **for illustrative purposes only.** They were developed using only immediate materials at hand and are intended solely as starting point for discussion. For instance, none of the attached examples altered the forecast of median values, but panelists should feel free to do so.

The example 10 percent limits are accompanied by graphs illustrating past values and projected future median values.

A technical possibility that some panelists may wish to consider deals with "skewness". Some of the examples place one boundary further from the median than the other boundary. This indicates a greater probability on one side of the distribution, but introduces a "skew" in the shape of the implied distribution. (If the upper boundary is further from the median, the skew is towards the lower boundary.) Panelists may prefer to move the median in a direction they think more probable or revise the boundaries so that they are even on both sides and the distribution is shaped more symmetrically.

Finally, note that the figures for 2018 were not projected in the HNTB study, but are provided in the example sheets.

Except where specified, the 2018 median values are obtained by assuming a constant average growth rate derived from the previous years' projected values.

VARIABLE:
POPULATION OF MINNEAPOLIS - SAINT PAUL (MSP)

Description

The population of Minneapolis - Saint Paul and surrounding municipalities making up the U.S. Dept. of Commerce Metropolitan Statistical Area (MSA).

How the Variable Affects Air Traffic

More people generates greater economic activity, which in turn generates a greater demand for air travel. This variable enters into the determination of air travel originating locally (Air Carrier Origination).

Baseline Assumptions

The projected values are drawn from U.S. Dept. of Commerce 1985 OBERS BEA Regional Projections, 1985. The value for 2018 is derived using a constant average growth rate derived from the previous year values.

Major Uncertainties

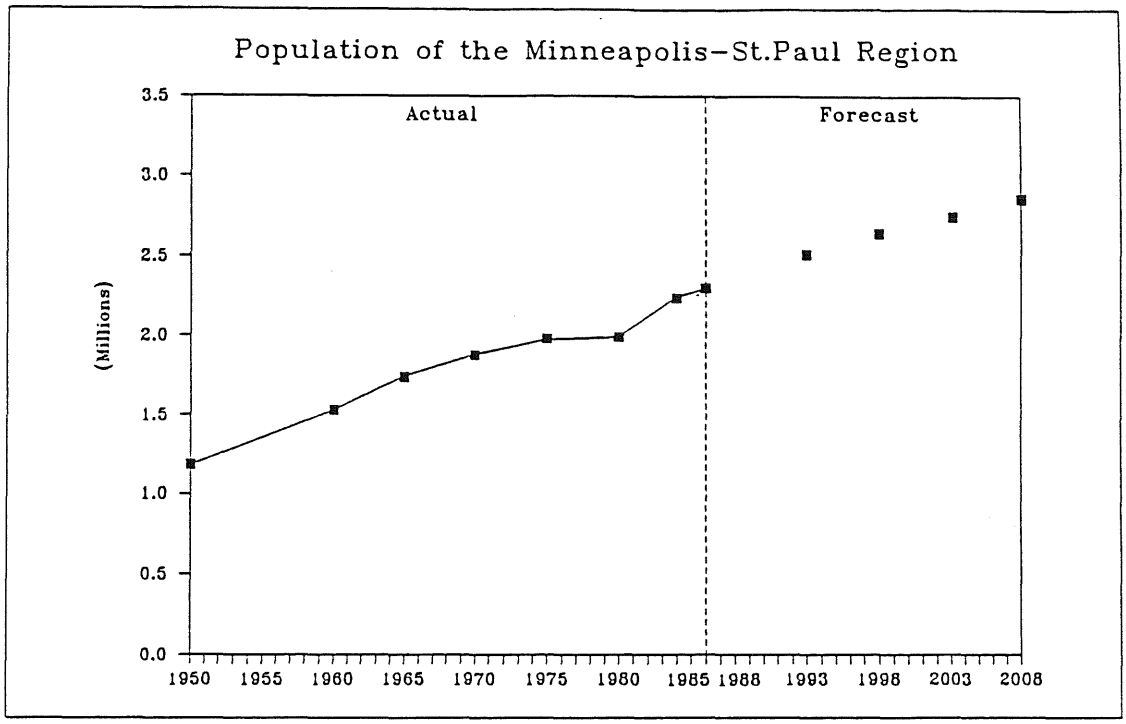
Population projections tend to be relatively stable. The chief factor of instability in regional projections stems from economic activity in a region being more or less active than the national average. This attracts new population or causes population to migrate. Some considerations are:

- Do U.S. Dept. of Commerce forecast methodologies for population have known weaknesses in their methodology?
- Are there dominant economic sectors in the MSP area which can lead to regional booms or recessions that are either independent of the national economy or more severe than the national economy? Will this change the median or introduce greater variability?
- The Dept. of Commerce projects that the Minneapolis - Saint Paul MSA will experience an average annual population growth of 1 percent over the next 20 years. The national figure is 0.67 percent. Panel members are encouraged to draw on personal expertise with respect to demographic and economic trends of the MSP region.

Example Upper and Lower 10% Limits

The example upper and lower limits were set according to arbitrary risk which grew over time. For each successive year the limits are set at plus or minus 1%, 2%, 3%, 4%, and 6%.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	2295.1	---	---	---
1993	2506.9	NO CHANGE	2481.8	2532.0
1998	2639.4	"	2586.6	2692.2
2003	2754.3	"	2662.9	2827.7
2008	2855.9	"	2741.6	2970.1
2018	---	3212.3	3019.6	3405.1

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

VARIABLE:
MSA PER CAPITA INCOME

Description

This is the average income per person in the Minneapolis-Saint Paul Metropolitan Statistical Area (MSA), after adjusting for inflation.

How the Variable Affects Air Traffic

Higher income per person for a given size population means greater economic activity, which in turn generates a greater demand for air travel. This variable is one of those used to determine the number of local trips (Air Carrier Originations).

Baseline Assumptions

The projected values are drawn from U.S. Dept. of Commerce 1985 OBERS BEA Regional Projections, 1985 and Economic Report of the President, January 1987. The value for 2018 is derived using a constant average growth rate derived from the previous year values.

Major Uncertainties

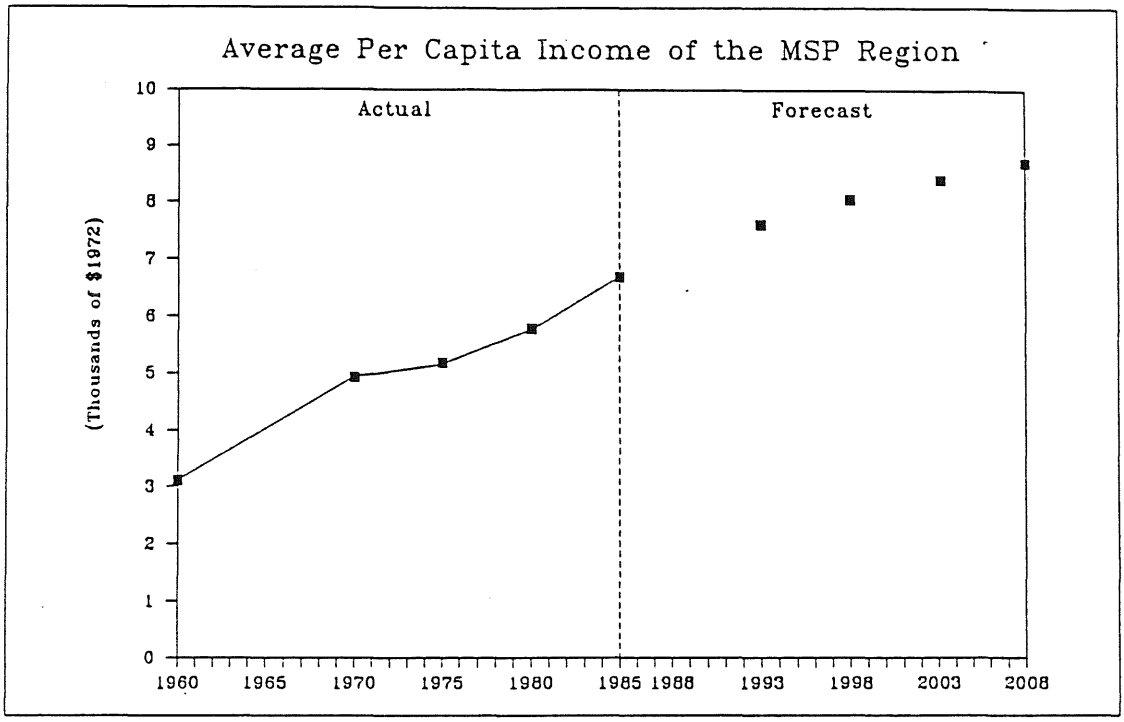
Per capita income growth is relatively stable over the long run, but there may be greater short term variation due to recessions and booms. Some considerations are:

- Do U.S. Dept. of Commerce forecast methodologies for per capita income have known weaknesses in their methodology?
- Are there dominant economic sectors in the MSP area which can lead to regional booms or recessions that are either independent of the national economy or more severe than the national economy?
- The Dept. of Commerce forecasts an annual growth of real per capita income of 1.16 percent over the next twenty years, compared to 1.62 percent nationally. This lower rate may be tied to the higher population growth rate, implying an age distribution among the local population at variance with national averages.

Example Upper and Lower 10% Limits

The example upper and lower limits were set according to arbitrary risk which grew over time. For each successive year the limits are set at plus or minus 1%, 2%, 3%, 4%, and 6%.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1985	6680	---	---	---
1993	7620	NO CHANGE	7544	7694
1998	8052	"	7891	8213
2003	8379	"	8127	8630
2008	8707	"	8359	9055
2018	---	10,116	9508	10.722

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

VARIABLE:
EMPLOYMENT

Description

The number of people working in the Metropolitan Statistical Area (MSA) of Minneapolis - Saint Paul (MSP). This area includes a list of surrounding municipalities defined by the U.S. Dept. of Commerce.

How the Variable Affects Air Traffic

More people working indicates greater economic activity and a greater demand for air travel. In the HNTB model, local employment is a key variable determining the number of people boarding aircraft who are starting their trips from MSP (Air Carrier Originations).

Baseline Assumptions

The projected values are drawn from U.S. Dept. of Commerce 1985 OBERS BEA Regional Projections, 1985 and Economic Report of the President, January 1987. The value for 2018 is not provided by the HNTB model. It is calculated using a constant average growth rate derived from the previous year values.

Major Uncertainties

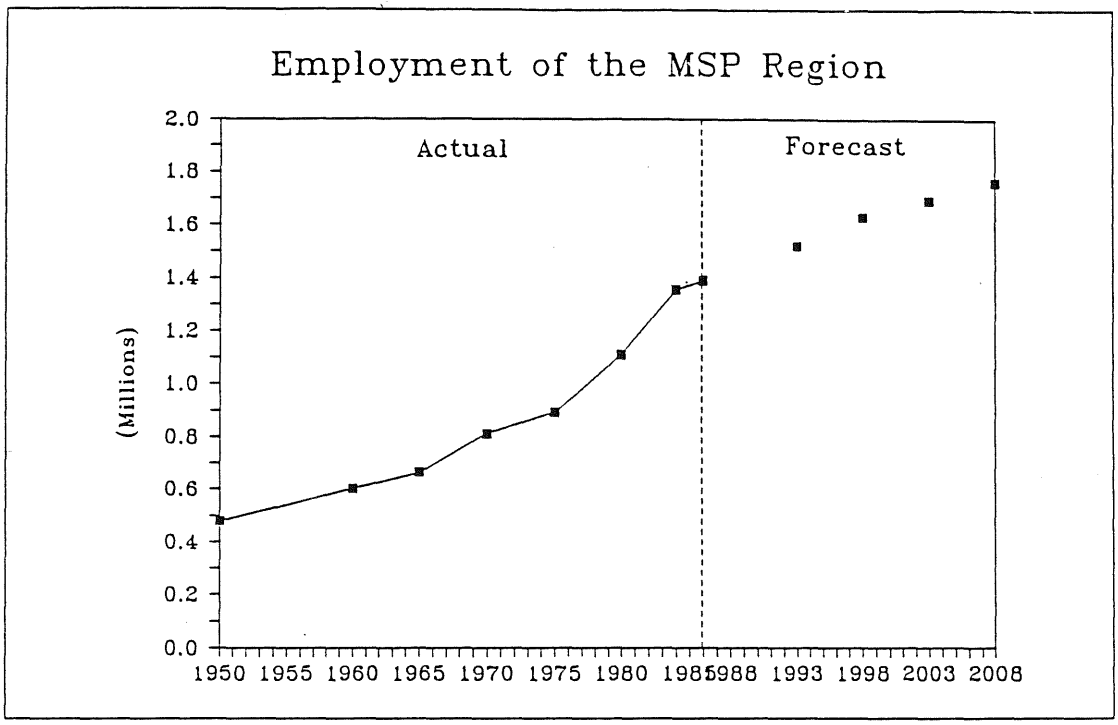
Some considerations:

- Do U.S. Dept. of Commerce forecast methodologies for employment have known weaknesses in their methodology?
- Are there dominant economic sectors in the MSP area which can lead to regional booms or recessions that are either independent of the national economy or more severe than the national economy? If so, what impact does this have on the median, and on uncertainty?
- The Dept. of Commerce forecasts an annual growth of employment 1.08 percent over the next twenty years, compared to 1.13 percent nationally. At the same time, population is projected to expand at a higher rate than the national average, implying an age distribution among the local population at variance with national averages.
- In the long term, employment is largely determined by population, which is very stable and relatively easy to predict. Everyone who will be over 20 twenty years from now is alive today. However, at any given moment there is the possibility of a recession or a boom. Does the level of uncertainty in the 10 percent limits adequately account for this?

Example Upper and Lower 10% Limits

The limits are placed equi-distant from the forecast median, indicating a symmetrical distribution. Their range increases over time to indicate increasing uncertainty. The size of the range is arbitrary.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1987	1388.9	---	---	---
1993	1519.2	NO CHANGE	1443	1595
1998	1628.5	"	1535	1722
2003	1693.2	"	1582	1804
2008	1760.4	"	1627	1893
2018	---	2007	1807	2208

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

VARIABLE:
GROSS NATIONAL PRODUCT

Description

Gross National Product is the total dollars of income earned by everyone in the United States. The figures here are "real" gross national product, meaning that they have been adjusted to remove the effects of inflation. GNP is a measure of U.S. economic activity.

How the Variable Affects Air Traffic

Although the level of economic activity affects the demand for air travel, the GNP is not a direct input to the HNTB model.

Baseline Assumptions

Change in GNP is based on U.S. Congressional Budget Office projections which project a real rate of growth in GNP of between 2.6 percent and 3.1 percent for the years 1986 to 1991, and 2.5 percent for each year thereafter.

Major Uncertainties

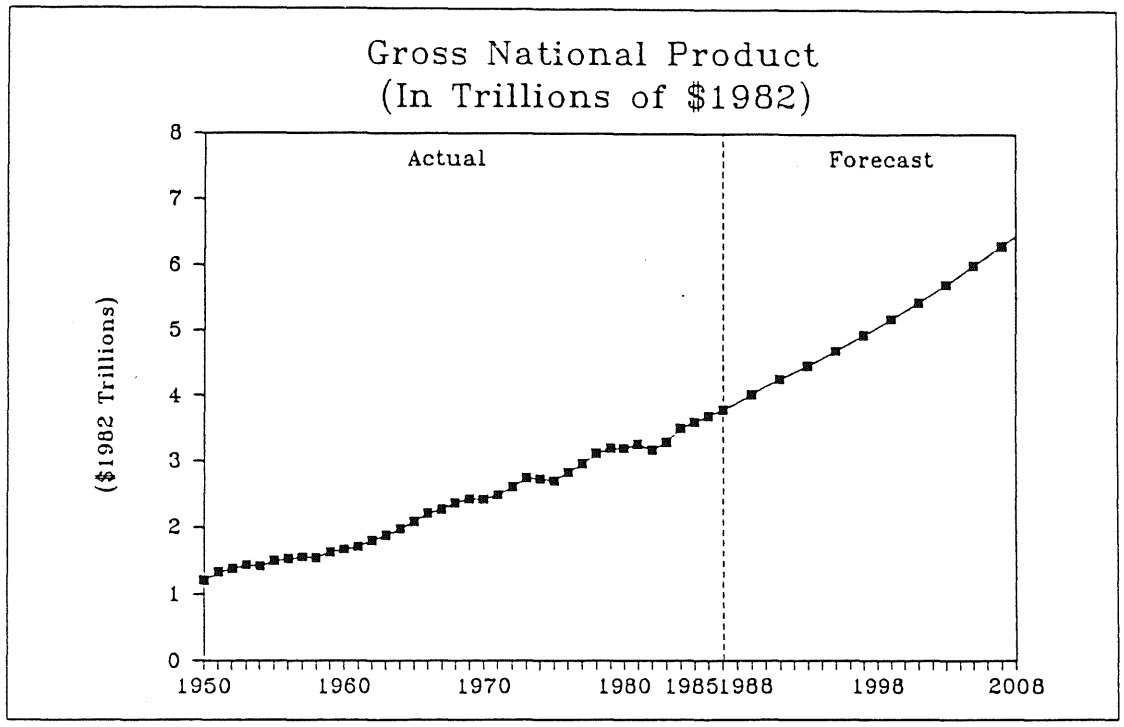
Some considerations:

- Is growth sustainable?
- Will the new lower exchange rate regime trigger higher than projected growth rates?

Example Upper and Lower 10% Limits

The example limits portray a symmetric distribution. Their range expands to indicate increasing uncertainty over time.

DATA SHEET



YEAR	FORECAST (Billions)	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	3677	---	---	---
1993	4460	NO CHANGE	4237	4683
1998	5047	"	4714	5380
2003	5710	"	5213	6207
2008	6460	"	5718	7202
2018	---	8269	6615	9923

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

VARIABLE:
RATIO OF ENPLANEMENTS TO ORIGINATIONS

Description

The total number of people getting on planes (enplanements) is made up of people starting their trips from Minneapolis-Saint Paul International (the number of Air Carrier Originations), and people transferring between flights. The ratio between people starting their trips and the total number of people enplaning is called the Ratio of Enplanements to Originations.

How the Variable Affects Air Traffic

The HNTB model makes use of the ratio (k) as follows:

If: k = Enplanements/Originations

then: Enplanements = k * Originations

This means that total enplanements may be imputed by multiplying the estimate of the Air Carrier Originations by a projected Ratio of Enplanements to Originations.

Baseline Assumptions

The ratio for Minneapolis - Saint Paul International is currently below the average of similar airports. The HNTB model assumes that the ratio of enplanements to originations (1.91) will converge to the average ratio of similar airports (2.13) and that this average will remain constant thereafter. This movement is justified by noting a general tendency of these ratios at other airports to move towards the mean in the recent past.

Major Uncertainties

Some considerations:

- Air traffic originating outside of Minneapolis - Saint Paul (MSP) is influenced by national economic activity. If economic growth or population growth in the MSP area diverges either from the national average, this will affect the ratio of enplanements originating in MSP versus those originating elsewhere.

- Is there reason to assume that the Minneapolis - Saint Paul International ratio will move all the way to the mean? At any given year there will be airports above and below the mean. Are there causative factors that keep MSP below the mean now that will last into the future?

- Is the current forecast warranted by NW merger and hubbing expectations? If there are major future decisions which

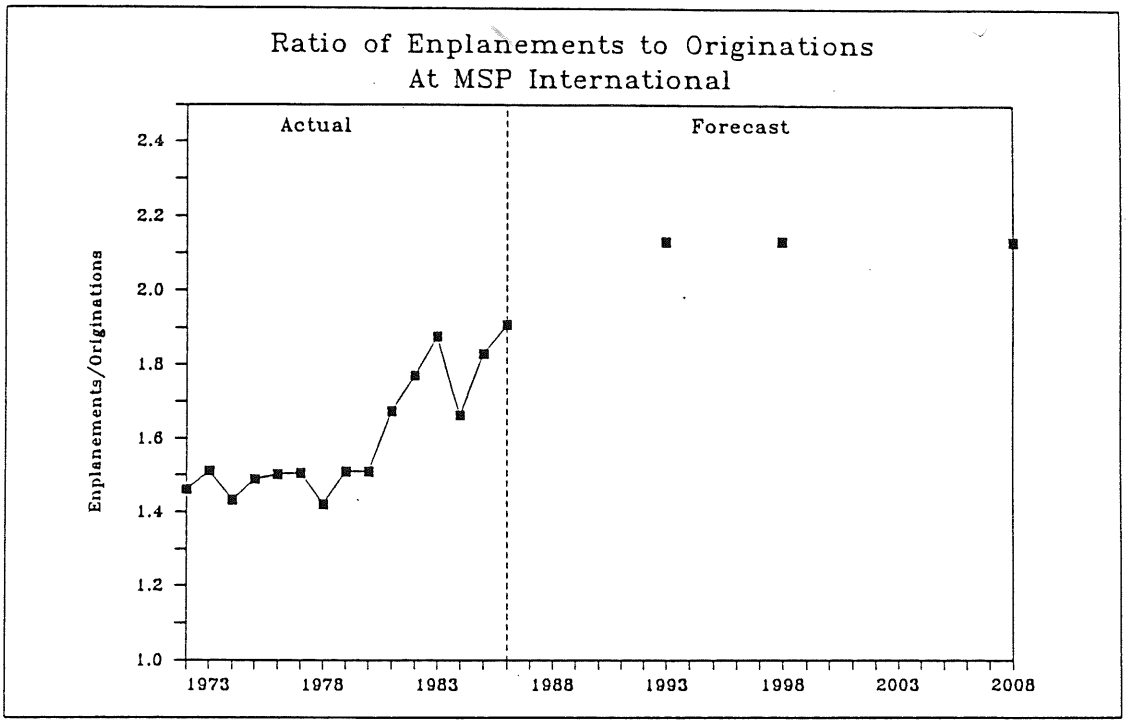
will affect the ratio of enplanements to originations, do they bring about a leftward or rightward skew?

- "Through" passengers are those who stay on the plane rather than disembark and transfer to another flight. Will increased routing efficiency lead to more through passengers, fewer non-originating enplanements and a lower ratio?

Example Upper and Lower 10% Limits

The lower limits are further from the projected median than the upper limits to indicate a skewness towards the ratio staying at its status quo. The limits expand over time to indicate increased uncertainty. The degree of their spread is arbitrarily chosen.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	1.91	---	---	---
1993	2.13	NO CHANGE	1.75	2.20
1998	2.13	"	1.70	2.22
2003	2.13	"	1.65	2.24
2008	2.13	"	1.60	2.26
2018	---	2.13	1.50	2.30

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

VARIABLE:
AVERAGE AIRCRAFT SIZE

Description

The average number of seats is a weighted average estimate of the number of seats available per air carrier departure based on the type and frequency of departures. The MSP average, 139, is considerably lower than the national average, 151. This may be due the nature of demand for MSP's primary service area, which includes not only the metropolitan area, but also many of the upper mid-west regions.

How the Variable Affects Air Traffic

Arrivals and Departures are a key workload measure for airports. Because one of the potential constraints to capacity is the number of operations (not the passengers per operation), the average number of seats per operation will have a direct impact on the passenger capacity of a given facility. Alternatively, bigger aircraft mean fewer arrivals and departures for a given number of passengers. This variable is used to convert the number enplanements (passengers boarding) to arrivals and departures.

Baseline Assumptions

The HNTB model uses FAA forecasts of average aircraft size. (Aviation Forecasts: 1985-1996, 1985). The FAA projects an increase in the average number of seats of 1.47 percent annually. As check, HNTB examine known fleet and purchasing decisions by major airlines serving Minneapolis - Saint Paul and the proposed noise budget. They conclude that these are consistent with the FAA forecast. After 1997, a growth rate of 1 percent per annum is assumed.

Major Uncertainties

Some considerations:

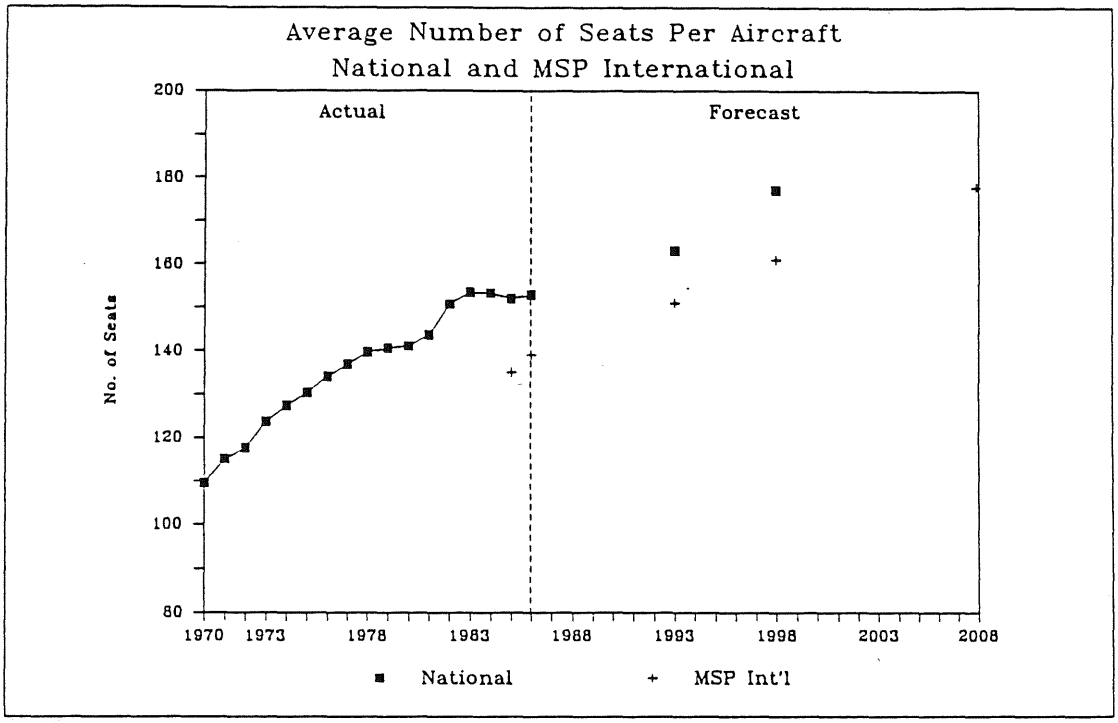
- Is the probable impact of the proposed noise budget adequately represented?
- Will changes in fuel costs, labor costs, or interest rates, slow or accelerate fleet renewal?
- Is the assumption of 1 percent growth after 1997 justified?

Example Upper and Lower 10% Limits

The upper and lower limits expand over time to indicate

increasing uncertainty. They begin at an arbitrary plus and minus 5 percent and end at plus and minus 15 percent. The distribution is symmetrical.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	139	---	---	---
1993	151	NO CHANGE	143	155
1998	161	"	148	165
2003		169	152	175
2008	178	NO CHANGE	157	185
2018	---	196	167	205

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

VARIABLE:
ENPLANING LOAD FACTOR

Description

The enplaning load factor is the percentage of seats of departing aircraft filled by enplaning passengers. The load factor at MSP is not calculated in the same fashion as the national estimate. Nationally, the average reflects the number of revenue passenger miles as a percent of total seat miles available. At MSP, the load factor is passenger departures as a percent of seat departures. Consequently, while the trends may be comparable, the absolute magnitude is not. Note that there are other "through" passengers who never leave their plane, so that the percentage of seats occupied will be higher than the enplaning load factor. Much as the average number of seats per departure is important to potential passenger capacity, average load factor reflects how effectively that capacity is being used.

How the Variable Affects Air Traffic

The Enplaning Load Factor is used in combination with the Average Aircraft size to convert the number of enplanements to the number of departures. (Arrivals are assumed to equal Departures) For example, in 1986 the average aircraft had 139 seats and it filled 49 percent of these from enplaning passengers (the Enplaning Load Factor). Since 49 percent of 139 is 68.1, we may say that for every 68.1 enplanements there was one departure.

Baseline Assumptions

The HNTB model assumes that the percentage of seats filled by enplaning passengers, will increase by 0.53 percent per year until 1996. This figure is derived from the FAA forecast Aviation Forecasts: 1985-1996, 1985. Subsequent to 1996, the model holds the enplaning load factor constant.

Major Uncertainties

Some considerations:

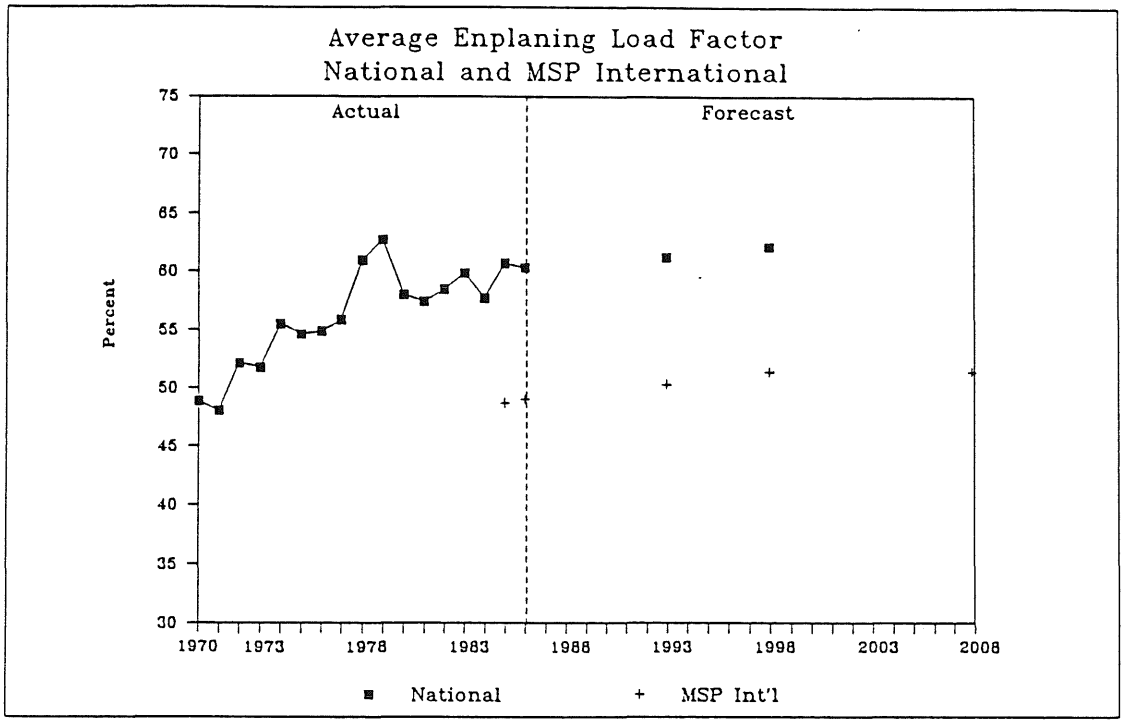
- Anything affecting the ratio of enplanements to originations may also affect the enplaning load factor. If the proportion of enplanements that are not originating rises, it is possible that the proportion of seats of "through" passengers will also rise, reducing the number of empty seats and reducing the enplaning load factor.

- Does the FAA projection fully capture future increases in seat utilization by airlines?

Examples of Upper and Lower 10% Limits

The upper and lower limits are set to reflect a symmetrical distribution with increasing uncertainty over time. The degree of uncertainty is arbitrary.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	49.0	---	---	---
1993	50.3	NO CHANGE	48.0	52.8
1998	51.3	"	47.0	56.3
2003	51.3	"	46.0	57.5
2008	51.3	"	45.0	58.7
2018	---	51.3	43.0	60.0

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

VARIABLE:
AVERAGE AIRLINE REVENUE PER PASSENGER/MILE

Description

This variable reflects the average price charged to customers for airline flights. Since competition will force revenues to approximate costs, this variable should be thought of in terms of airlines average costs.

How the Variable Affects Air Traffic

Lower prices create an increase in air travel. In the HNTB model this price variable directly effects only the people getting on planes who start their trips from the Minneapolis-Saint Paul Airport (Air Carrier Originations). The effect of lower prices on the number of people changing planes is felt indirectly at a later stage of the model, since they are treated as a multiple of the Air Carrier Originations.

Baseline Assumptions

The HNTB model assumes that, after adjusting for inflation, real revenue per passenger mile will be constant.

Major Uncertainties

Some considerations which may affect costs are:

- Oil Prices. Will they be higher or lower in real terms? Note, for example, the rise in the graph during 1973-74, the year of the OPEC oil boycott and the 1979-80 oil crisis.

- Increased fuel efficiency of new aircraft.

- Other technological improvements, such as improved routing through hubbing and further use of computers.

- Labor costs. Deregulation has brought pressure on unionized airlines to lower their labor costs as market protection has been removed. Have the full effects of deregulation on labor cost been felt at Minneapolis - Saint Paul International? Are labor costs likely to fall in the future in real terms?

- Real interest rates. Higher rates mean higher financing costs. Note the rise in the graph during 1980 to 1981, years of rising interest rates.

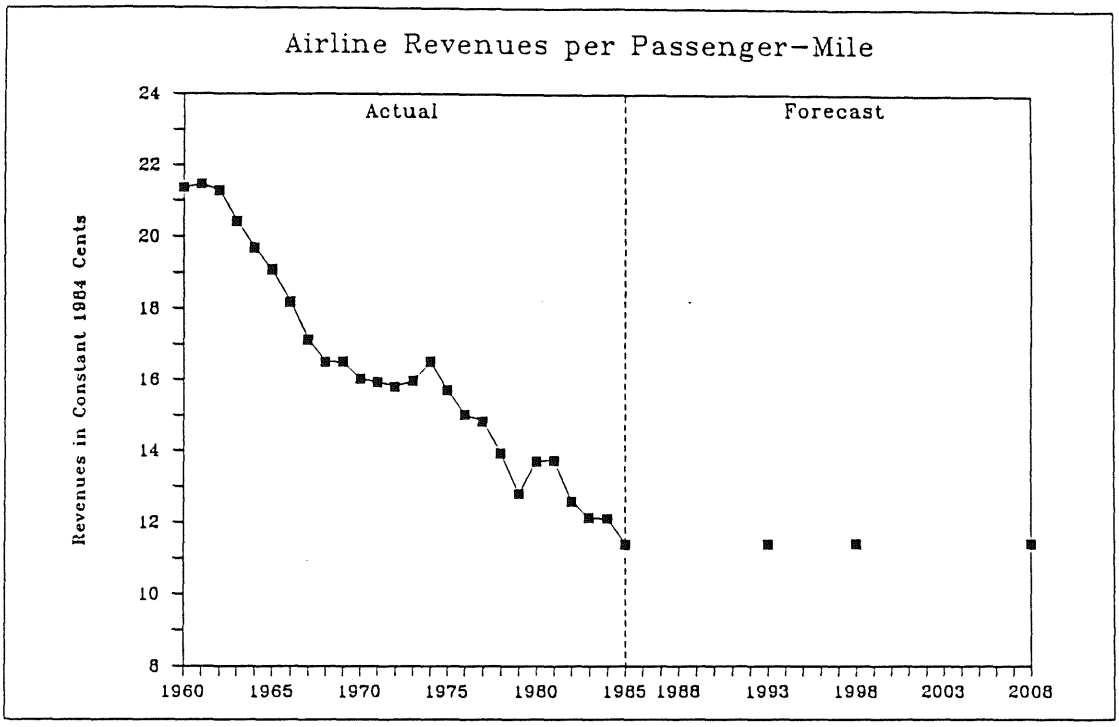
- Airport charges. Will the trend towards cost recovery by airports continue and have a significant impact on prices charged airline passengers?

- The general trend of airline revenue per passenger mile has been downward

Example Upper and Lower 10% Limits

The lower limit falls dramatically over time to represent potential impact of new technology. The upper limit stays low in the short run to indicate a likelihood that advancing technology will dampen any upward cost movement. In the longer term, the upper limit increases to reflect potential oil shortages and the lack of alternative energy supplies.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1985	11.4	---	---	---
1993	11.4	NO CHANGE	10.0	13.0
1998	11.4	"	9.0	13.5
2003	11.4	"	8.5	14.0
2008	11.4	"	8.0	14.5
2018	---	11.4	7.5	15.5

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

VARIABLE:
PEAK LOAD FACTOR

Description

The Peak Load Factor, expressed as a percent of the Enplaning Load Factor, is generally higher than the average load factor because the proportion of seats filled by enplaning passengers during peak hours is higher than the overall average, and there is usually a higher proportion of originating flights since people begin trips at these hours. Therefore, the Enplaning Load Factor during peak hours will be higher than the average, previously cited Enplaning Load Factor. The HNTB model assumes that the factor will be 125 percent, or that the peak hour load factor will be 25 percent higher than the Enplaning Load Factor.

How the Variable Affects Air Traffic

Once Peak Hour Operations have been determined, planners will wish to estimate the number of passengers enplaned during the peak hours. The higher the enplaning load factor, the more enplanements accounted for by each plane and the higher the peak hour enplanements.

Baseline Assumptions

The HNTB model assumes a peak load factor of 125 percent.

Major Uncertainties

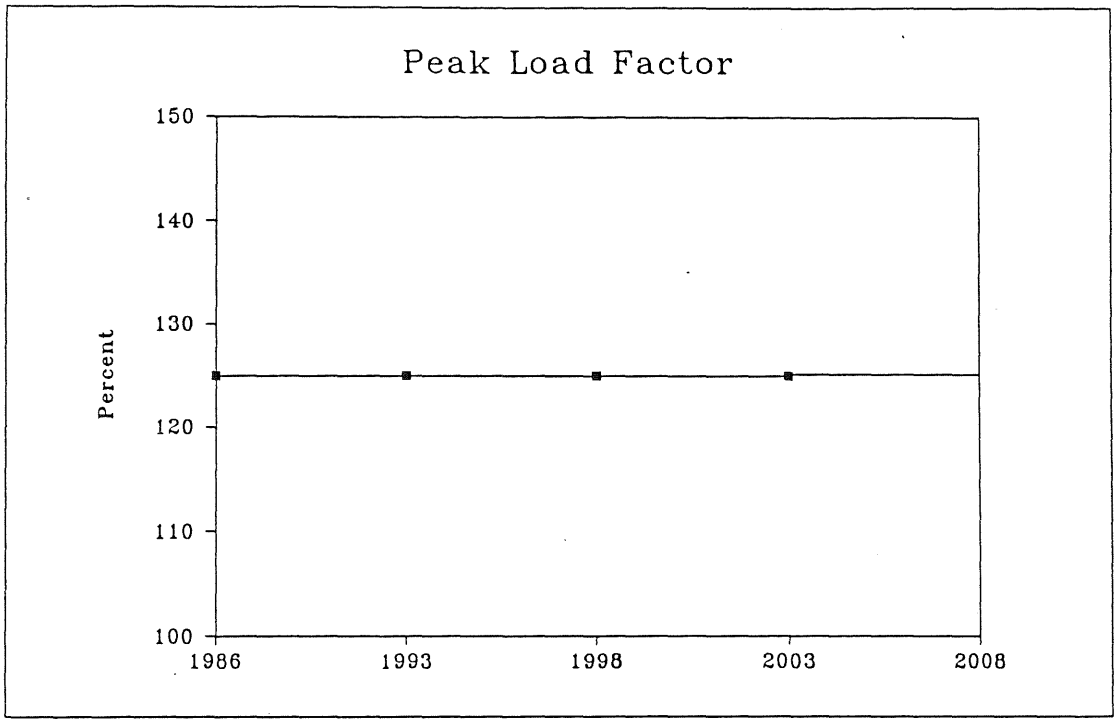
Some considerations:

- None suggested.

Example Upper and Lower 10% Limits

The upper and lower limits expand over time to indicate increasing uncertainty. They are approximately equidistant from the mean to indicate a symmetrical distribution. The degree of uncertainty is chosen arbitrarily.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1987	125	---	---	---
1993	125	NO CHANGE	123	127
1998	125	"	122.4	128
2003	125	"	121.8	128.2
2008	125	"	121.2	128.8
2018	---	125	120.0	130.0

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

VARIABLE:
PEAK MONTH OPERATIONS

Description

Peak month operations is the proportion of annual traffic accounted for by the busiest month expressed as a percentage of annual Aircraft Operations (arrivals and departures).

How the Variable Affects Air Traffic

This variable is used in conjunction with hourly traffic data to determine the peak load faced by the airport. This in turn has an important impact on planning, since the size of facilities is governed by the peak load they are expected to handle.

Baseline Assumptions

The HNTB model assumes that the current share of the peak month (August) will remain constant at 9.06 percent of annual Aircraft Operations.

Major Uncertainties

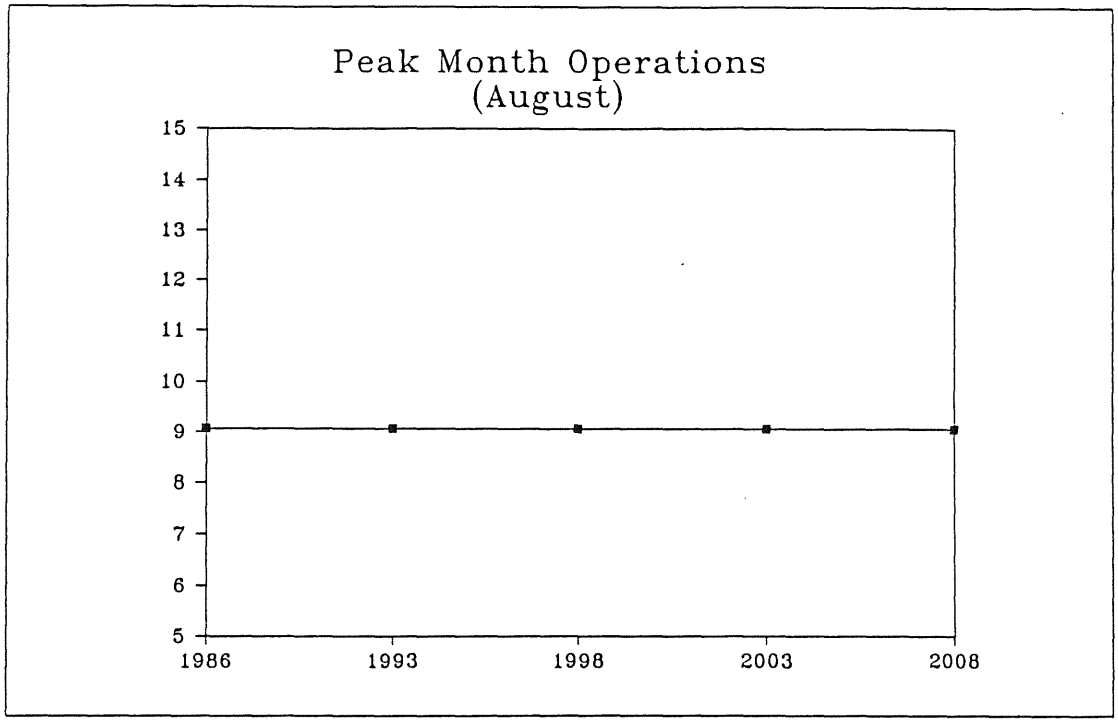
The key factor is not the identity of the month but the percentage accounted for by the peak month. Some considerations are as follows:

- Will the proportion of enplanements in the peak month caused by vacation travel increase? Will this increase the proportionate share of the peak months? A related concern is the aging demography of the population.
- The peak month cannot have less than one twelfth or 8.33 percent of the annual traffic.

Example Upper and Lower 10% Limits

The example upper and lower limits increase over time to indicate increasing uncertainty. The degree of uncertainty is arbitrarily chosen. The upper and lower limits are equidistant from the median, describing a symmetrical distribution.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1987	9.06	---	---	---
1993	9.06	NO CHANGE	8.90	9.22
1998	9.06	"	8.78	9.56
2003	9.06	"	8.67	9.92
2008	9.06	"	8.55	10.28
2018	---	9.06	8.33	11.06

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

VARIABLE:
PEAK HOUR PEAK MONTH OPERATIONS

Description

The proportion of arrivals and departures occurring during the busiest hour of an average day on the busiest month. It is expressed as a percentage of the daily total of arrivals and departures. The average day is calculated by dividing the busiest month's traffic by the number of days in the month.

How the Variable Affects Air Traffic

The Peak Hour Peak Month Operations identifies the peak load that airport facilities will be expected to handle repeatedly. This will affect planning of the size of facilities. (Note: The peak hour of the peak day is not used since this peak would not occur often. Instead we have the peak hour of the average day in the peak month.)

Baseline Assumptions

The HNTB assumes that the general daily pattern of peaks will continue. The three busiest periods are in the morning before 9:00, in the two hours following 12:00, and from 5:00-5:59 in the evening. The evening peak was the biggest in 1987 with 10.2 percent of average daily operations during the peak month. However, it is also assumed that the share of the peak hour will fall over time as operating hours at the airport are extended, and as increased hubbing by Northwest Airline cause more connecting flights. Connecting flights will tend to occur in off-peak hours because their passengers will be departing and arriving at peak hours at other airports.

Major Uncertainties

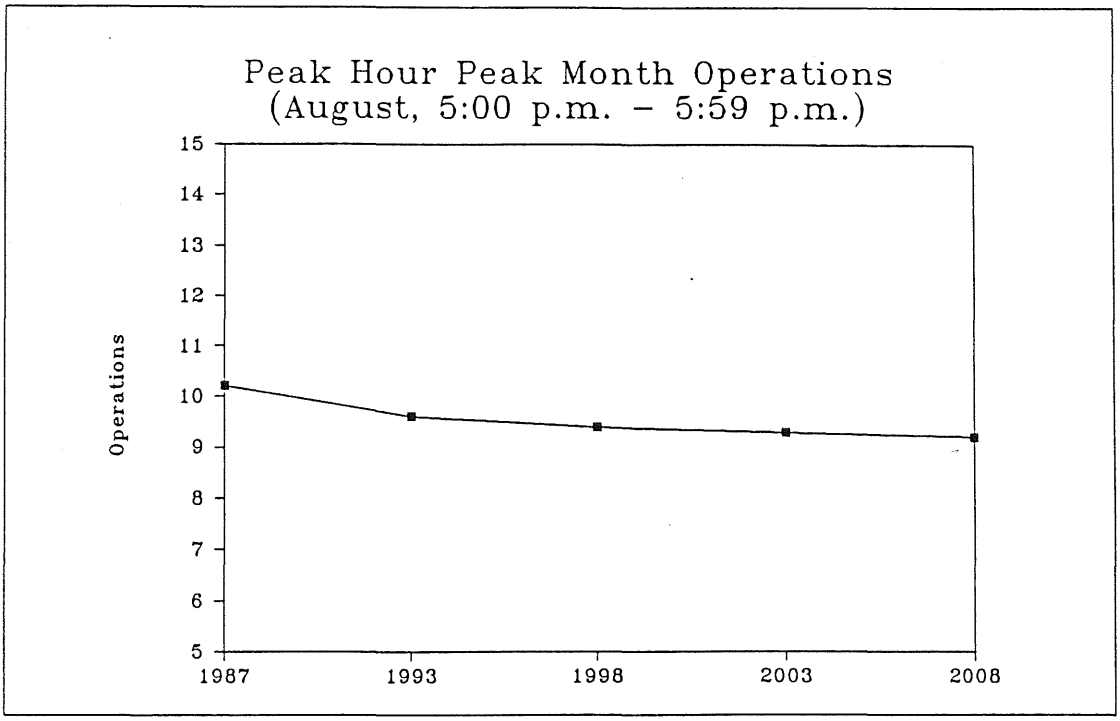
Some considerations:

- Is the Minneapolis - Saint Paul International Airport planning future pricing policies to shift operations away from peaks? Have these been accounted for?
- Does the absence of analysis of a weekly cycle have an impact on a systematically recurring peak hour?
- Is there an anticipated change in the mix of business and vacation travel? Will this affect peaks?
- The lower bound on a peak load hour is 1/24 of the day or a little over 4 percent.

Example Upper and Lower 10% Limits

The upper and lower limits expand over time to indicate increasing uncertainty. They are approximately equidistant from the mean to indicate a symmetrical distribution. The degree of uncertainty is chosen arbitrarily.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1987	10.2	---	---	---
1993	9.6	NO CHANGE	9.1	10.1
1998	9.4	"	8.8	10.2
2003	9.3	"	8.4	10.3
2008	9.2	"	8.1	10.3
2018	---	9.00	7.5	10.5

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

VARIABLE:
INCOME ELASTICITY

Description

This is the income elasticity of the demand for air travel originating in Minneapolis - Saint Paul. Income elasticity is the percentage change in quantity demanded resulting from a 1 percent change in real per capita income. For example, the 1986 value of 1.268 means that a 1 percent increase in per capita income in Minneapolis - Saint Paul would cause a 1.268 percent increase in the number of airline trips originating locally (Air Carrier Originations).

How the Variable Affects Air Traffic

This variable determines how sensitive Air Carrier Originations are to changes in per capita income. Holding everything else constant, an increase in income elasticity implies a higher demand for air travel.

Baseline Assumptions

The methodology employed in the HNTB model (linear regression) indirectly forces the income elasticity to decline over time when Air Carrier Originations are expanding faster than income, as they have historically. This may or may not be justified. (The linear regression model estimates a fixed "beta" which represents dy/dx. The mathematical definition of elasticity is (dy/dx)*(x/y). If dy/dx is held constant and x/y falls, then elasticity falls.)

Major Uncertainties

Some considerations affecting the sensitivity of Air Carrier Originations to changes in per capita income are as follows:

- Is there any reason to expect income elasticity to fall?

- Income elasticity is often theorized to change with average income. For example, in developing countries the income elasticity of the demand for mo-peds is initially very high as people use their income gains to obtain better transport. As income rises further, income elasticity becomes low, even negative, as people replace their mo-peds with motorcycles and cars. In the latter stage, the mo-ped industry would be called a "mature industry". Is the air travel a mature industry? If not, will it mature in the forecasting period and what affect will that have on income elasticity?

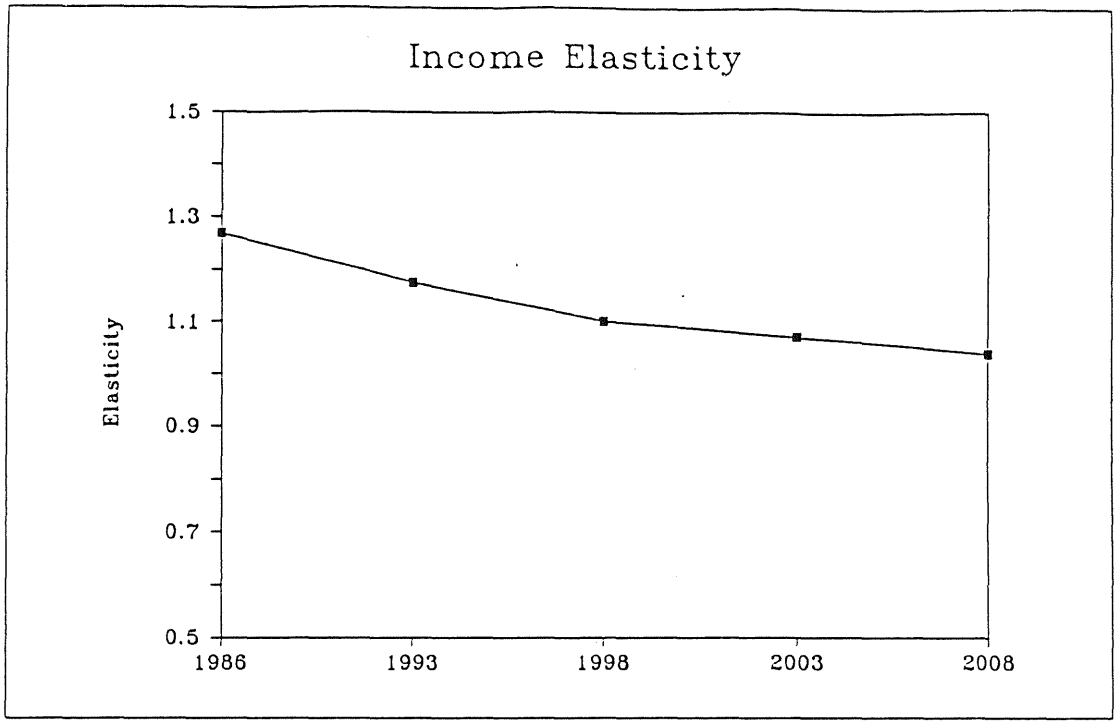
- Demographics. Will the older population mix in the future affect the sensitivity of the demand for air travel to income? What differences are there in local demographics that may affect this consideration? (Recall that population

growth for MSP is projected to be higher than the national average.)

Example Upper and Lower 10% Limits

The lower limit allows for increasing uncertainty over time, growing from an arbitrary 5 percent to 15 percent. The upper limit allows for a greater than 10 percent probability of the current income elasticity remaining constant over time. Essentially this is a modified mature industry scenario which allows for a significant possibility of the elasticity of income remaining the same.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	1.268	---	---	---
1993	1.175	NO CHANGE	1.116	1.30
1998	1.100	"	1.041	1.30
2003	1.070	"	0.970	1.30
2008	1.038	"	0.905	1.30
2018	---	0.925	0.786	1.30

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

VARIABLE:
FARE ELASTICITY

Description

This is the fare elasticity of the demand for air travel originating in Minneapolis - Saint Paul. Fare elasticity is the percentage change in quantity demanded resulting from a 1 percent change in fares (prices), as measured by Revenue per Passenger Mile. For example, the 1986 value of -0.0091 means that a 1 percent increase in fares would cause a 0.0091 percent decrease in the number of airline trips originating locally (Air Carrier Originations).

How the Variable Affects Air Traffic

This variable determines how sensitive Air Carrier Originations are to changes in fares. Holding everything else constant, a larger fare elasticity implies a lower demand for air travel. (Thus the negative sign.)

Baseline Assumptions

The methodology employed in the HNTB model (log-linear regression) assumes a constant price elasticity of (-0.81), meaning that a 1 percent rise in fares reduces Air Carrier Originations by 0.81 percent. This is not changed over time.

Major Uncertainties

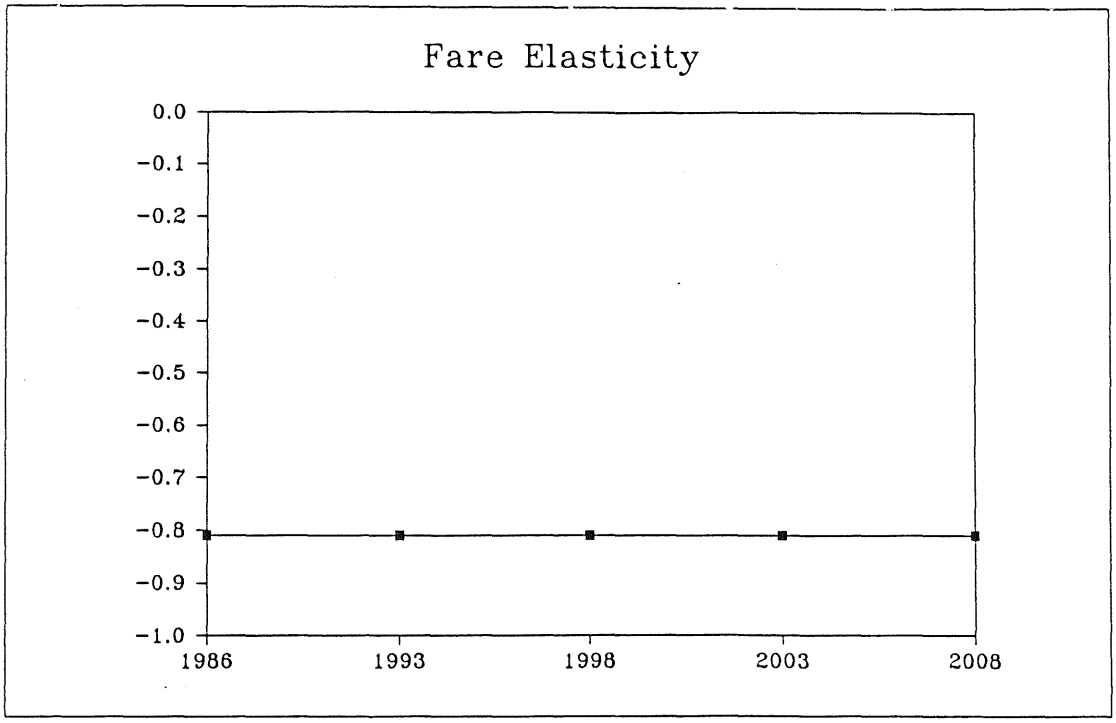
Some considerations affecting the sensitivity of Air Carrier Originations to fares include

- Will the development and growth of alternative business communications, such as fax machines, create more substitutes for business travel and making business more sensitive to air fares?
- Will the proportion of originations accounted for by vacation travel increase, and would this increase the price sensitivity of air carrier originations? Is vacation travel more price elastic than business travel?

Example Upper and Lower 10% Limits

The upper and lower limits are equally distant from the median. This implies a symmetrical distribution. The range increases over time to indicate increased uncertainty.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1987	-0.81	---	---	---
1993	-0.81	NO CHANGE	-0.77	-0.85
1998	-0.81	"	-0.76	-0.86
2003	-0.81	"	-0.79	-0.88
2008	-0.81	"	-0.72	-0.90
2018	---	-0.81	-0.65	-0.97

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

VARIABLE:
EMPLOYMENT ELASTICITY

Description

Employment elasticity is the percentage change in people from the MSP taking plane trips resulting from a 1 percent change in employment. For example the 1986 value of 1.75 means that a 1 percent increase in per capita income in Minneapolis - Saint Paul would cause a 1.75 percent increase in the number of airline trips originating locally (Air Carrier Originations).

How the Variable Affects Air Traffic

This variable determines how sensitive Air Carrier Originations are to changes in local employment. Holding everything else constant, an increase in employment elasticity implies a higher demand for air travel.

Baseline Assumptions

The methodology employed in the HNTB model (log linear regression) holds employment elasticity constant over time. This implies that so long as fares are held constant, a given number of employed people will always demand approximately the same number of plane flights.

Major Uncertainties

Some considerations affecting the sensitivity of Air Carrier Originations to changes in employment.

- We expect people's average income to rise over time. Will a given size labor force demand more air flights as their income rises? If so then employment elasticity should rise (given that average income is not an input to the model).

- If employment elasticity is expected rise with income, is the airline industry a "mature industry"? For example, in developing countries demand for mo-peds initially expands quickly as income expands. As income rises further growth in demand for mo-peds slows or even becomes negative as people replace their mo-peds with motorcycles and cars. In the latter stage, the mo-ped industry would be called a "mature industry". If air travel is a mature industry then employment elasticity will not rise as quickly as income.

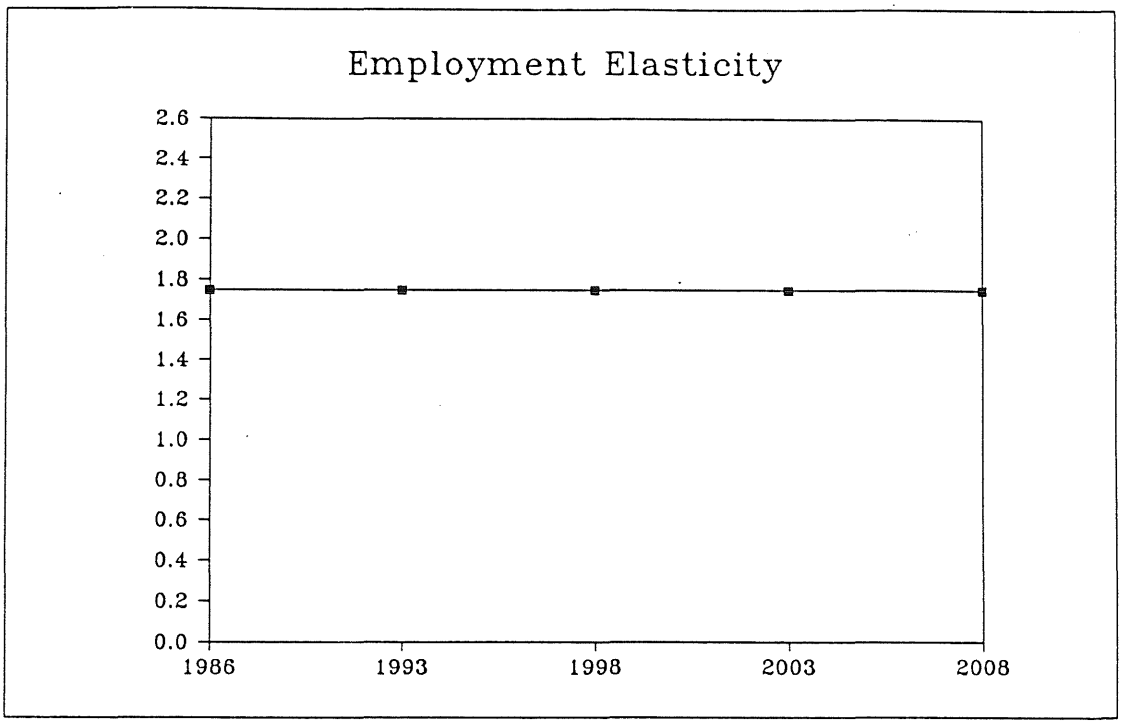
- Demographics. Will the older population mix in the future affect the sensitivity of the demand for air travel to employment? Will a given size of work force demand more air travel if they are older? What differences are there in

local demographics that may affect this consideration? (Recall that population growth for MSP is projected to be higher than the national average.)

Example Upper and Lower 10% Limits

The upper limit is further from the median than the lower limit to indicate the potential impact of increased income. This implies a skewed distribution. The range of the limits increase over time to indicate increasing uncertainty.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1987	1.75	---	---	---
1993	1.75	NO CHANGE	1.66	1.93
1998	1.75	"	1.63	1.98
2003	1.75	"	1.60	2.05
2008	1.75	"	1.55	2.15
2018	---	1.75	1.40	2.45

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

VARIABLE:
REGIONAL CARRIER ENPLANEMENTS

Description

Regional Carrier Enplanements is the number of passengers boarding regional carriers and air taxis, and carriers which typically serve the small communities within a several hundred mile radius of MSP.

How the Variable Affects Air Traffic

Regional Carrier Enplanements are distinct from enplanements of domestic carriers. They represent a different kind of passenger using a different class of planes. While domestic carrier enplanements are forecast by the HNTB model using several input variables, the smaller volume of Regional Carrier Enplanements is itself an input variable. Enplanements are themselves a measure of the workload of airport facilities. The number of enplanements is used in combination with aircraft size to determine the number of arrivals and departures by regional carriers.

Baseline Assumptions

While the number of carriers has not increased significantly over the last two year (from 6 to 7), many have entered into code-sharing agreements with the major carriers. Under such an agreement, the regional airline uses the air carrier's code in published schedule and reservation systems. As a result, preliminary 1986 data show a 60 percent increase in operations over 1985 levels. Based on discussions with airlines, including NW, HNTB forecast a 15 percent annual growth rate through 1990. After 1990 the growth rate is assumed to diminish to the 6 percent forecast by the FAA for regional carriers in Aviation Forecasts: 1987-1998, 1987.

Major Uncertainties

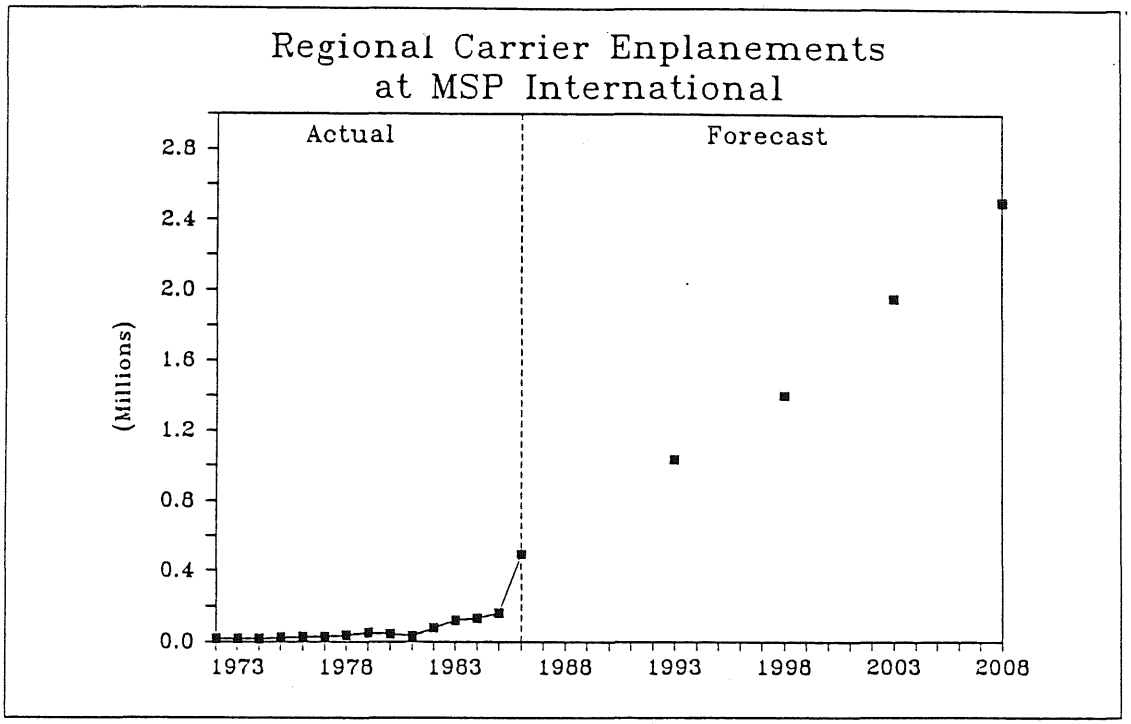
Some considerations:

- The local growth rate for regional carriers is projected to be much higher than the national average. Is this justified?
- Is the 6 percent national growth rate justified?

Example Upper and Lower 10% Limits

The lower limits are much further from the median than the upper limits to reflect the potential for lower growth than current expectations. The range widens over time to reflect increased uncertainty.

DATA SHEET



YEAR	FORECAST (000s)	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	489.7	---	---	---
1993	1034.6	NO CHANGE	850	1068
1998	1397.7	"	1115	1457
2003	1950.4	"	1511	2051
2008	2503.1	"	1880	2655
2018	---	4482.7	3157	4840

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

VARIABLE:
AVERAGE NO. OF SEATS, REGIONAL CARRIER DEPARTURES

Description

The average number of seats is calculated on the basis of a weighted average of the size of regional carrier aircraft departures from MSP. The MSP average, 30.0, is higher than the national average, 21.5.

How the Variable Affects Air Traffic

Arrivals and Departures are a measure of the workload of an airport. The more seats on the average plane, the fewer departures for a given number of passengers (enplanements) by regional carriers.

Baseline Assumptions

Over the next ten years the FAA forecasts a 2.9 percent annual growth in the average size of regional carrier aircraft. Because the MSP average is already higher than the national average, it is assumed that the average aircraft size will increase by only 2.5 percent through 1998. Beyond 1995, growth is expected to be lower, at 1.5 percent annually.

Major Uncertainties

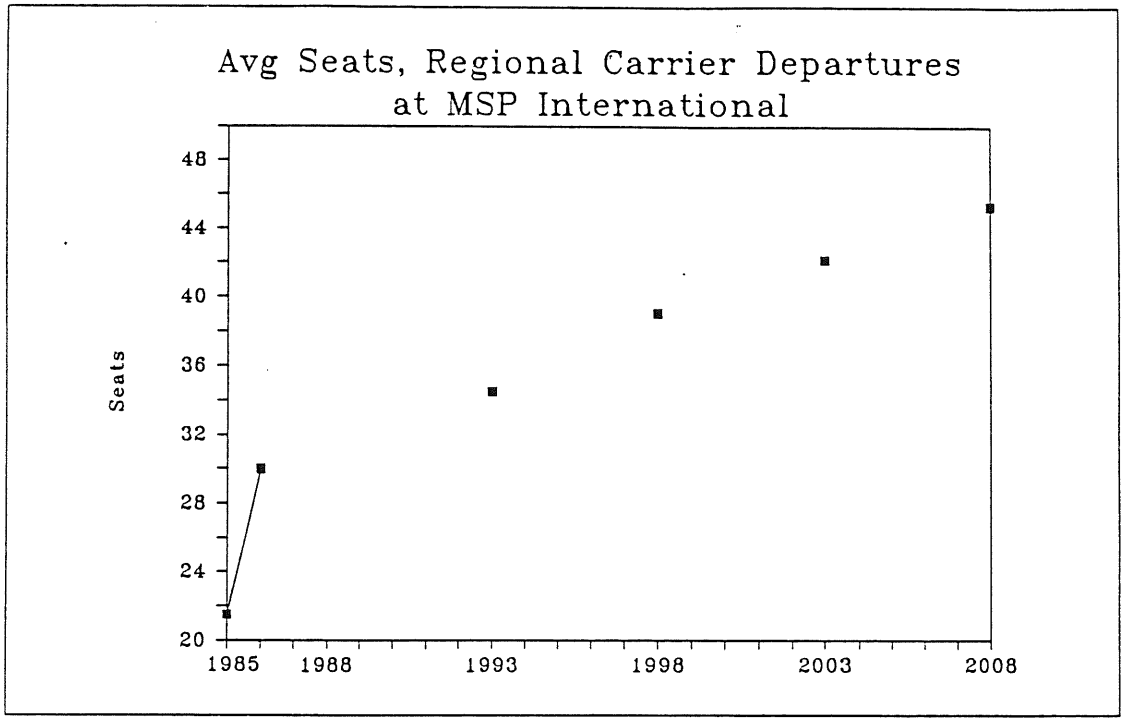
Some considerations:

- One of the reasons for the higher than average planes size is the presence of RC/NW CVR's. The current forecast assumes that this fleet will not be expanded. Is this valid?
- If panelists have maintained the high growth forecast for regional enplanements, is this consistent with a low growth in plane size? Will accelerated fleet acquisition change the average aircraft size more than projected?
- How does uncertainty in the growth of enplanements affect uncertainty in fleet acquisition and plane size?
- Is there some practical upper limit to regional aircraft average size due to the volume of traffic at individual service points?

Example Upper and Lower 10% Limits

The lower limit is farther from the median than the upper limit to reflect the potential of an upper limit on practical plane sizes for regional carriers.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	29.0	---	---	---
1993	34.5	NO CHANGE	33.0	35.9
1998	39.0	"	35.9	40.0
2003	42.2	"	38.0	43.7
2008	45.3	"	40.0	47.1
2018	---	52.5	44.8	54.9

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

VARIABLE:
INTERNATIONAL ENPLANEMENTS

Description

International Enplanements are passengers boarding flights for non-domestic destinations. These are distinct from the domestic enplanements also discussed by panelists.

How the Variable Affects Air Traffic

Enplanements are a measure of the workload of airport facilities. More passengers may require larger facilities. Enplanements are combined with average plane size of international flights to determine the workload of arrivals and departures.

Baseline Assumptions

Prior to 1980, international activity at MSP International was primarily limited to charter flights with foreign flag carriers. In 1980, however, Northwest began scheduled service to northern Europe. The relatively short history of MSP's international enplanements, combined with the unstable commercial environment of the 1980's, made a conventional statistical forecast using local data impossible. Therefore, FAA forecasts for United States international enplanements were used. These forecasts show an annual average growth of 4.7 percent for 1987-1998.

Major Uncertainties

Some considerations.

- HNTB note that the 4.7 percent growth rate in international enplanements exceeds the projected growth rate in domestic originations (people starting domestic trips from the MSP area). They credit the difference to increased hubbing by NW bringing in more passengers to transfer to international flights. Given this, should the growth rate be higher than the national average to account for the increase in locally originating international enplanements as well?

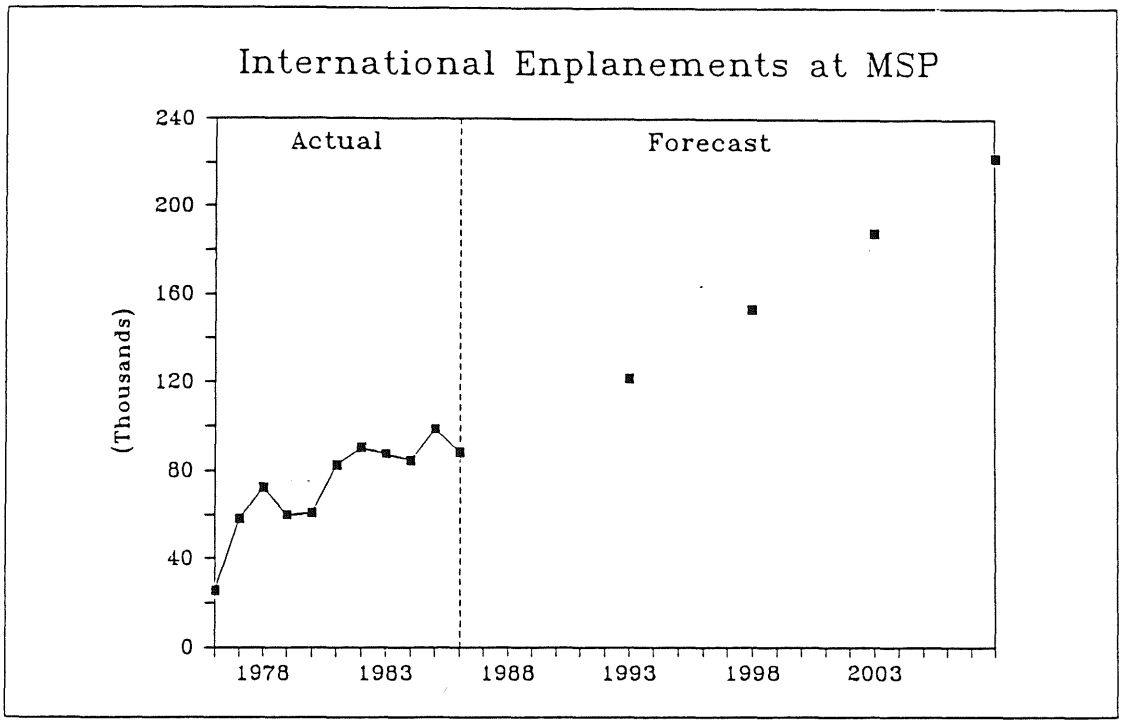
- As NW's international flight schedule improves, passengers who formerly took domestic flights to other airports to transfer to international flights may take a direct international flight from MSP. This kind of shift is meant to be excluded from this projection. These "divertable" enplanements are estimated separately.

- Is the business/recreation mix of international flights different from domestic flights? Will future changes in the vacation travel stemming from demographic changes affect the international enplanements?

Example Upper and Lower 10% Limits

The example limits portray a symmetric distribution. Their range expands to indicate increasing uncertainty over time.

DATA SHEET



YEAR	FORECAST	ALTERNATIVE ESTIMATE	INDICATE 10% LOWER LIMIT*	INDICATE 10% UPPER LIMIT*
1986	88.1	---	---	---
1993	121.6	NO CHANGE	115.5	127.7
1998	153.0	"	142.9	163.1
2003	187.6	"	171.3	203.9
2008	222.2	"	196.7	247.7
2018	---	322.6	258.1	387.2

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

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

FORECAST METHODOLOGY AND FINDINGS

May 1988

Prepared By:

APOGEE RESEARCH
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SUMMARY

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

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, the public can make a much more informed decision regarding how much capacity should be added and how soon. This same framework can also be used to assess the expected impacts (economic, social, and environmental) of not meeting unconstrained demand. The results of this last set of assessments will be reported later this year.

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 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 Summary Table 1). 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.

SUMMARY TABLE 1

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.

Thus, in addition to this base forecast, the Study prepared two alternatives:

- a "Reduced Hub" which assumed that Northwest would shift roughly 20 percent of its expected hubbing activity elsewhere, that the growth in regional traffic would be slower than anticipated, and that the expected growth in the size of aircraft will be somewhat slower than the baseline projection.

- a "Super Hub" option where there would be enough excess capacity to enable hubbing activity to nearly double, an option unlikely without a new airport.

The concept of level of service offers one way to compare these three forecasts. Summary Table 2 shows the airport capacity needed to give an 80 percent chance of meeting the demand under each forecast. Current average capacity during good flying weather is about 103 operations per hour, indicating a severe shortfall without significant changes.

As discussed in more detail in the companion report on capacity options, there are a series of options available to help meet this demand. In addition to the possibility of a new commercial airport to replace MSP, the region has three types of options for dealing with the high probability of continued growth in aviation demand:

- Additional runways and taxiways at the current site;

- Improved air traffic control procedures; and

- Restrained growth due to limited capacity.

As reflected by this final option, no rule says all the expected demand must be served. The cost -- financial, environmental, and political -- of adding new capacity is clearly substantial and may make a significant expansion infeasible. If airfield capacity is not expanded enough to offer a high probability of meeting expected demand, peak-period congestion will increase, adding to travel delays. While traffic will be diverted to other regions, connecting traffic and smaller aircraft are likely to be diverted first. As a result, of course, the Region will suffer economic losses, but the magnitude of these losses should be compared with the direct and indirect costs of adding significant new capacity.

SUMMARY TABLE 2

Capacity Needed to Ensure
an 80 percent Chance of Meeting Demand Under:

Base Case	
Five Year	119 Operations
Ten Years	132 Operations
Fifteen Years	148 Operations
Twenty Years	158 Operations
Thirty Years	210 Operations
Reduced Hub	
Ten Years	128 Operations
Fifteen Years	142 Operations
Twenty Years	149 Operations
Thirty Years	195 Operations
Super Hub	
Ten Years	173 Operations
Fifteen Years	191 Operations
Twenty Years	200 Operations
Thirty Years	260 Operations

I. INTRODUCTION

The fact that someone needs a forecast is itself evidence that there are risks associated with the future and that there is some value in the ability to evaluate and plan for those risks with respect to investment decisions. The Minneapolis-St. Paul International Airport (MSP) is no exception. Consider, for example, the following issues:

- Will air traffic at MSP International outstrip the airport system's ability to accommodate unconstrained growth?
- When is this likely to occur?
- 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 degree to which any one of the questions is answered correctly is vitally important to the future of the region's economic base and, ultimately, its quality of life. This is true for all types of public works investments from highways to solid waste disposal, but 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.

The economic value of MSP to the region has been well documented. The airport has been shown to generate between $1.7 billion and $2.1 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

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[1] Based on two recent analyses of the economic impact of aviation on the Minneapolis-St.Paul region: Martin Associates, The Economic Impact of the Minneapolis/St. Paul Airport, prepared

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?

With respect to costs, many of the alternatives to enhance capacity at MSP have already been explicitly identified and theoretical capacity gains estimated. Yet the actual capacity yields of each -- those attained in practice -- as well as the likely date of implementation remain to be determined. Clearly, without those inputs, most models forecasting impacts would falter, yielding little.

In short, with so many variables, only one thing is certain -- virtually every forecast will be 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 risk assessment. 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 resultant forecast will not offer a single "take it or leave it" answer. Rather, information can be presented that actually reflects the uncertainties involved--and how they might influence a forecast.

The remainder of this report covers three topics. Chapter II, "Recent Trends," describes the historical demand for services at MSP and the expected national trends. Next, Chapter III, "Forecasts and Probability," provides a brief overview of the technique used in risk assessment, the necessary inputs, and the interpretation of the outputs. The final section (Chapter IV), "Preliminary Model Results," summarizes the preliminary findings

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for the Greater Minneapolis Chamber of Commerce, January 1988, and Charles River Associates, "Economic Roles and Impacts of Aviation," prepared for the Metropolitan Council of the Twin Cities Area, 1985.

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

of the process and suggests possible interpretations. Appendix A provides detailed backup and information on the major economic variables used as inputs for the forecasts, and Appendix B lists the members of the Expert Panels who offered technical advice on the process.

II. RECENT TRENDS

The forecaster's primary resource is the past. Yet the past holds a limited number of clues about the future. Thus, while we must consider the direction of historical trends, they must also be weighed carefully with the insights offered by those active in aviation. It is in this context that these trends are presented.[3]

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. While coping with strong growth in traffic at MSP, the finances of MSP have remained strong and even improved somewhat.

Air Traffic Activity at MSP

In the aggregate, enplanement data show that activity at MSP has increased considerably over the period 1972 to 1987 (Figure 1). 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. Whereas originations comprised two-thirds of all enplanements in 1972, for example, they now represent only a little more than 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.

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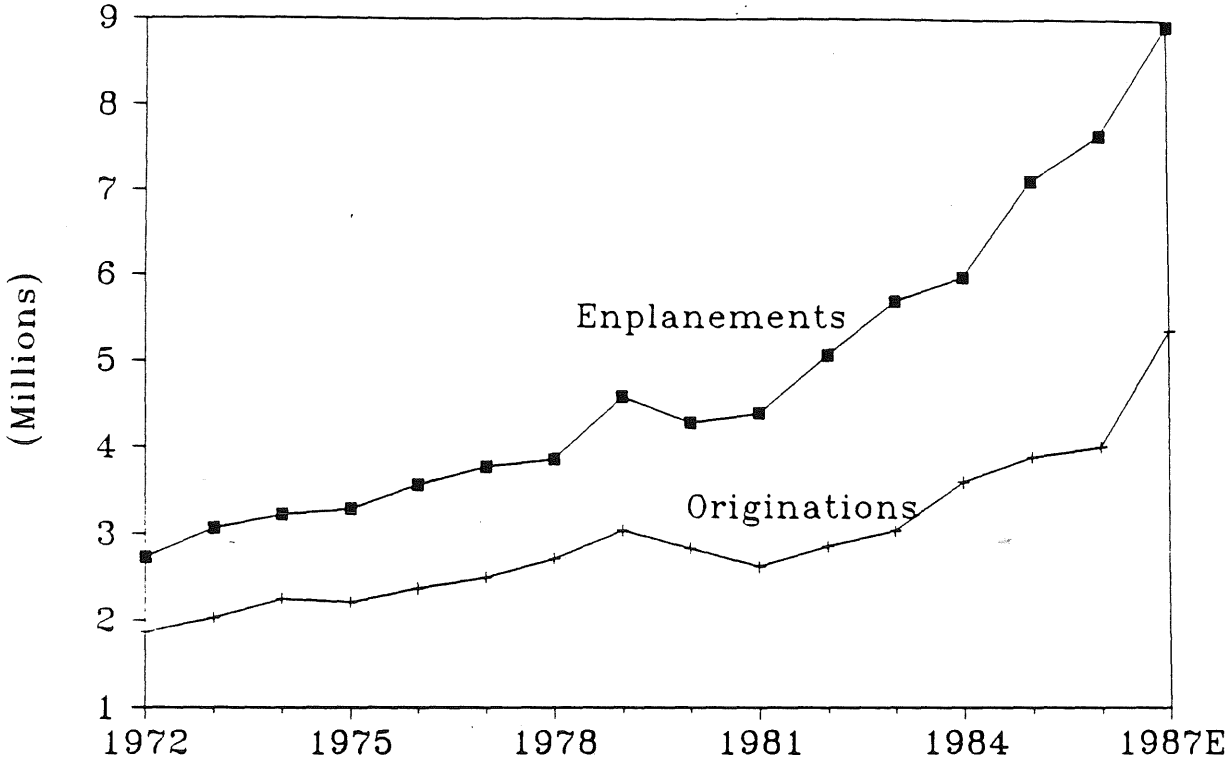
[3] For a more complete discussion of historical trends at MSP International, see "Working Paper Number 1: Background," prepared for the Metropolitan Council of the Twin Cities, December 1987.

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
1986	52.4	47.6	100.0

Source: Howard Needles Tammen & Bergendoff

Figure 1.
Passenger Enplanements at MSP International



National Trends

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. 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 estimates that by 1996, for example, 29 U.S. airports (including MSP) will face average delays of more than eight minutes.

System Projections. The FAA's forecast of passenger traffic calls for an average annual growth rate of 4.4 percent for the next two years and 4.6 percent through the end of the century.[4] While rapid, these trends are somewhat slower than recent years -- 7.7 percent in 1987 and 5.9 percent average from 1980 through 1987. 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 0.4 percent a year for the next twelve years versus the 20.4 percent real decline in the last three years alone. This change is expected in part because the FAA foresees a decline in the number of fare wars and also because it expects that carriers will "opt for higher profits at the expense of slower traffic."

This growth will affect both airports and air traffic control. The FAA projects traffic at airports with FAA towers to increase by 37 percent by 1999 and traffic handled at the FAA's enroute air traffic control centers to grow by 34 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 1987 to 19 percent in 1999. Air carriers, general aviation, and the military all show small relative declines.

Impact of Deregulation. Aviation has historically been the fastest growing mode of public works, and federal economic deregulation of the airline industry precipitated even faster

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[4] These and other national forecasts are drawn from FAA Aviation Forecasts, Fiscal Years 1988-1999, Federal Aviation Administration - APO 88-1, (February 1988).

growth and dramatic institutional changes. Deregulation, for example, radically changed the market climate in which airlines-- and airports -- operate. Once subject to strict regulation of routes and fares, commercial air carriers are now free to revise routes, adjust fares, and introduce or terminate service to particular airports as market conditions seem to warrant.[5] This new freedom from federal intervention has had pronounced effects on the airline industry. It has spurred intense competition and even price wars among the airlines, resulted in a reconfigured route system, and encouraged the start-up of new carriers.

Although deregulation has not caused radical changes in the financial management of airports, recent trends do reflect the uncertainties of a new, open market. They also show signs of shifts in management policy and practice that were under way before deregulation began.

In addition, an indirect reflection of the increased competition brought on by deregulation is more extensive use of "hubs," or central passenger exchange points for airlines. Hubbing can be beneficial for both the airport involved and the airline, but, particularly in the wake of deregulation, disadvantages also exist. Airlines previously considered established and low-risk have suffered serious financial difficulties, and in airports highly dependent on a hub airline, such difficulties can mean serious risks. Further, reduced competition means the hub airline has greater market dominance than before.

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[5] Exceptions include the four airports (DCA, LGA, JFK, ORD) where landing rights (slots) must be purchased from other airlines. Also, limits on gate space or counter space at individual airports may restrict the market.

III. FORECASTS AND PROBABILITY

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 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.

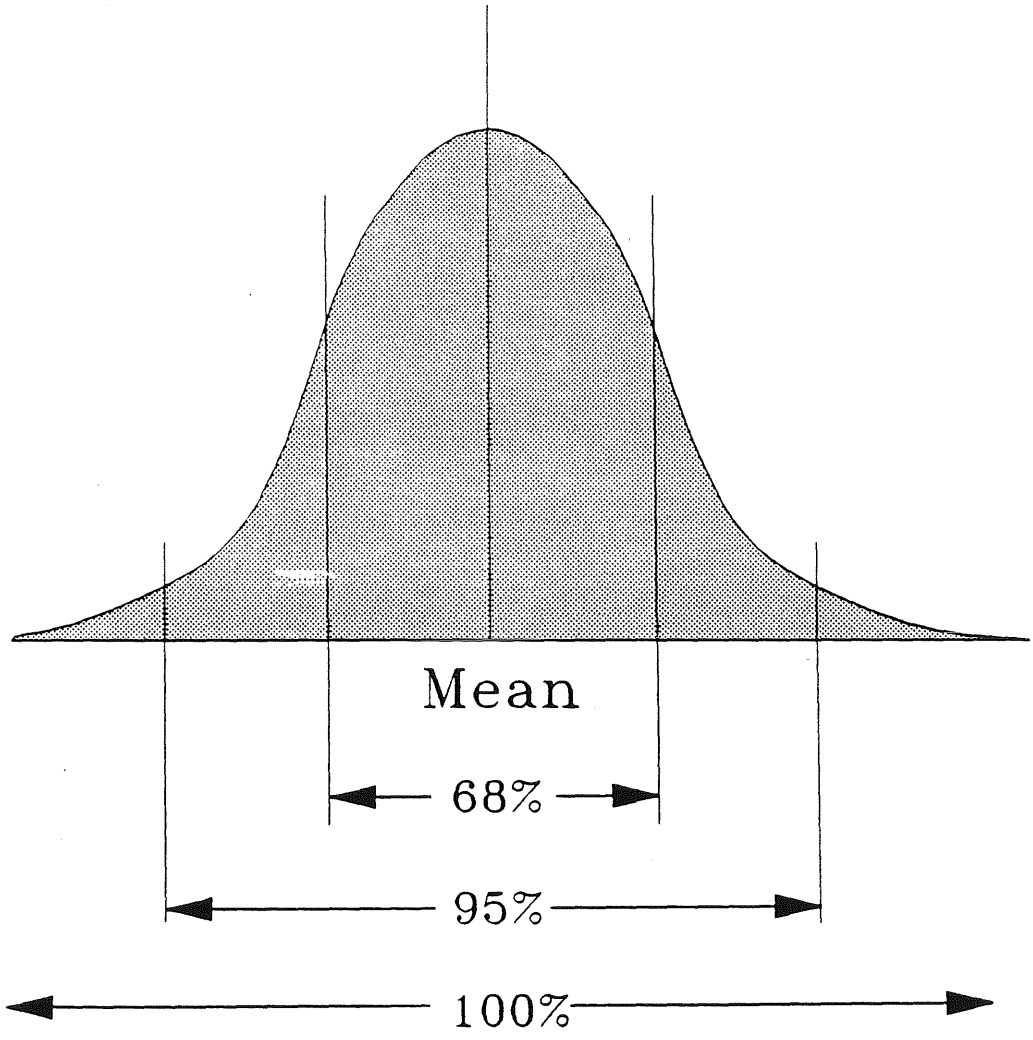
Probability in Public Investment Decision Making

Probability provides a way around the limitations of such point estimate forecasts by measuring the confidence or "odds" that an outcome will actually materialize.[6] The shape depicted in Figure 2 is called a probability distribution and its mathematical description is called a "probability density function." The "mean," or average, is synonymous with what we term the expected outcome. Figure 2 may be regarded as describing the confidence that an economic variable -- say, gross national product (GNP) -- will achieve a given growth rate in a future year (say, 1990).

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[6] For more details, see "Working Paper Number 2: Analytical Framework," prepared for the Metropolitan Council, December 8, 1987.

Figure 2. Probability:
A Measure of Confidence/Risk



The lines marked "68%" and "95%" are called "standard deviations" and provide a measure of the dispersion of the actual answer. That is, they measure the likelihood of being wrong. The 95 percent "confidence range" means that the probability of economic growth being above or below these limits is only five percent.[7] The wider the 95 percent confidence range (the flatter the curve), the greater is the risk that the actual growth rate will deviate widely from its expected value.

Two important characteristics of probability distributions should be noted. First, standard deviations get wider as forecasts become more distant. For example, the probability distribution for a prediction of GNP in the year 2000 would have a much flatter shape, reflecting the much lower confidence of making more distant forecasts.

Second, probability distributions are not necessarily "symmetrical." The traditional "bell curve" shown in Figure 2 is symmetrical because the shape of the curve (the probabilities) are the same on either side of the mean -- there is an equal chance that the actual result will end up too high as too low. This is characteristic of some forecasts but not of others. Over the years, for example, economists have erred too high in their GNP projections with about the same magnitude and frequency as their underestimates (except for short-term forecasts, they have rarely been exactly right). In contrast, forecasters tend to overstate the magnitude of technology-driven cost savings more often than they understate them. The latter phenomenon is depicted by an asymmetrical probability distribution -- known in statistical jargon as a "skewed" distribution.

How does 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.

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[7] In this symmetrical case, the odds are 2.5 percent that actual growth will be higher than shown by the 95 percent line and 2.5 percent that growth will be lower.

So it is with public investment. Figure 3 illustrates a few examples of the odds of running out of airport capacity in a particular year. Points to the right indicate more limited capacity, with the vertical line showing where capacity equals traffic. Both alternatives in Case A predict adequate capacity and thus could be represented by the same line on a chart. Alternative #1 is much less risky however (the distribution is tall and narrow) than Alternative #2 even though they both display the same expected outcome (the same mean). That is the risk of running short of capacity (the area to the right of the expected outcome) is greater under Alternative #2.

In case B, the expected outcomes themselves are different. The first alternative requires an expected capacity that exceeds that of the second; however, there is less dispersion around the outcome of Alternative #1 and thus a limited risk of winding up with radically too much capacity if MSP were expanded.

In case C, the second alternative provides greater assurance of not exceeding the minimum level of capacity but also creates a somewhat greater risk of over-investment. Thus, once risk and confidence are properly understood (and summarized in terms of overall costs and benefits) more reasoned investment decisions are possible.

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

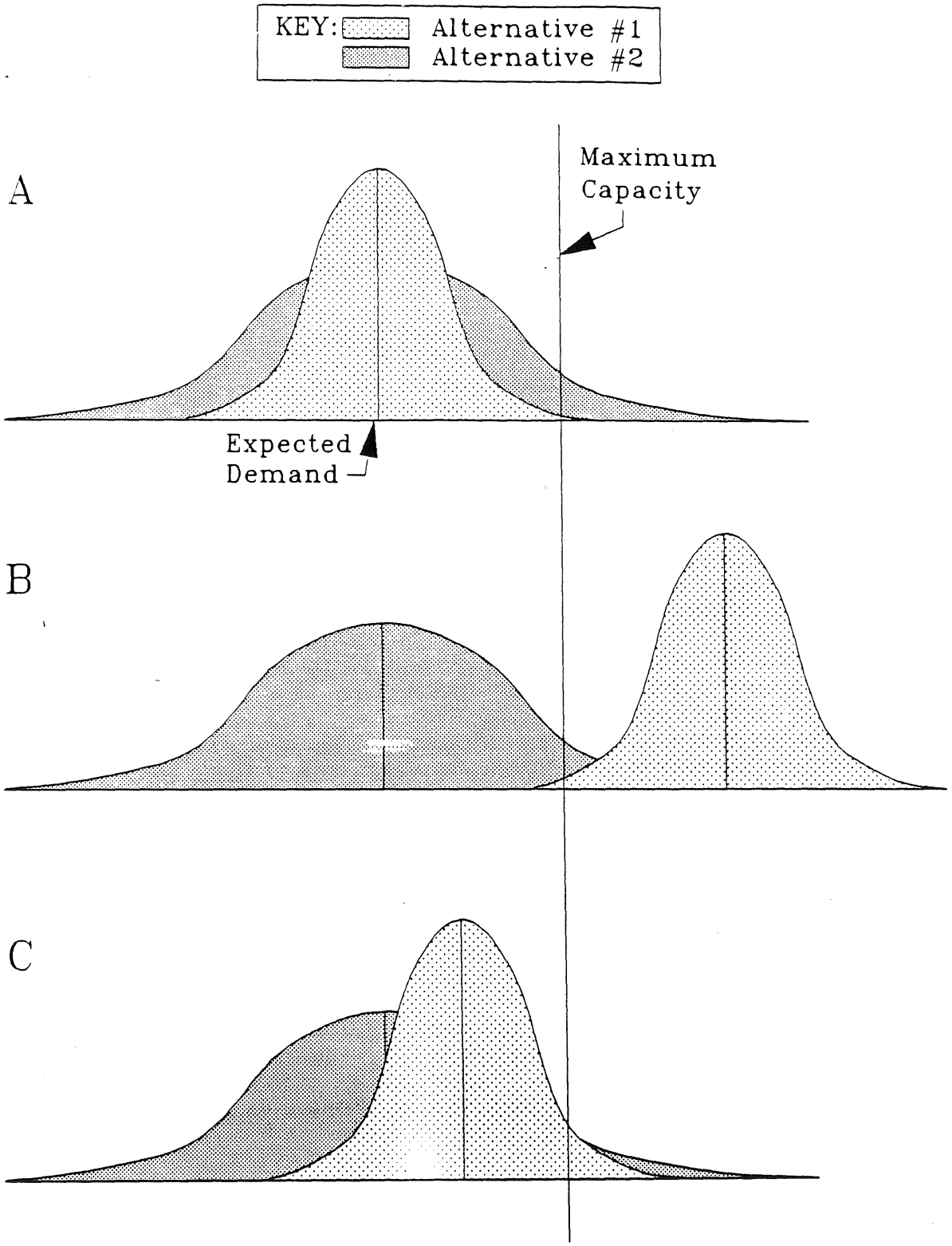
Before risk assessment can be applied, the first step is to select the baseline forecasts and ascertain which variables must be considered in the forecasting model.

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.[8] In the MAC Master Plan Update, separate forecasts

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[8] 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.

Figure 3. Risk and Return
The Need to Examine Probability



were made for air carrier, regional carrier, cargo, general aviation and military, each with their own independent variables.

Figure 4 demonstrates a forecast model structure and logic diagram for air carrier traffic - the most important component of future demand at MSP. In addition, a table is provided which describes the individual inputs into the logic diagram.

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.

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. The purpose of the logic and structure diagrams is to illustrate more clearly how the different factors (inputs, outputs, assumptions and other factors) integrate with one another and into the forecast model itself.

Step 2: Development of Initial Estimates

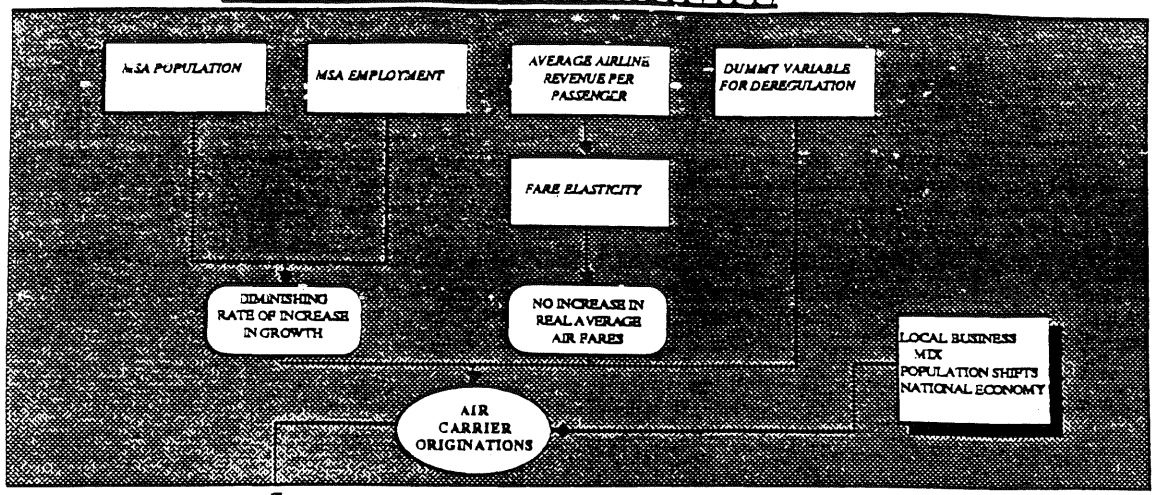
The initial estimates of the distribution about each forecast variable were constructed first by recording the baseline assumptions for each forecast factor in a probability chart.[9]

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

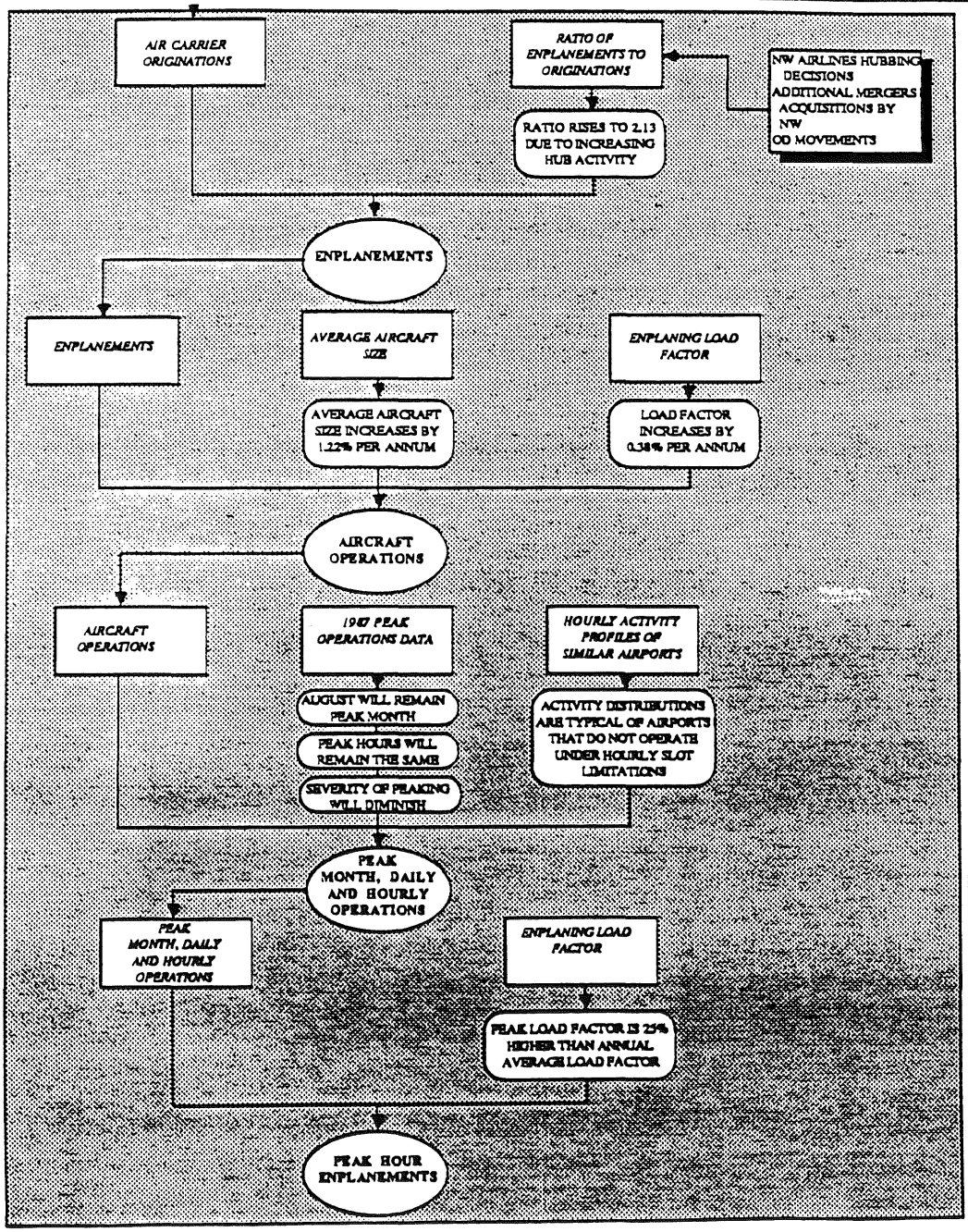
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[9] These data were drawn from the Howard Needles Tammen & Bergendoff Master Plan Update, (February 1988).

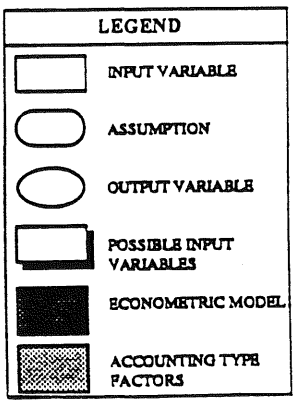
LOGIC MODEL FOR HNTB FORECASTING MODEL
(DOMESTIC AIR CARRIER ACTIVITY)



ECONOMETRIC MODEL



ACCOUNTING TYPE FACTORS



FORECASTS FOR DOMESTIC AIR CARRIERS

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.

working group. They were 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. See Appendix B for a list of panel members. 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.

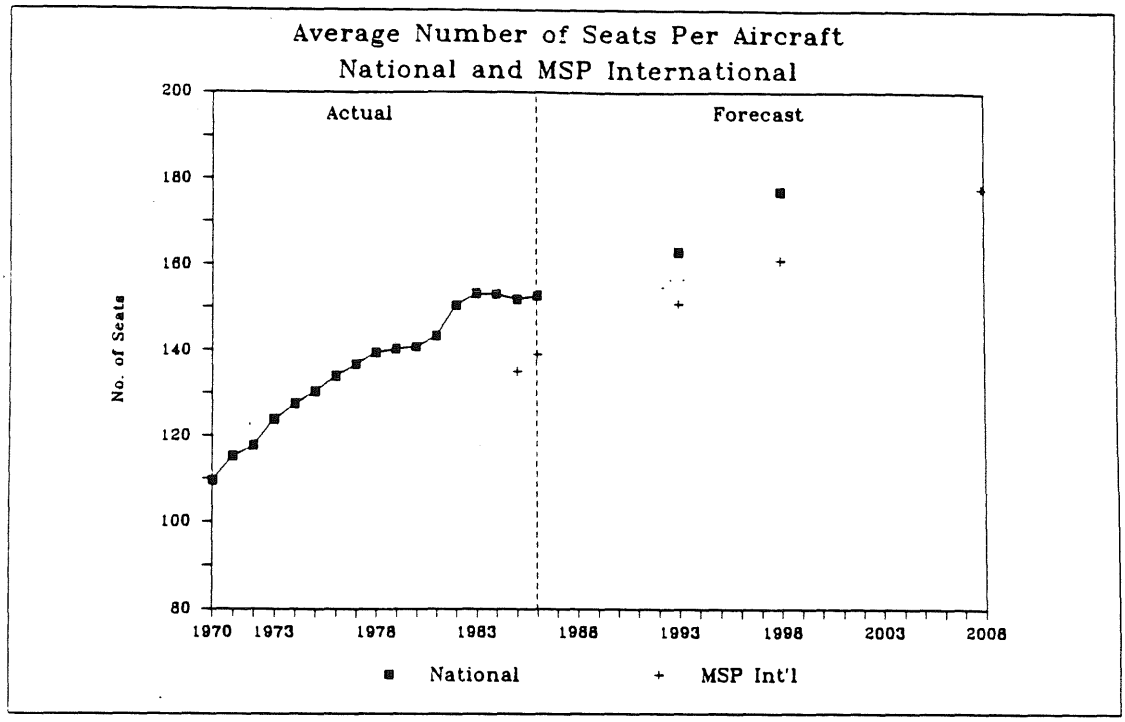
For each of the key variables the panel members were given a sample data sheet showing historical trends and the baseline forecast -- Figure 5 is the one for Average Aircraft Size. Similar data sheets were prepared for each variable that influenced the forecast. The panel members were asked to assess 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."[10]

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 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.

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

Figure 5. Sample Data Sheet Presented to Expert Panel



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.

Step 4: Incorporation into the Model & Monte Carlo Simulation

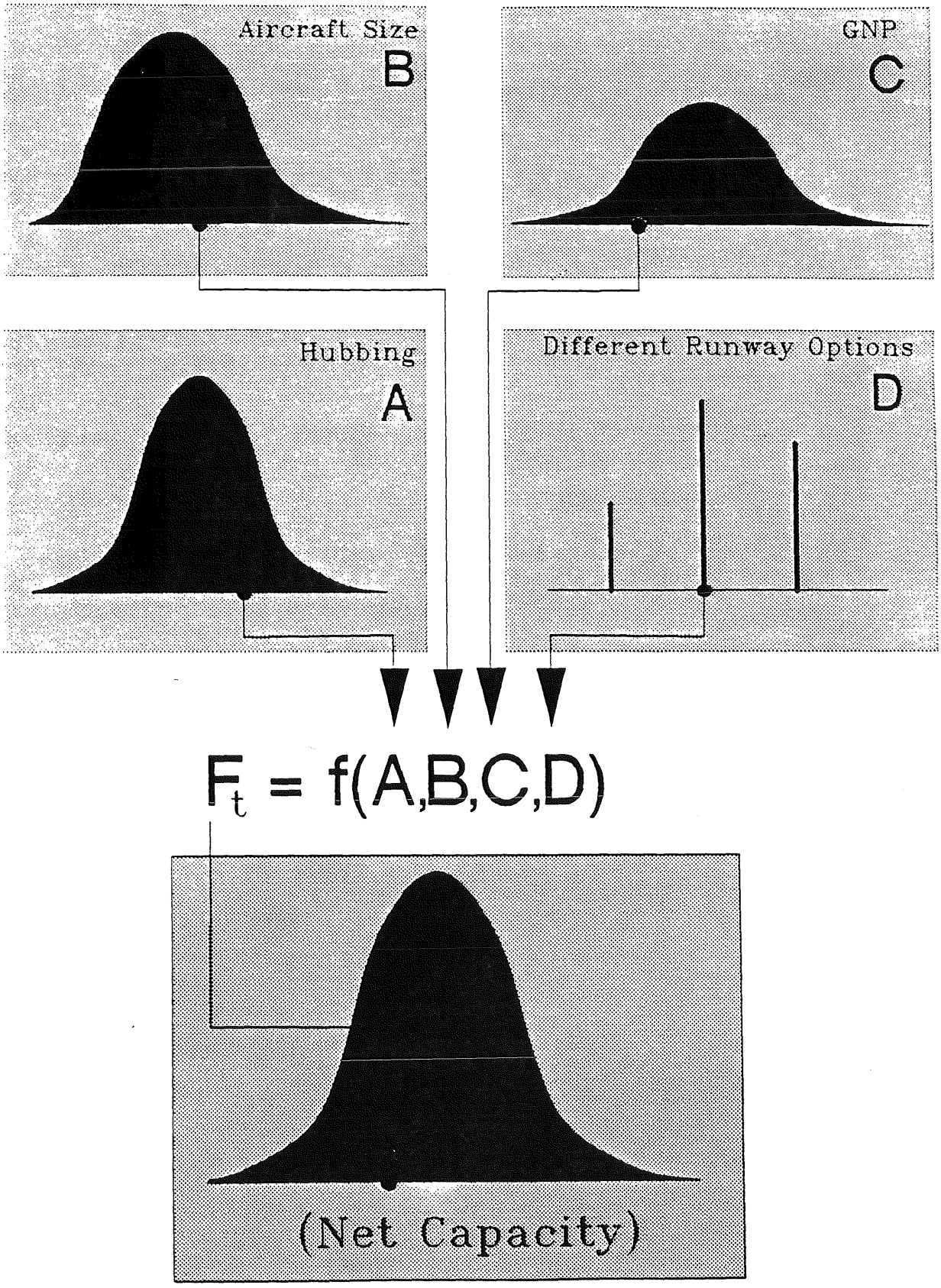
Once final distributions were generated for all of the identified variables, each distribution was used as input to the Monte Carlo simulation. Monte Carlo simulation is simply a systematic way to combine probabilities. Consider, for example, that the net capacity of MSP ("F") in any year "t" -- and 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 6).

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 6. Monte Carlo Simulation:
A Way to Combine Probabilities



IV. FUTURE TRAFFIC AT MSP

This Chapter presents a brief overview of types of results and their interpretation as well as preliminary Monte-Carlo traffic simulations carried out using the assumptions and methods outlined in Chapter III. While these results may be further refined as new information is received, major changes are not anticipated.

Results: An Example

The probability distributions for Average Aircraft Size (Figure 7) provides a good example of a key step in the forecasting process. The distributions for each of the key input variables are included in Appendix A. The peaks of the curves correspond to the baseline forecasts prepared as part of the MAC Master Plan. The baseline model used estimates that are consistent with FAA forecasts of average aircraft size. The FAA projects an increase in the average number of seats of 1.47 percent annually - roughly two seats per year. After 1997, a growth rate of 1 percent per annum is assumed.

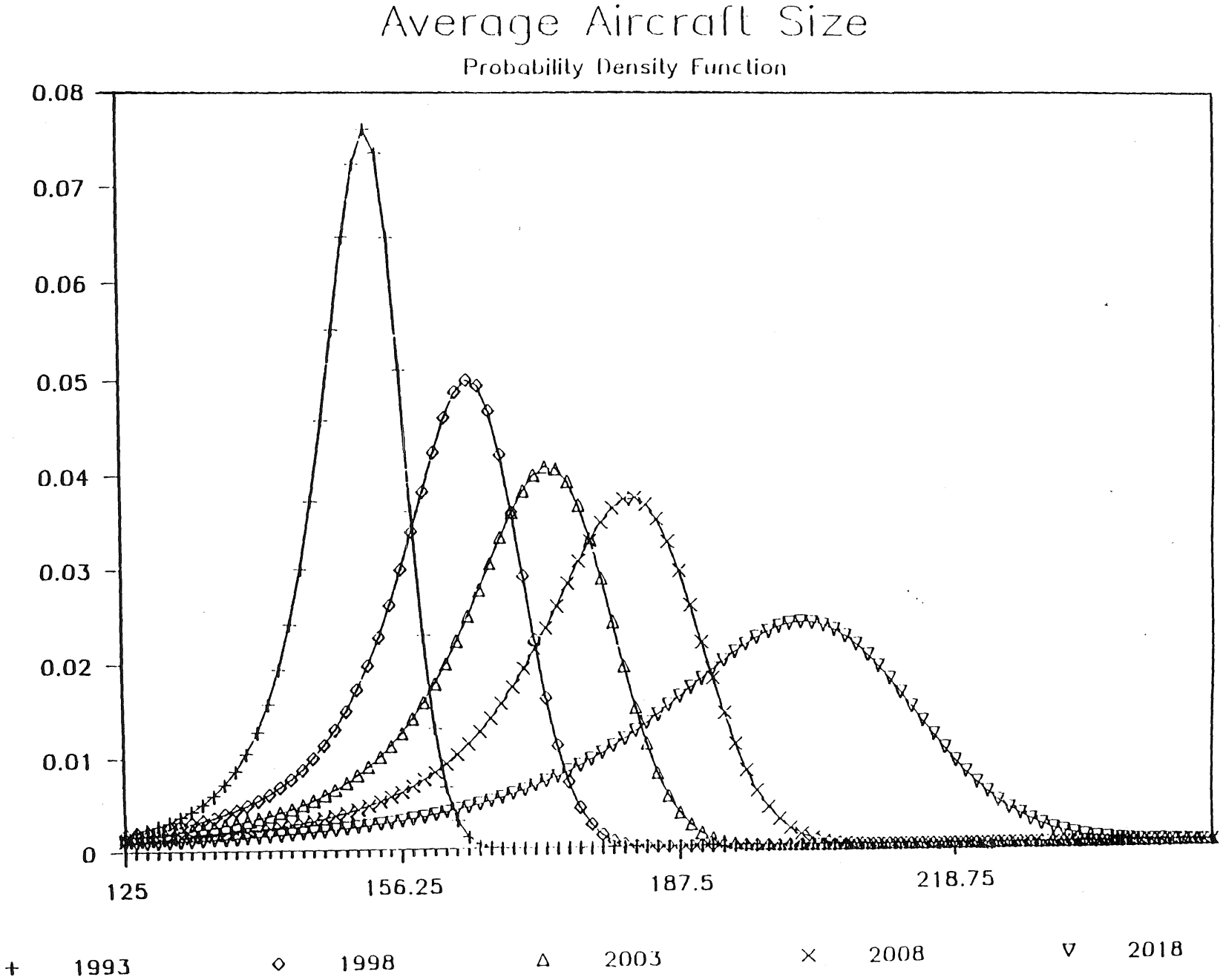
The flattening of the curves over time reflects increasing uncertainty of the forecasts for the distant future. Major areas of uncertainty include:

- Will noise regulations increase the estimated pace of fleet replacement?
- Will increasing fuel or labor costs slow the rate of growth and fleet renewal, making estimated growth rates overly optimistic?

The distribution is skewed to the left, reflecting the belief that if the base forecast is wrong, it's most likely to be too high. That is, the base estimate is more likely to over-estimate future average aircraft size than underestimate it.

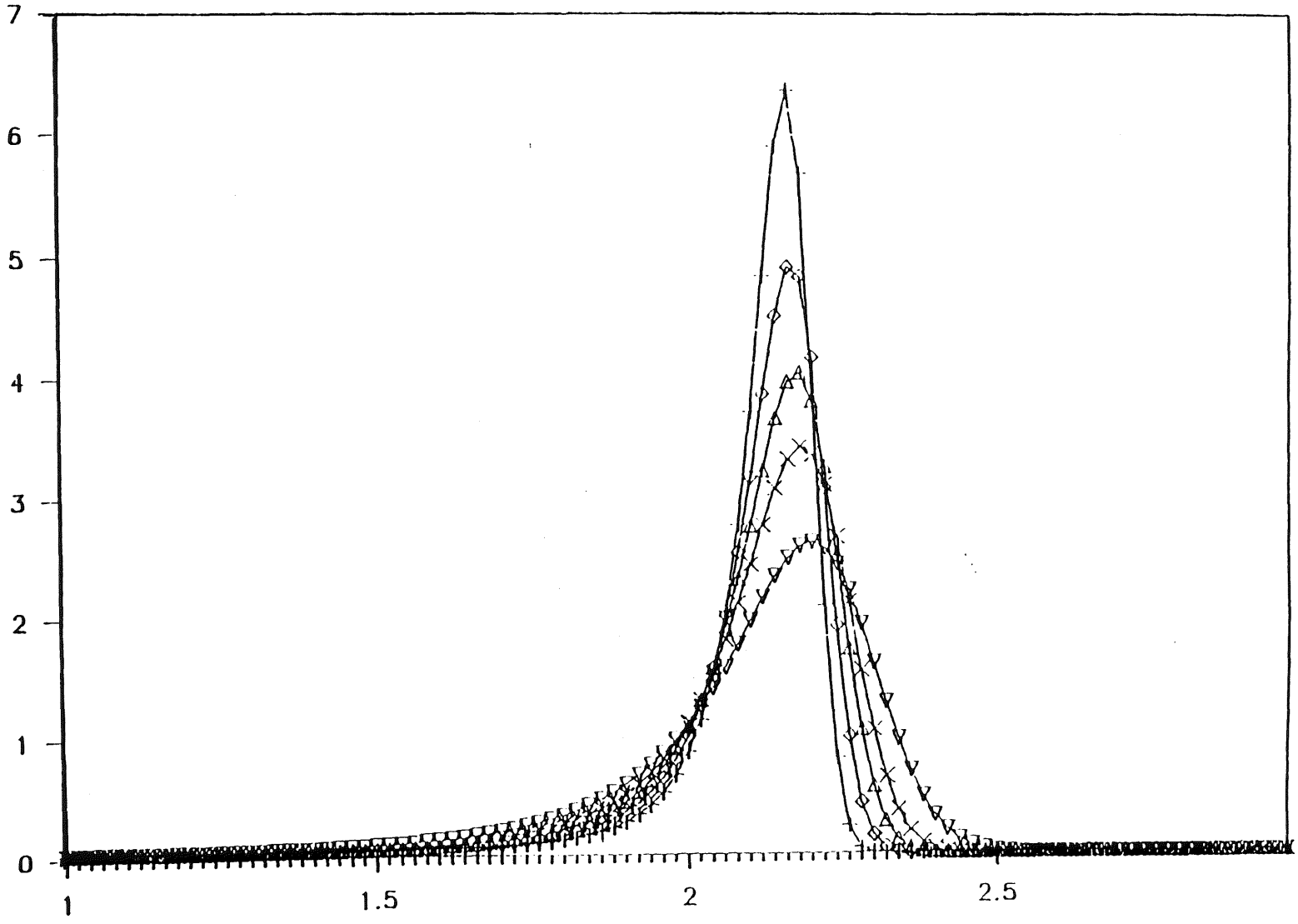
The ratio of enplanements to originations provides a further example of results form the forecasting process (Figure 8). Once again, the peaks reflect the MAC Master Plan baseline, the distribution becomes flatter over time, and the distribution is skewed to the left. As before, this reflects the increasing uncertainty of future estimates and our belief that the baseline estimate may be too optimistic.

The ratio of enplanements to originations for Minneapolis-Saint Paul International is currently below the average of similar airports. MAC's consultant assumes that the current ratio of enplanements to originations (1.91) will converge to the average ratio of similar airports (2.13) and that this average will remain constant thereafter. This movement is justified by


Average Aircraft Size
Probability Density Function
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
125
156.25
187.5
218.75
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

Ratio Enplanements/Originations

Probability Density Function



noting a general tendency of these ratios at other airports to move towards the mean in the recent past. Some considerations which may affect the skew include:

- Air traffic originating outside of Minneapolis - Saint Paul either is influenced by national economic activity. If economic growth or population growth in the MSP area diverges from the national average, this will affect the ratio of enplanements originating at MSP versus those originating elsewhere.

- Is there reason to assume that the MSP ratio will move all the way to the mean? At any given year there will be airports above and below the mean. Are there causative factors that keep MSP below the mean now that will last into the future?

- Is the current forecast warranted by Northwest's merger and hubbing expectations? Are future "Boardroom" decisions more likely to bring about a leftward or rightward skew?

- "Through" passengers are those who stay on the plane rather than disembark and transfer to another flight. Will the prospect of increased direct flights lead to more through passengers, fewer non-originating enplanements, and thus a lower ratio?

Forecast Model Results

As with any simulation result, the results stem from the characteristics of the nature of the probability distributions for each of the variables that underlie the forecasts (the individual distributions are summarized graphically in Appendix A).

Tables 3 and 4 compare selected forecasts presented in the Master Plan Update with summary statistics (means and standard deviations) drawn from the Monte-Carlo simulations for the Base Case. As the Tables indicate, the simulations tend to yield mean forecasts that lie slightly below those of the Master Plan update in any given year. In other words, the Base Case forecasts used here are slightly more conservative than those of the MAC Master Plan.

Tables 5, 6, 7 and 8 summarize a wider range of results from the traffic simulations for MSP. These four tables present a level of service view of four measures of demand for aviation services at MSP: domestic originations, total enplanements, total annual operations, and peak-period operations respectively. For each level of demand shown along the left-hand column, these tables show the probability that the actual demand will equal or exceed that for the forecast year.

Table 6, for example, indicates that the mean forecast of enplanements in the year 2003 is 14 million and that there is a 35 percent chance that enplanements will exceed that level. Table 8 summarizes the forecasts of peak-hour operations at MSP. The statistics indicate a 66 percent chance that peak-hour operations in 2003 will exceed 120 but that by the year 2008 the probability of peak-hour traffic exceeding 120 take offs and landings will have risen to 80 percent. The tables allow a wide range of probabilities to be examined in this way.

Two charts follow Tables 6 and 8, and summarize these data graphically. These charts can be used to show the year in which the probability of exceeding a given level of demand -- given a certain size airport -- is expected to be reached. For example, the chart following Table 6 shows that if MSP were expanded to handle 12 million enplaning passengers a year (current demand is about 8.6 million), there would only be a ten percent chance that this would be inadequate to meet demand in the year 1993. However, there is about a 69 percent chance that such an airport would be inadequate just five years later in 1998, 86 percent chance in 2003, 93 percent chance in 2008 and 97 percent in 2018.

These summary tables are also useful for relating the level of aviation service that the region wishes to provide to the required size of airport. For example, if it were desired to give an 80 percent assurance of meeting future demand, the answer would be provided by looking across the "20 percent" line -- this shows 20 percent chance of <u>not</u> meeting the demand. Using the Figure after Table 8 this shows that by 1993 a peak-period capacity of 120 operations per hour would be needed (current VFR capacity at MSP averages 103 operations per hour). By 1998, capacity for about 132 operations per hour would be needed, increasing to 147 in 2003, 156 in 2008, and more than 200 in 2018.

An 80 percent chance of meeting all the expected demand represents a high level of service. Because it is based on average numbers, the typical master plan implicitly assumes only a 50 percent chance of meeting the expected demand. Again, the figure shows that this would require only about 110 operations per hour in 1993, 116 in 1998, and 180 in 2018. There is no obviously correct target to select for the desired level of service. Rather, the answer depends in large part on tradeoffs among the cost to provide the service, the expected economic gains from providing a higher level of service, and likely environmental impacts from different traffic levels. Individual value judgments are a key part of such tradeoffs. For example, if greater emphasis is given to economic development, a higher quality of aviation service would be desired, thus implying a goal closer to an 80 percent assurance.

Alternative Forecasts

The discussion here focuses on the results of the Base Case forecast that reflects the distributions that were judged most likely by the Study Team. Two alternative sets of forecasts were also prepared:

- Reduced Hub assumes a reduced level of hubbing and slower growth in regional carriers as well as a slower growth in the seize of commercial aircraft, and

- Super Hub which assumes a near doubling in hubbing activity at MSP.

These alternative are most useful for comparisons with the capacity options. In general, the Reduced Hub option reduced the expected level of demand by 10 to 15 percent relative to the Base Case. The Super Hub option is really only relevant in the case of excess capacity such as might be possible with a replacement airport.

Table 3: Comparison of Traffic Forecasts--2008

	Master Plan Update	MSP Adequacy Study	
		Mean	Standard Deviation
Domestic Originations (Millions)	6.3	6.0	0.90
Domestic, Regional and International Enplanements (Millions)	16.2	15.3	2.28
Domestic, Regional and International Operations	534,000	523,351	83,432
Peak-Hour Domestic and Regional Operations	141	142	23

Table 4: Comparison of Forecast Peak-hour Operations

YEAR	Master Plan Update	MSP Adequacy Study	
		Mean	Standard Deviation
1993	116	112	12
1998	120	120	15
2008	141	142	23
2018	NA	183	47

Table 5. Comparison of Base Case Enplanements

YEAR	Master Plan Update	MSP Adequacy Study
1993	11,600,000	11,000,000
1998	13,300,000	12,700,000
2003	NA	14,000,000
2008	16,300,000	15,400,000
2018	NA	19,800,000

Table 4: Probability (In Percent) That MSP Domestic Originations Will Exceed Number Shown at Left

Millions of Originations	1993	1998	2003	2008	2018
4.0	98.8	99.6	99.6	99.6	99.6
4.4	84.6	97.2	96.5	96.8	98.2
4.8	26.6	76.6	89.6	92.0	95.6
5.2	3.6	48.0	69.4	79.0	93.5
5.6	0.4	19.6	45.6	60.8	90.0
6.0		7.8	26.0	43.2	80.6
6.4		1.8	11.8	26.2	67.5
6.8		0.2	5.0	18.0	57.6
7.2			2.4	9.2	45.4
7.6			1.2	4.8	33.0
8.0			0.2	2.2	26.0
8.4				1.6	16.4
8.8				0.6	10.0
9.2					6.8
Mean (Millions)	**4.7**	**5.3**	**5.6**	**6.0**	**7.3**
Standard Deviation (Millions)	**0.29**	**0.49**	**0.69**	**0.90**	**1.35**

Table 5: Probability (In Percent) That MSP Domestic Regional and International Enplanements Will Exceed Number Shown at Left

Millions of Enplanements	1993	1998	2003	2008	2018
8.0	99.6	99.8	99.9	99.9	99.9
8.8	99.0	99.4	99.6	99.5	99.2
9.6	94.0	98.2	99.2	99.2	99.0
10.4	77.8	94.5	97.0	98.0	98.3
11.2	36.8	84.0	92.4	95.0	97.9
12.0	10.2	69.0	86.2	92.6	97.0
12.8	1.8	39.0	72.0	84.4	94.8
13.6		18.0	55.6	73.2	93.5
14.4		7.0	34.8	62.0	90.6
15.2		3.8	20.0	45.0	88.2
16.0		0.8	9.0	34.0	83.6
16.8			5.2	21.8	78.0
17.6			2.0	13.8	70.0
18.4			1.4	8.2	62.0
Mean (Millions)	11.0	12.6	14.0	15.3	19.8
Standard Deviation (Millions)	0.85	1.3	1.77	2.28	3.66

Table 6: Probability (In Percent) That MSP Domestic Regional and International Operations Will Exceed Number Shown at Left

Millions of Operations	1993	1998	2003	2008	2018
250	99.6	99.9	99.7	99.7	98.4
300	99.2	99.8	99.6	99.4	97.6
350	89.4	94.8	97.0	97.0	95.6
400	44.8	77.4	87.0	91.0	94.0
450	8.2	35.2	60.0	78.0	91.6
500	1.2	11.6	41.0	60.6	85.0
550	0.2	1.6	15.0	27.6	80.2
600			2.4	15.5	65.6
650			1.0	5.5	53.0
700				1.8	44.0
750				0.2	30.0
800					21.2
Mean (Millions)	400,757	437,854	484,440	523,351	682,846
Standard Deviation (Millions)	40,092	51,983	69,418	83,432	168,888

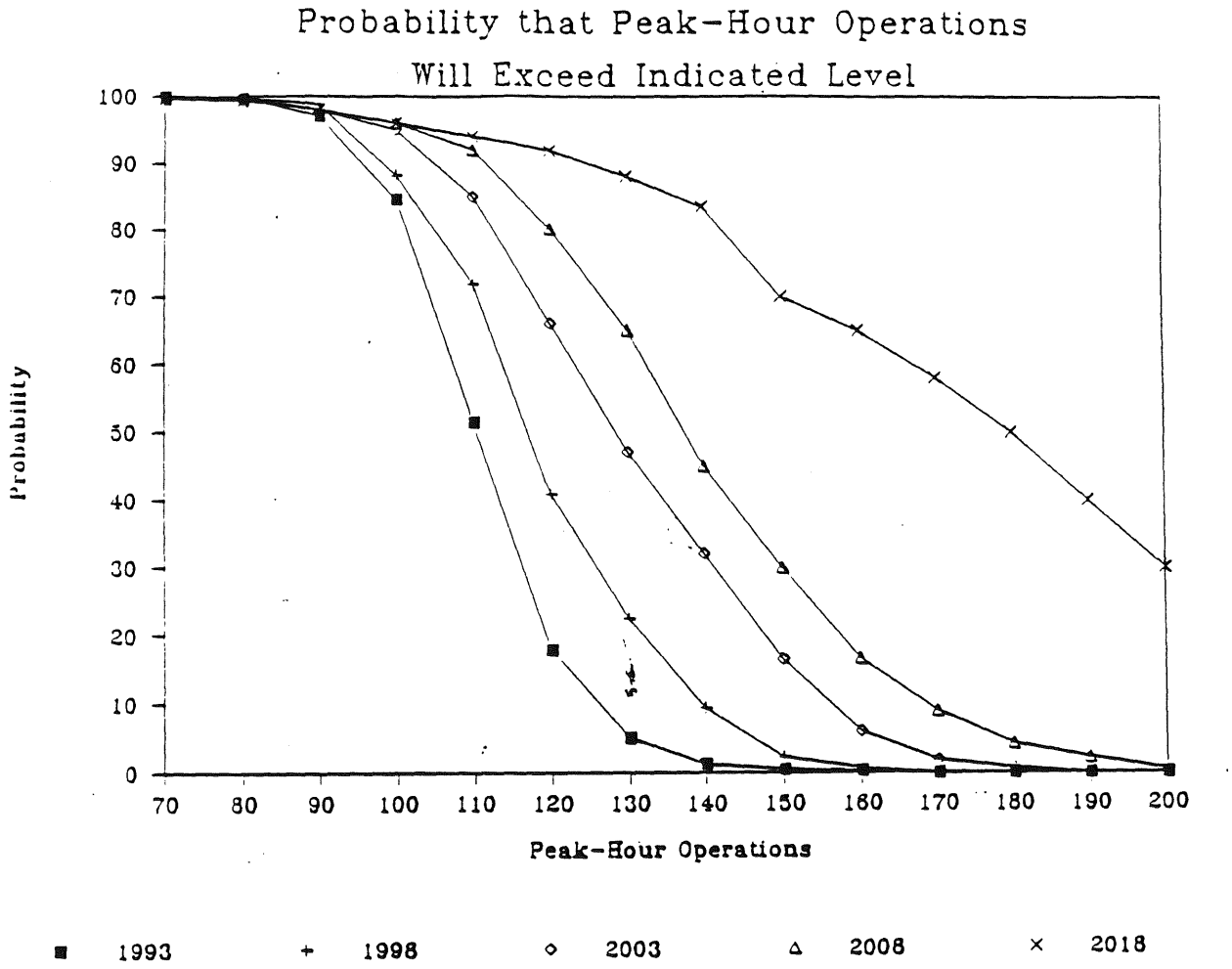
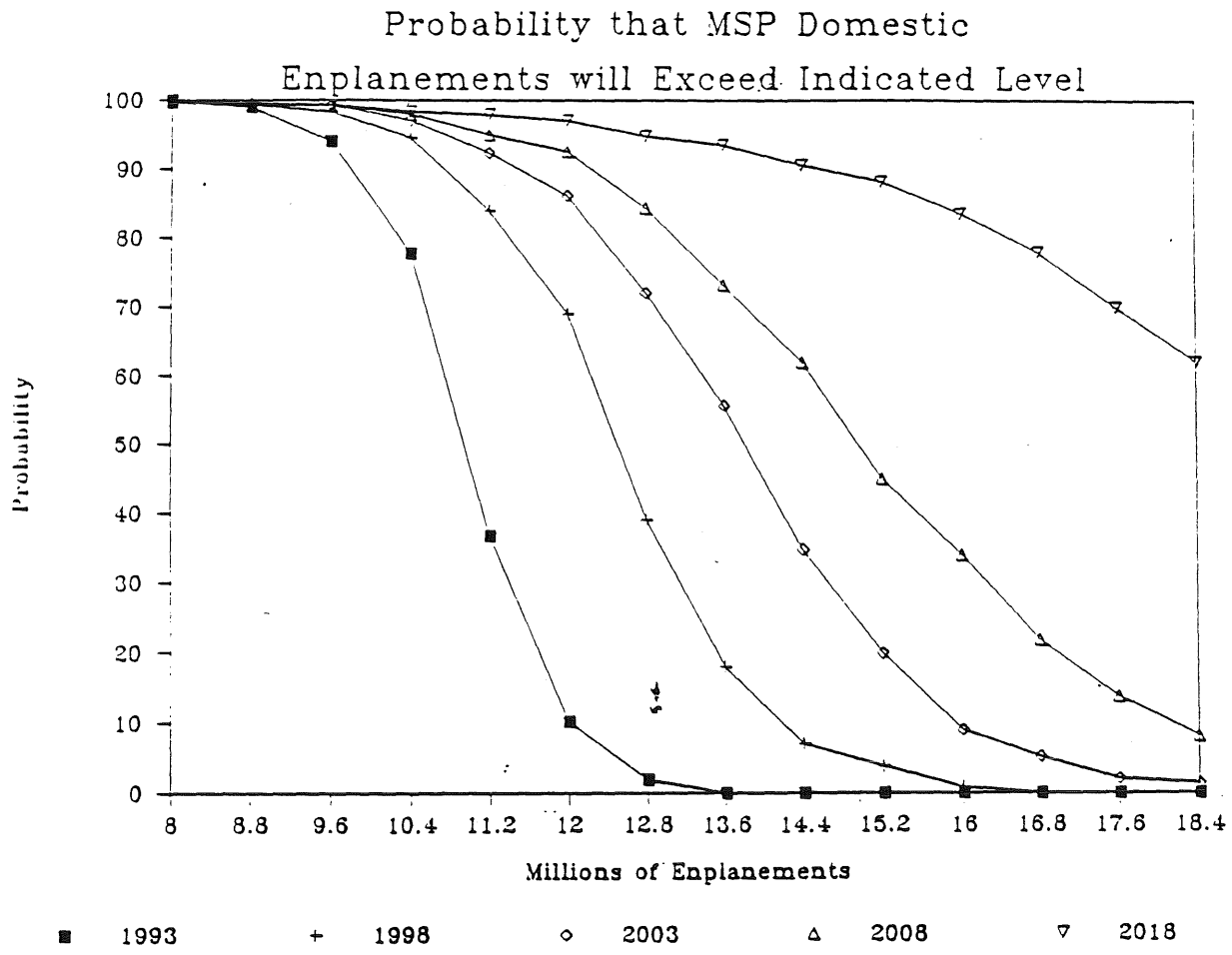

Probability that Peak-Hour Operations
Will Exceed Indicated Level
Probability
100
90
80
70
60
50
40
30
20
10
0
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Peak-Hour Operations
1993
1998
2003
2008
2018

Table 7: Probability (In Percent) That Peak-hour Domestic and Regional Operations at MSP Will Exceed Number Shown at Left

Peak-Hour Operations	1993	1998	2003	2008	2018
70	99.9	99.9	99.9	99.6	98.2
80	99.6	99.8	99.6	99.4	96.8
90	97.0	98.8	98.0	98.0	96.2
100	84.6	88.2	95.0	96.0	95.2
110	51.4	71.8	85.0	92.0	94.0
120	17.8	40.8	66.0	80.0	91.8
130	5.0	22.5	47.0	65.0	88.0
140	1.2	9.4	32.0	45.0	83.4
150	0.4	2.2	16.5	30.0	70.0
160	0.2	0.6	6.0	16.6	65.0
170			1.8	9.0	58.0
180			0.6	4.2	50.0
190				2.2	40.0
200				0.4	30.0
Mean Operations	112	120	132	142	183
Standard Deviation Operations	12	15	19	23	47

Table 8: Probability That Peak-hour Operations at MSP Will Exceed Current IFR and VFR Capacity

Variable	1993	1998	2003	2008
IFR Capacity (85)	98.8	99.8	99.4	99.0
VFR Capacity (103)	75.0	85.6	93.5	95.0
Mean-Operations	112	120	132	142
Standard Deviation-Operations	12	15	19	23


Probability that MSP Domestic
Enplanements will Exceed Indicated Level
Probability
100
90
80
70
60
50
40
30
20
10
0
8
8.8
9.6
10.4
11.2
12
12.8
13.6
14.4
15.2
16
16.8
17.6
18.4
Millions of Enplanements
1993
1998
2003
2008
2018

APPENDIX A
Summary of Input Variables

This appendix describes each of the input variables used in the simulation developed for MSP International and shows the values and probability distributions used as inputs for the forecast. The description includes a definition of the variable, a brief discussion of how that variable affects air traffic, important factors and assumptions that may affect future estimates, and major uncertainties of the estimate. In addition, historical trends are shown graphically (where possible), followed by a chart that depicts the final estimate for each input and its potential variability for specific forecast years: 1993, 1998, 2003, 2008, and 2018.

Forecast means are identical to the point estimate forecasts of the Master Plan Update prepared for the Metropolitan Airports Commission by Howard Needles Tammen & Bergendoff (HNTB). These means correspond to the highest point of each curve.

In addition to the variables described in detail here, several other variables were examined analytically by the MSP Adequacy Team and by the Expert Panels. These variables -- Gross National Product, metropolitan population, and fare elasticity for business and non-business trips -- were analyzed for their long-term influence on other factors and to ensure internal consistency among the variables, but they were not incorporated into the simulation algorithim.

List of Variables

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VARIABLE:
EMPLOYMENT

Description

"Employment" is the number of people working in the Metropolitan Statistical Area (MSA) of Minneapolis - Saint Paul (MSP). This area includes a list of surrounding municipalities defined by the U.S. Dept. of Commerce.

How the Variable Affects Air Traffic

More people working indicates greater economic activity and a greater demand for air travel. In the HNTB model, local employment is a key variable determining the number of people boarding aircraft who are starting their trips from MSP (Air Carrier Originations).

Baseline Assumptions

The projected values are drawn from U.S. Dept. of Commerce 1985 OBERS BEA Regional Projections, 1985 and Economic Report of the President, January 1987. The value for 2018 is not provided by the HNTB model. It is calculated using a constant average growth rate derived from the previous year values.

Major Uncertainties and Considerations

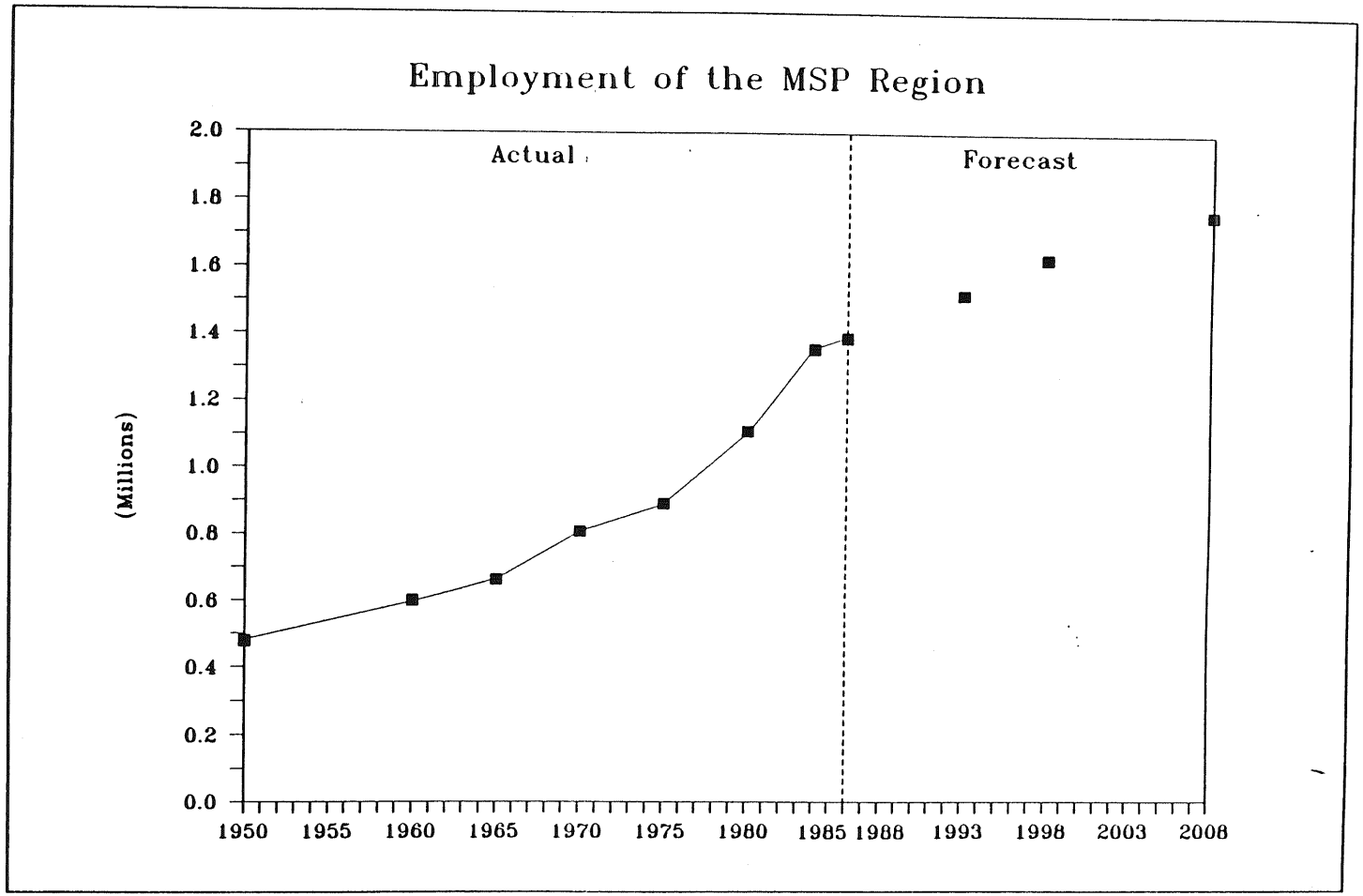
- The Twin Cities economy tends to follow that of the nation through business cycles and the local economy in general is quite sensitive to national trends.

- The Twin Cities economy is also influenced by its high standing as a headquarters town, the medical and high tech industries, and the agri-business sector. The service sector is strong and should continue to grow. Air travel is sensitive to the service-to-manufacturing employment ratio. The higher the ratio, the higher the greater the demand for air travel. What impact do these have on the median and on uncertainty?

- The Dept. of Commerce forecasts an annual growth of employment 1.08 percent over the next twenty years, compared to 1.13 percent nationally. At the same time, population is projected to expand at a higher rate than the national average, implying an age distribution among the local population at variance with national averages. Although the Twin Cities region has enjoyed high employment growth rates over the last 10-15 years, these rates cannot be sustained without an infusion of working-age people.

- In the long term, employment is largely determined by population, which is very stable and relatively easy to predict. Everyone who will be over 20 twenty years from now is alive today. However, at any given moment there is the possibility of a recession or a boom.

- There should be relative stability in the ratio of employment to population. However, the locally high female participation rates may go higher as the non-working, older age group moves on.


Employment of the MSP Region
Actual
Forecast
(Millions)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1950
1955
1960
1965
1970
1975
1980
1985
1988
1993
1998
2003
2008


Employment
Probability Density Function
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1400
1650
1900
2150
+ 1993
◇ 1998
Δ 2003
× 2008
∇ 2018

VARIABLE:
EMPLOYMENT ELASTICITY

Description

Employment elasticity is the percentage change in people taking plane trips that results from a 1 percent change in employment. For example, the 1986 value of 1.75 means that a 1 percent increase in employment in Minneapolis-Saint Paul would cause a 1.75 percent increase in the number of airline trips originating locally (Air Carrier Originations).

How the Variable Affects Air Traffic

This variable determines how sensitive Air Carrier Originations are to changes in local employment. Holding everything else constant, an increase in employment elasticity implies a higher demand for air travel.

Baseline Assumptions

The methodology employed in the HNTB model (log linear regression) holds employment elasticity constant over time. This implies that so long as fares are held constant, a given number of employed people will always demand approximately the same number of plane flights.

Major Uncertainties and Considerations

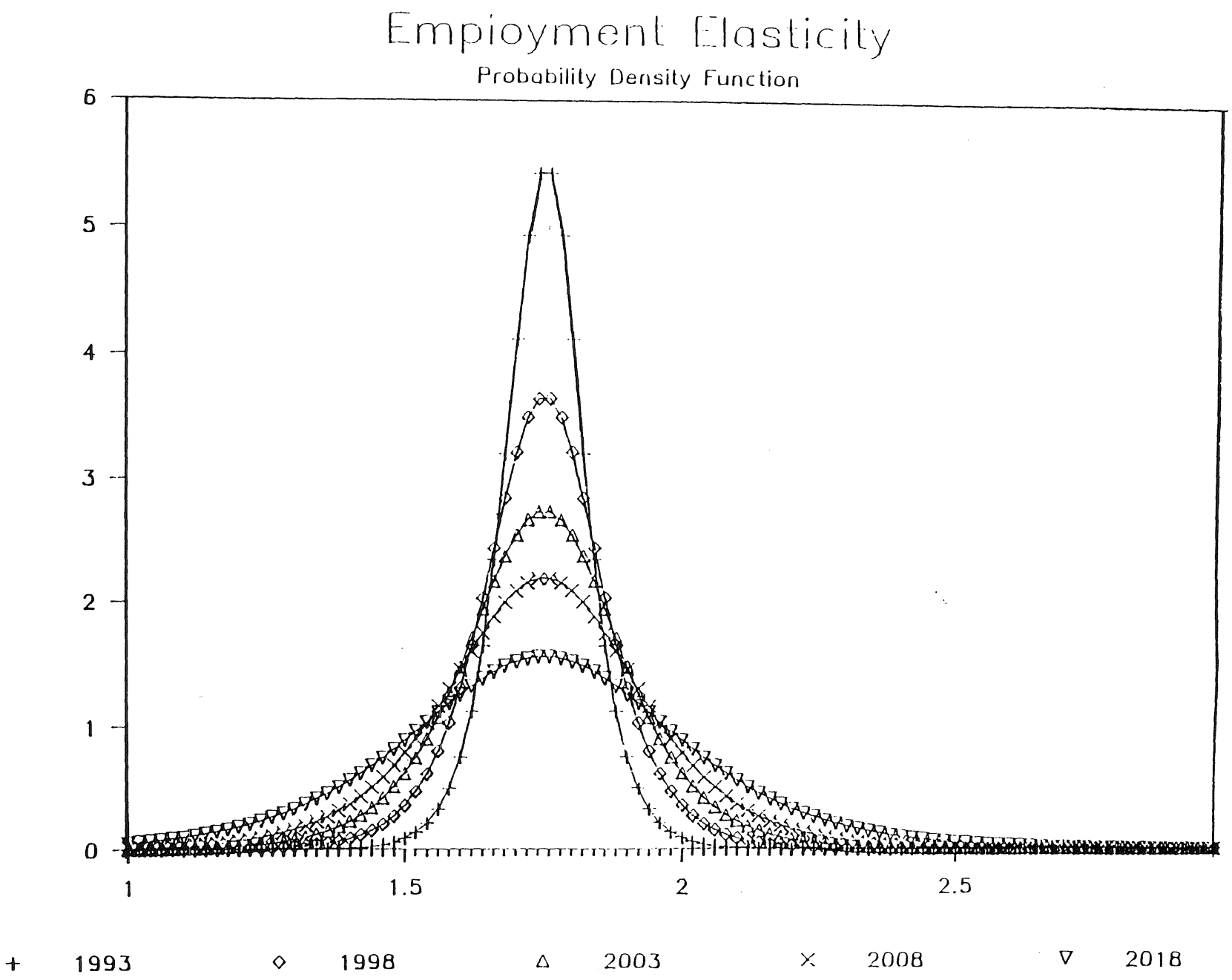
- Average income is expected to rise over time. Will a given size labor force demand more air flights as their income rises? If so, then employment elasticity should rise (given that average income is not an input to the model).

- If employment elasticity is expected to rise with income, is the airline industry a "mature industry"? For example, in developing countries demand for mo-peds initially expands quickly as income expands. As income rises further, growth in demand for mo-peds slows or even becomes negative as people replace their mo-peds with motorcycles and cars. In the latter stage, the mo-ped industry would be called a "mature industry". If air travel is a mature industry then employment elasticity will not rise as quickly as income.

- What impact will the "internationalization" of the Twin Cities economy have?

- Demographics. Will the older population mix in the future affect the sensitivity of the demand for air travel to employment? Will a given size of work force demand more air travel if they are older? What differences are there in local

demographics that may affect this consideration? (Note: population growth for MSP is projected to be higher than the national average.)


Empioyment Elasticity
Probability Density Function
6
5
4
3
2
1
0
1
1.5
2
2.5
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

VARIABLE:
AVERAGE AIRLINE REVENUE PER PASSENGER-MILE

Description

This variable reflects the average price charged to customers for airline flights. Since competition will force revenues to approximate costs, this variable should be thought of in terms of airlines' average costs.

How the Variable Affects Air Traffic

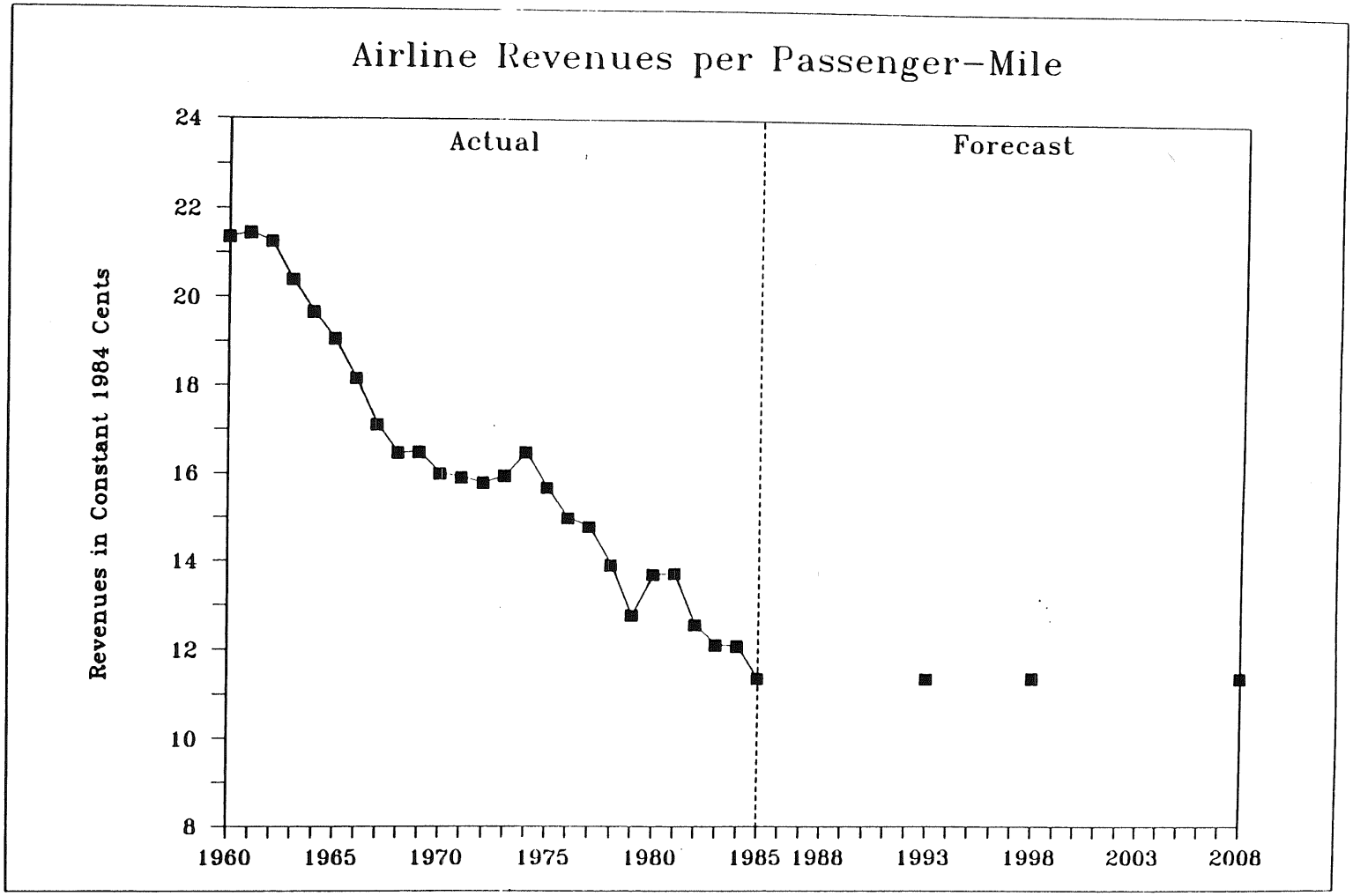
Lower prices create an increase in air travel. In the HNTB model this price variable directly effects only the people getting on planes who start their trips from the Minneapolis-Saint Paul Airport (Air Carrier Originations). The effect of lower prices on the number of people changing planes is felt indirectly at a later stage of the model, since they are treated as a multiple of the Air Carrier Originations.

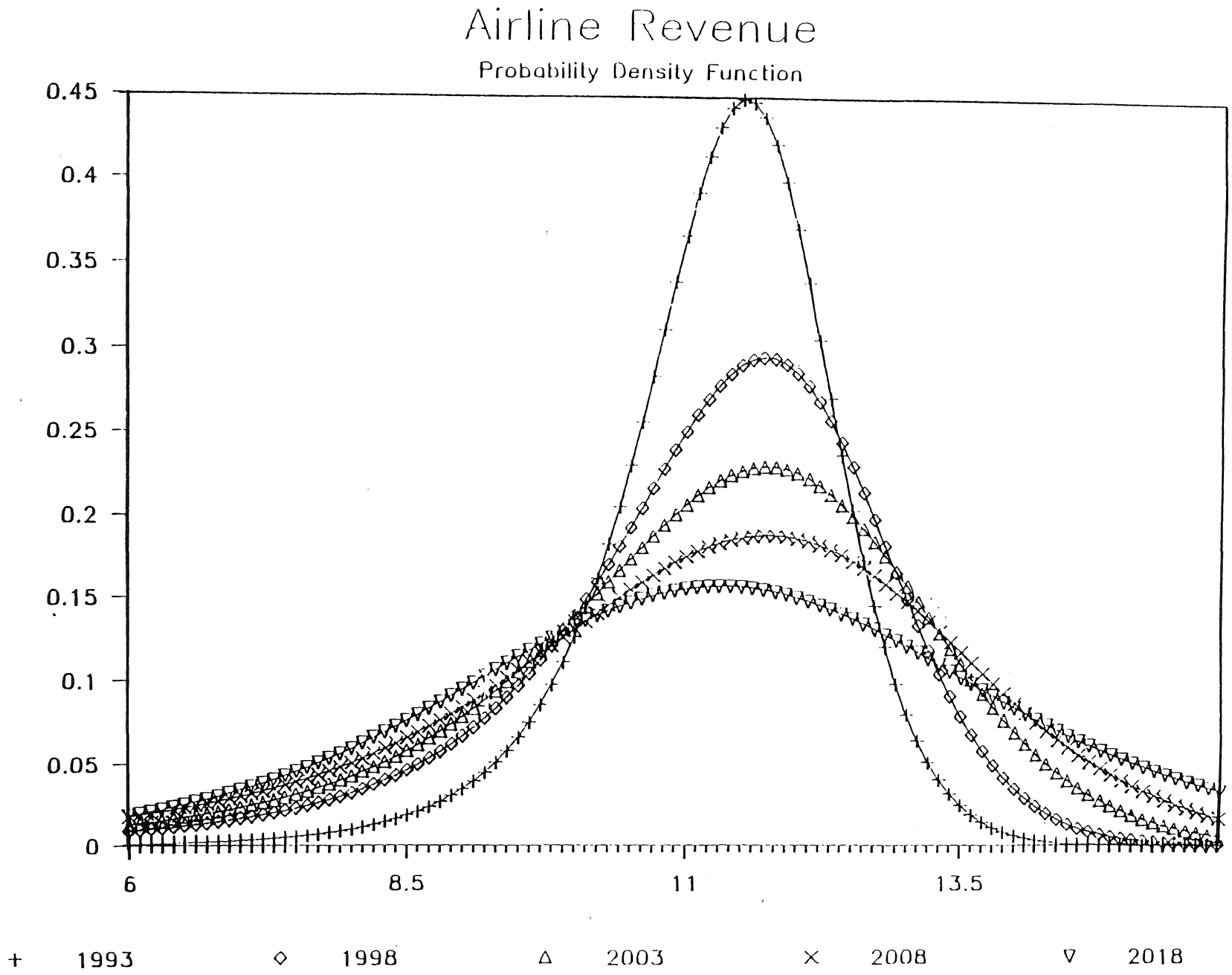
Baseline Assumptions

The HNTB model assumes that, after adjusting for inflation, real revenue per passenger-mile will be constant.

Major Uncertainties and Considerations

- Oil Prices. Will they be higher or lower in real terms? Note, for example, the rise in the graph during 1973-74, the year of the OPEC oil boycott and the 1979-80 oil crisis.
- Increased fuel efficiency of new aircraft.
- Other technological improvements, such as improved routing through hubbing and further use of computers.
- Labor costs. Deregulation has brought pressure on unionized airlines to lower their labor costs as market protection has been removed. Have the full effects of deregulation on labor cost been felt at Minneapolis - Saint Paul International? Are labor costs likely to fall in the future in real terms?
- Real interest rates. Higher rates mean higher financing costs. Note the rise in the graph during 1980 to 1981, years of rising interest rates.
- Airport charges. Will the trend towards cost recovery by airports continue and have a significant impact on prices charged airline passengers?
- The general trend of airline revenue per passenger mile has been downward.


Airline Revenues per Passenger–Mile
Revenues in Constant 1984 Cents
24
22
20
18
16
14
12
10
8
Actual
Forecast
1960
1965
1970
1975
1980
1985
1988
1993
1998
2003
2008


Airline Revenue
Probability Density Function
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
8.5
11
13.5
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

VARIABLE:
FARE ELASTICITY

Description

This is the fare elasticity of the demand for air travel originating in Minneapolis - Saint Paul. Fare elasticity is the percentage change in quantity demanded resulting from a 1 percent change in fares (prices), as measured by Revenue per Passenger Mile. For example, the 1986 value of -0.0091 means that a 1 percent increase in fares would cause a 0.0091 percent decrease in the number of airline trips originating locally.

How the Variable Affects Air Traffic

This variable determines how sensitive Air Carrier Originations are to changes in fares. Holding everything else constant, a larger fare elasticity implies a lower demand for air travel. (Thus the negative sign in the estimate.)

Baseline Assumptions

The methodology employed in the HNTB model (log-linear regression) assumes a constant price elasticity of (-0.81), meaning that a 1 percent rise in fares reduces Air Carrier Originations by 0.81 percent. This estimate is not changed over time.

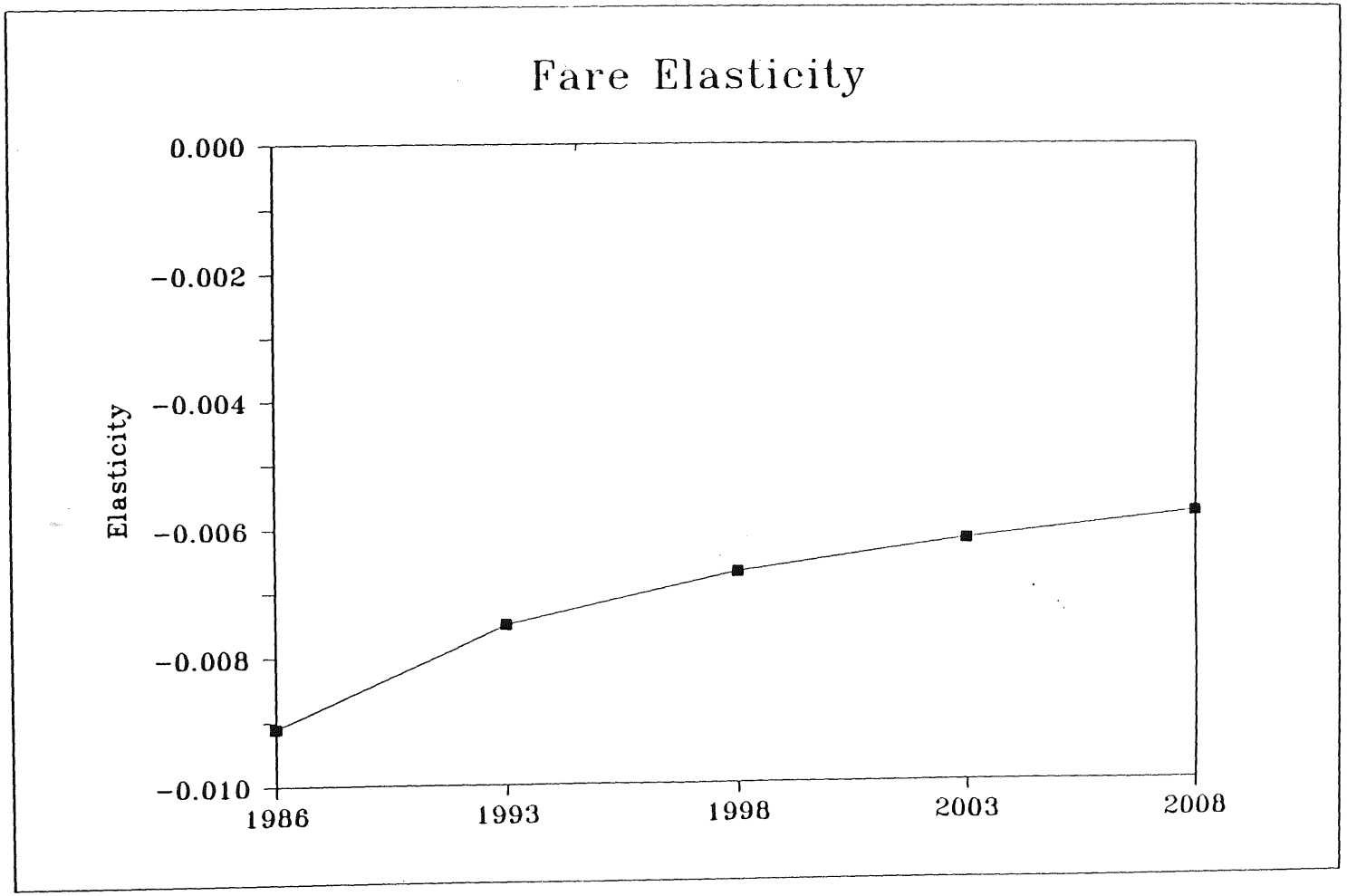
Major Uncertainties and Considerations

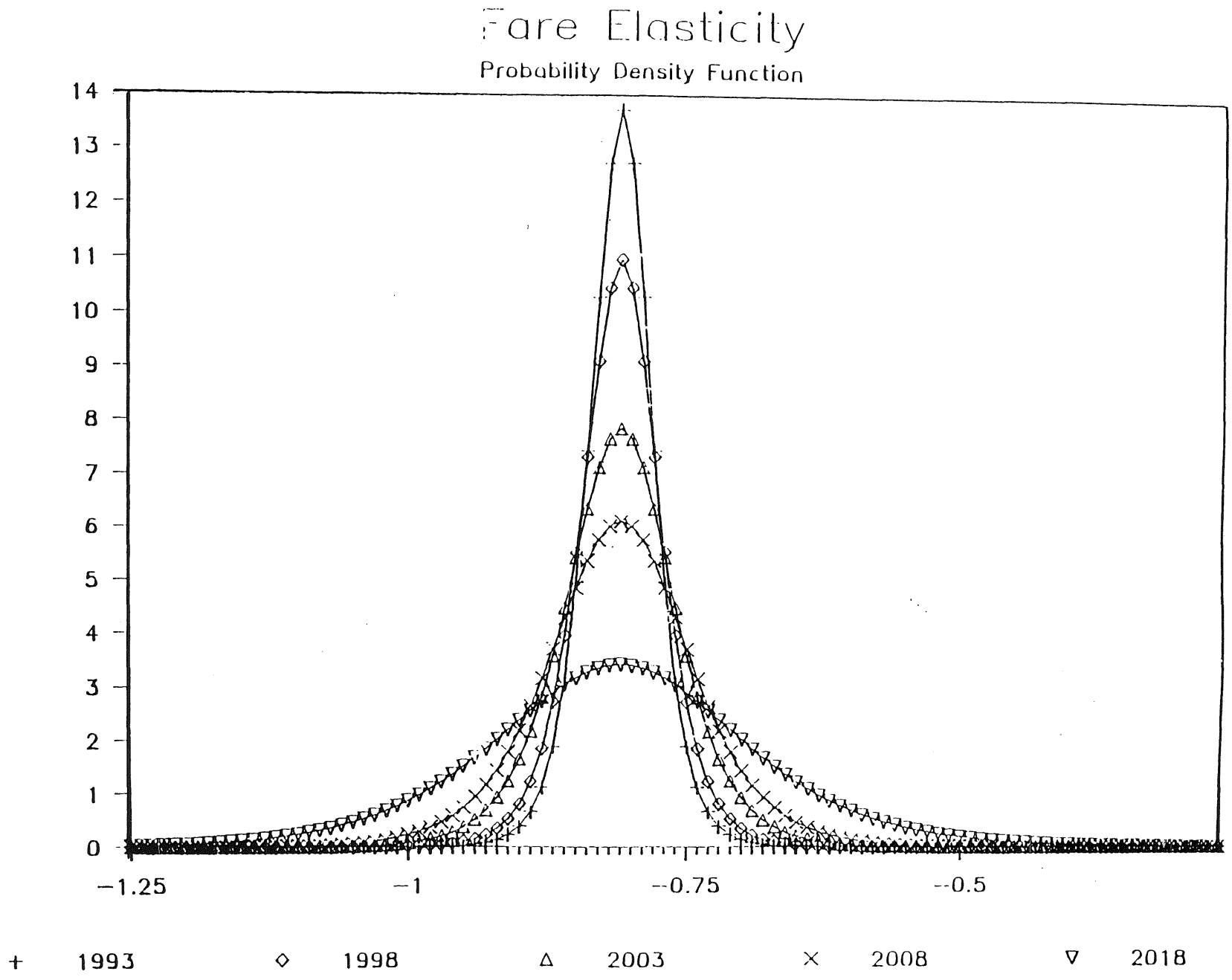
- Telecommunications technology has been heralded as a substitute for air travel, although little substitution has been empirically noted. Will the development and growth of alternative business communications such as fax machines create more substitutes for business travel and making business more sensitive to air fares?

- Will the proportion of originations accounted for by vacation travel increase, and would this increase the price sensitivity of air carrier originations? Is vacation travel more price elastic than business travel?

- In the top 30 markets for MSP, the non-business/pleasure markets are more related to income and fare elasticities while business markets are more closely correlated to GNP. The ratio of business to non-business is 60 to 40. These markets are likely to grow at different rates.

- Total travel costs (as opposed to airfares alone) have been identified as an issue of growing importance since, for example, the costs of hotel and ground transportation often exceed the cost of an airline ticket.


Fare Elasticity
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
Elasticity
1986
1993
1998
2003
2008


Fare Elasticity
Probability Density Function
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1.25
−1
--0.75
--0.5
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

VARIABLE:
RATIO OF ENPLANEMENTS TO ORIGINATIONS

Description

The total number of people getting on planes (enplanements) is made up of people starting their trips from Minneapolis - Saint Paul International (the number of Air Carrier Originations), and people transferring between flights. The ratio between people starting their trips and the total number of people enplaning is called the Ratio of Enplanements to Originations.

How the Variable Affects Air Traffic

The HNTB model makes use of the ratio (k) as follows:

If: k = Enplanements/Originations

then: Enplanements = k * Originations

This means that total enplanements may be imputed by multiplying the estimate of the Air Carrier Originations by a projected Ratio of Enplanements to Originations.

Baseline Assumptions

The ratio for Minneapolis - Saint Paul International is currently below the average of similar airports. The HNTB model assumes that the ratio of enplanements to originations (1.91) will converge to the average ratio of similar airports (2.13) and that this average will remain constant thereafter. This movement is justified by noting a general tendency of these ratios at other airports to move towards the mean in the recent past.

Major Uncertainties and Considerations

- Air traffic originating outside of MSP is influenced by national economic activity. If economic growth or population growth in the MSP area diverges either from the national average, this will affect the ratio of enplanements originating in MSP versus those originating elsewhere.

- MSP has only five banks per day in 1988 compared to other major hubs with 7-8 banks per day. If more banks are added then the ratio of enplanements to originations ought to rise for each additional bank.

- The addition of new banks is more likely determined by the availability of afield capacity than by the level of market demand. In addition, the lack of capacity may force the relocation of some through traffic to other uncongested airports (Milwaukee).

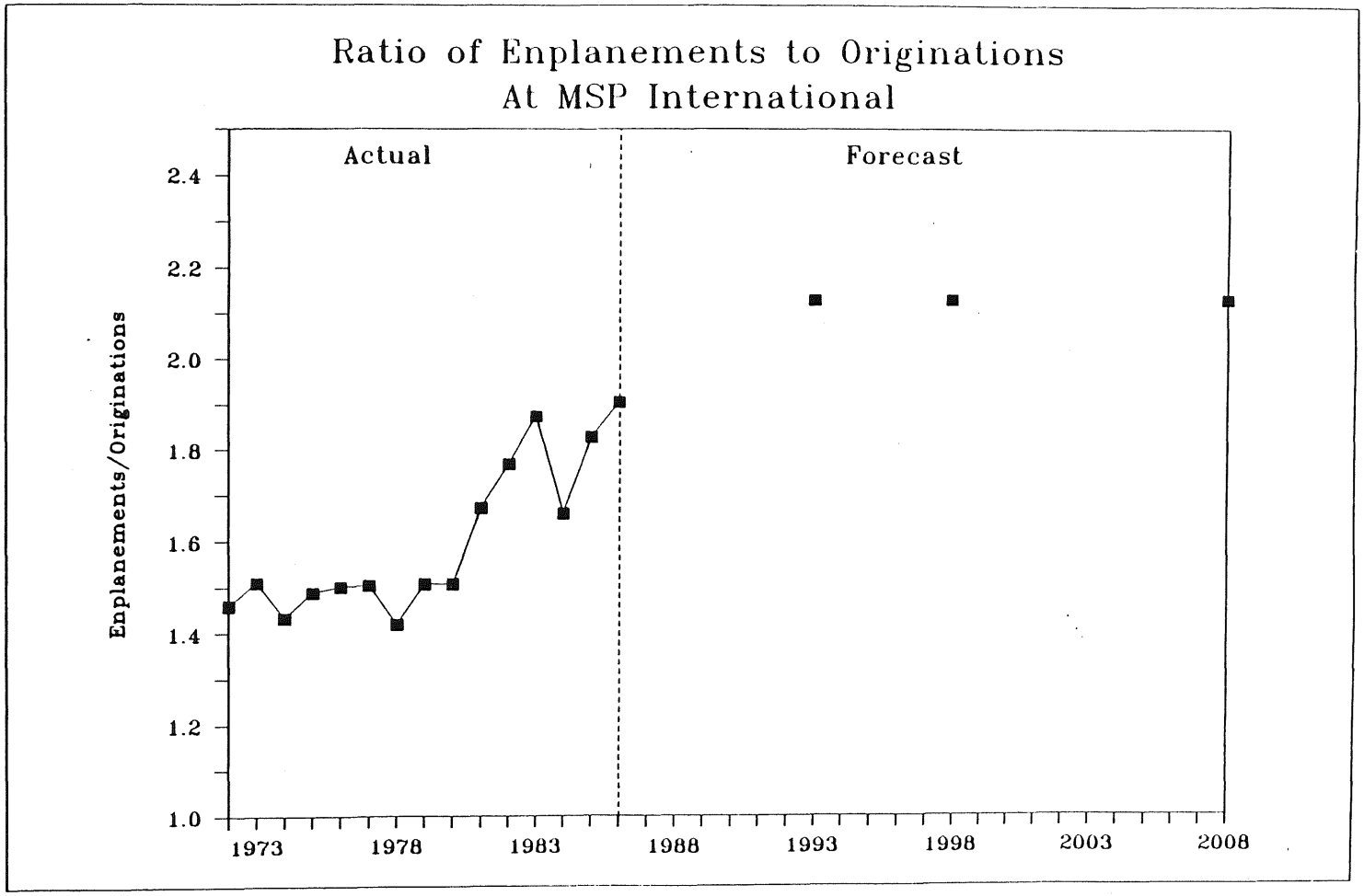
- Regardless of what happens to Northwest, MSP will be a hub for some airline because of the strength of the local air travel market.

- Is there reason to assume that the Minneapolis - Saint Paul International ratio will move all the way to the national mean? At any given year there will be airports above and below the mean. Are there causal factors that keep MSP below the mean now that will last into the future?

- Is the current forecast warranted by NW merger and hubbing expectations? If there are major future decisions which will affect the ratio of enplanements to originations, do they bring about a leftward or rightward skew?

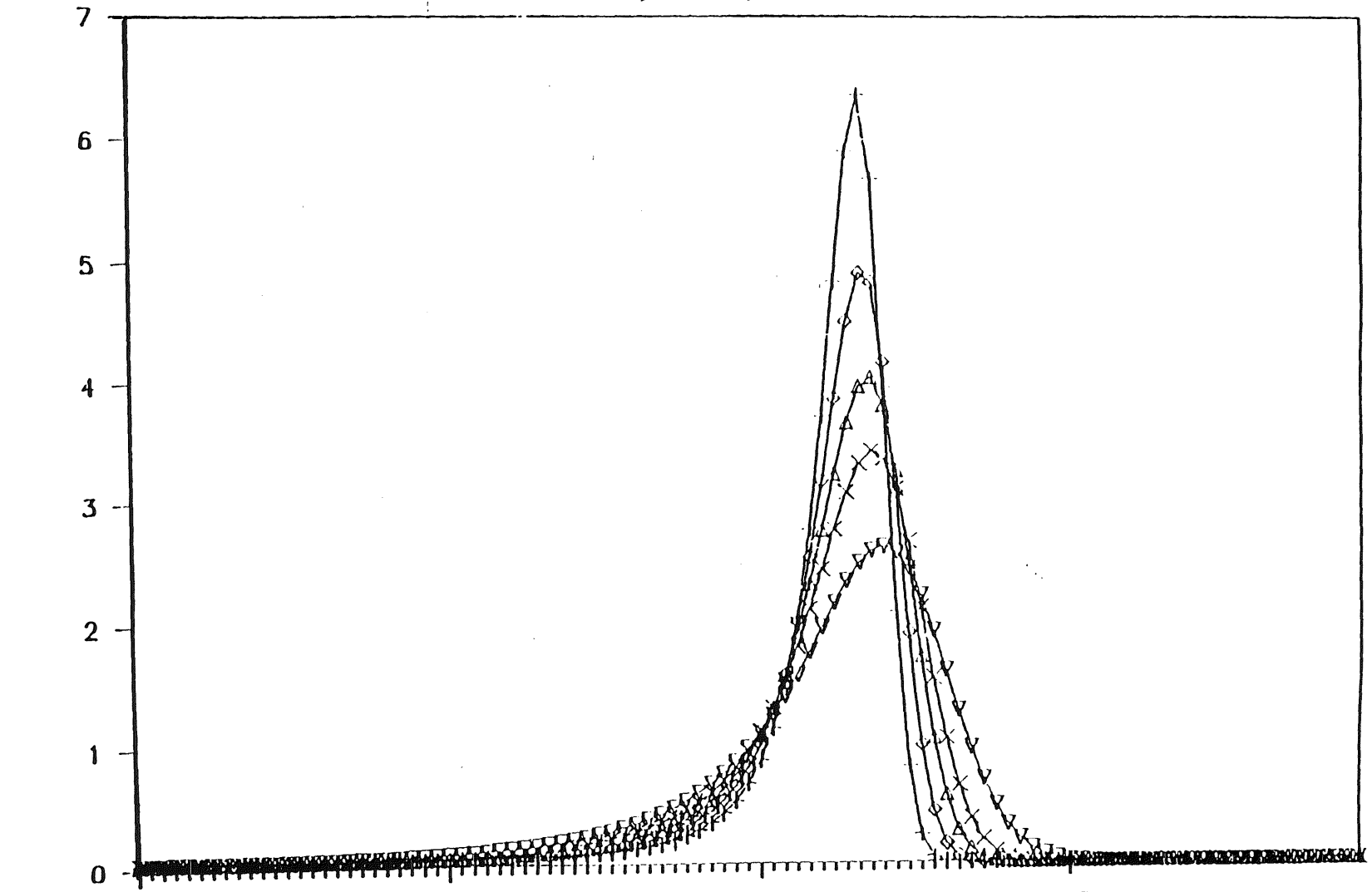
- "Through" passengers are those who stay on the plane rather than disembark and transfer to another flight. Will increased routing efficiency lead to more through passengers, fewer non-originating enplanements and a lower ratio?

- Environmental capacity constraints could present problems at MSP and force down the ratio of enplanements to originations.


Ratio of Enplanements to Originations
At MSP International
Actual
Forecast
Enplanements/Originations
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
1973
1978
1983
1988
1993
1998
2003
2008

Ratio Enplanements/Originations

Probability Density Function



VARIABLE:
AVERAGE AIRCRAFT SIZE

Description

The average aircraft size is a weighted average estimate of the number of seats available per air carrier departure based on the type and frequency of departures. The MSP average, 139, is somewhat lower than the national average, 151. This may be due the nature of demand for MSP's primary service area, which includes not only the metropolitan area, but also many of the upper mid-west regions.

How the Variable Affects Air Traffic

Arrivals and Departures are a key workload measure for airports. Because one of the potential constraints to capacity is the number of operations (not the passengers per operation), the average number of seats per operation will have a direct impact on the passenger capacity of a given facility. Alternatively, bigger aircraft mean fewer arrivals and departures for a given number of passengers. This variable is used to convert the number enplanements (passengers boarding) to arrivals and departures.

Baseline Assumptions

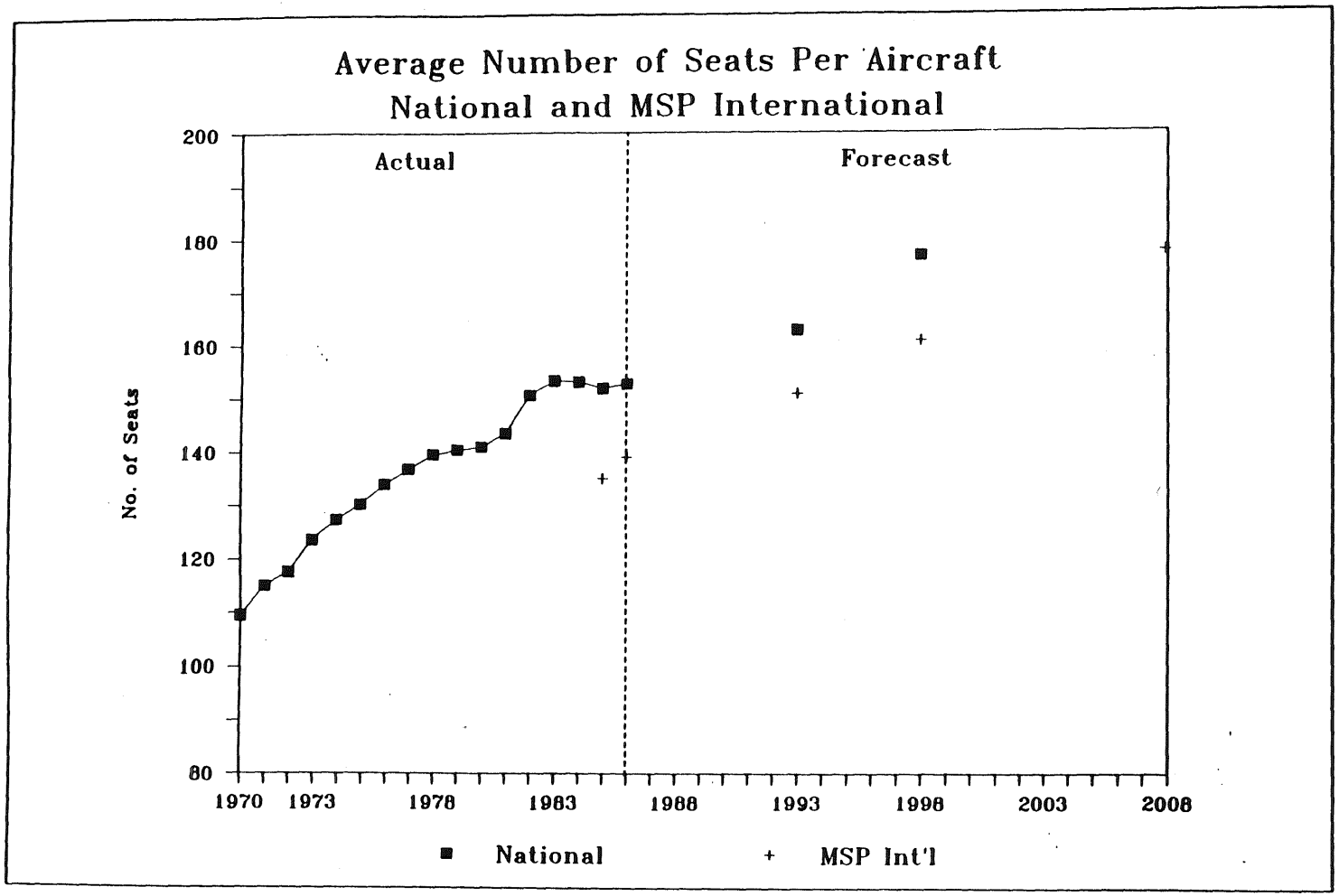
The HNTB model uses FAA forecasts of average aircraft size. (Aviation Forecasts: 1985-1996, 1985). The FAA projects an increase in the average number of seats of 1.47 percent annually. As check, HNTB examine known fleet and purchasing decisions by major airlines serving Minneapolis - Saint Paul and the proposed noise budget. They conclude that these are consistent with the FAA forecast. After 1997, a growth rate of 1 percent per annum is assumed.

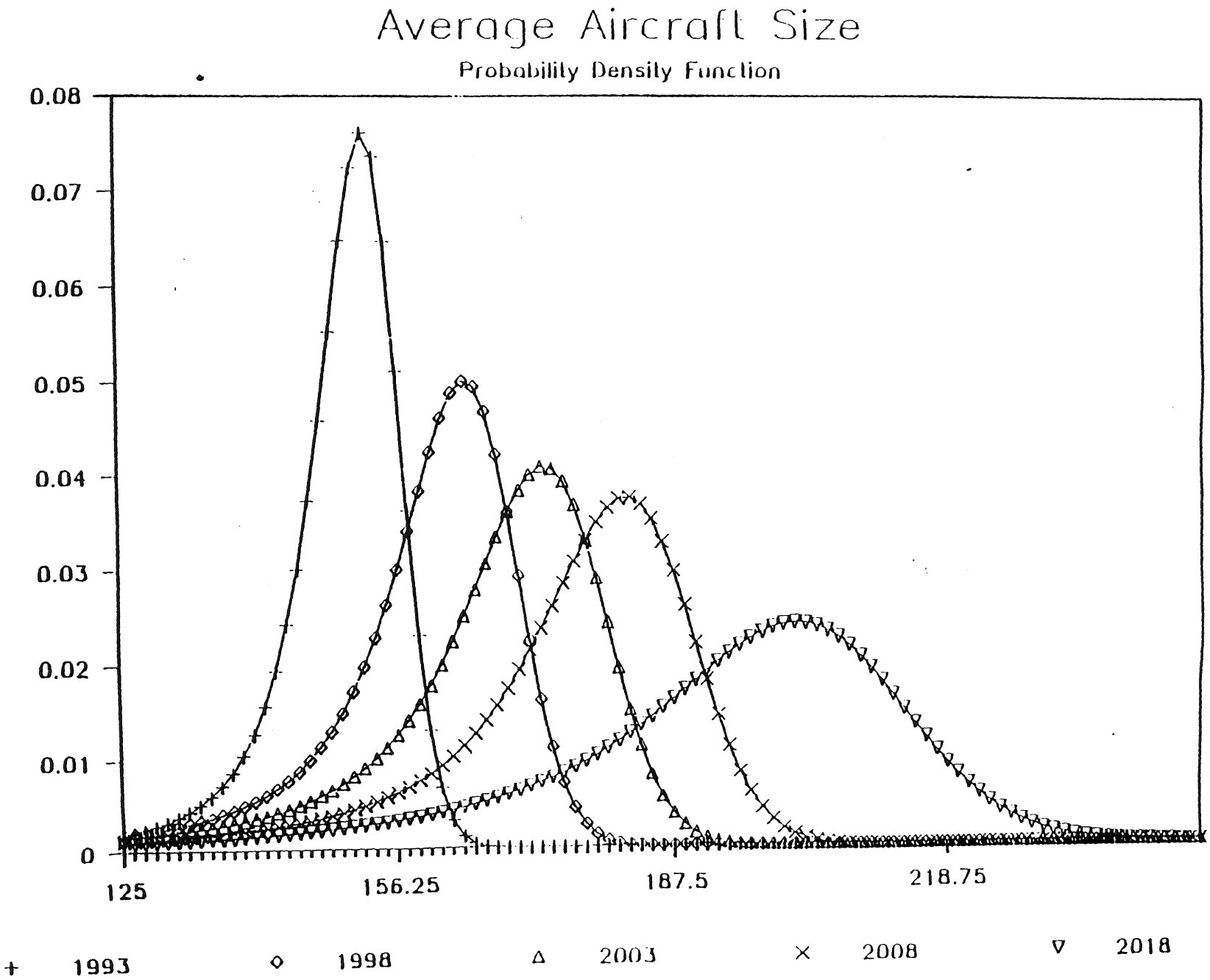
Major Uncertainties and Considerations

- Is the probable impact of the proposed noise budget adequately represented?

- Will changes in fuel costs, labor costs, or interest rates, slow or accelerate fleet renewal? Currently, for example, the cost of new aircraft is rising faster than inflation. Airlines are, therefore, more likely to keep the existing fleet in service longer.

- Is the assumption of 1 percent growth after 1997 justified? Average aircraft size should, for example, continue to grow at the anticipated two seat per year rate, but less than a two-seat increase is likely over the next 10 to 15 years, followed by a greater than two-seat increase thereafter.


Average Number of Seats Per Aircraft
National and MSP International
Actual
Forecast
No. of Seats
200
180
160
140
120
100
80
1970
1973
1978
1983
1988
1993
1998
2003
2008
National
MSP Int'l


Average Aircraft Size
Probability Density Function
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
125
156.25
187.5
218.75
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

VARIABLE:
ENPLANING LOAD FACTOR

Description

The enplaning load factor is the percentage of seats of departing aircraft filled by enplaning passengers. The load factor at MSP is not calculated in the same fashion as the national estimate. Nationally, the average reflects the number of revenue passenger miles as a percent of total seat miles available. At MSP, the load factor is passenger departures as a percent of seat departures. Consequently, while the trends may be comparable, the absolute magnitude is not. Note that there are other "through" passengers who never leave their plane, so that the percentage of seats occupied will be higher than the enplaning load factor. Much as the average number of seats per departure is important to potential passenger capacity, average load factor reflects how effectively that capacity is being used.

How the Variable Affects Air Traffic

The Enplaning Load Factor is used in combination with the Average Aircraft size to convert the number of enplanements to the number of departures. (Arrivals are assumed to equal Departures) For example, in 1986 the average aircraft had 139 seats and it filled 49 percent of these from enplaning passengers (the Enplaning Load Factor). Since 49 percent of 139 is 68.1, we may say that for every 68.1 enplanements there was one departure.

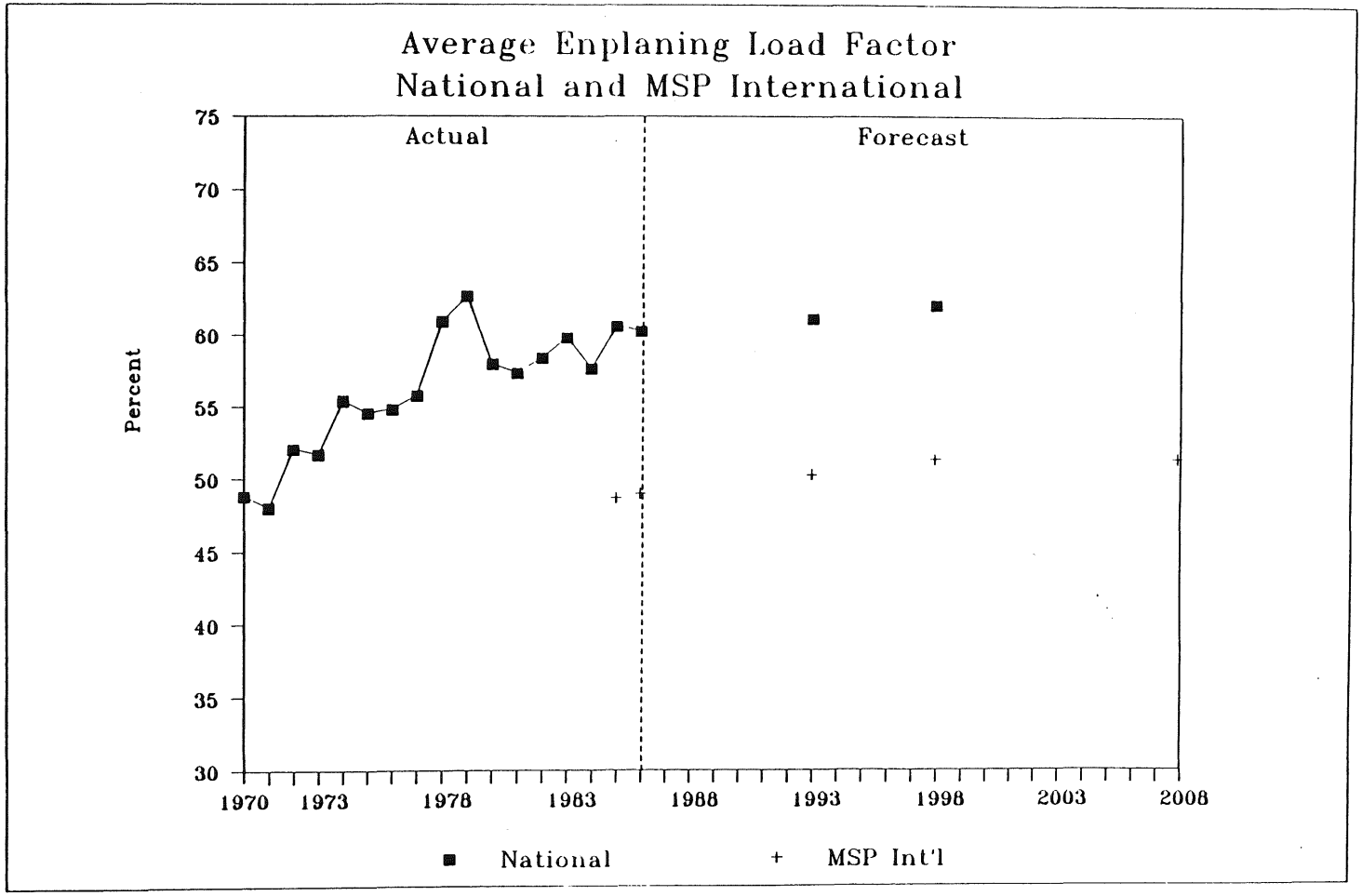
Baseline Assumptions

The HNTB model assumes that the percentage of seats filled by enplaning passengers, will increase by 0.53 percent per year until 1996. This figure is derived from the FAA forecast Aviation Forecasts: 1985-1996, 1985. Subsequent to 1996, the model holds the enplaning load factor constant.

Major Uncertainties and Considerations

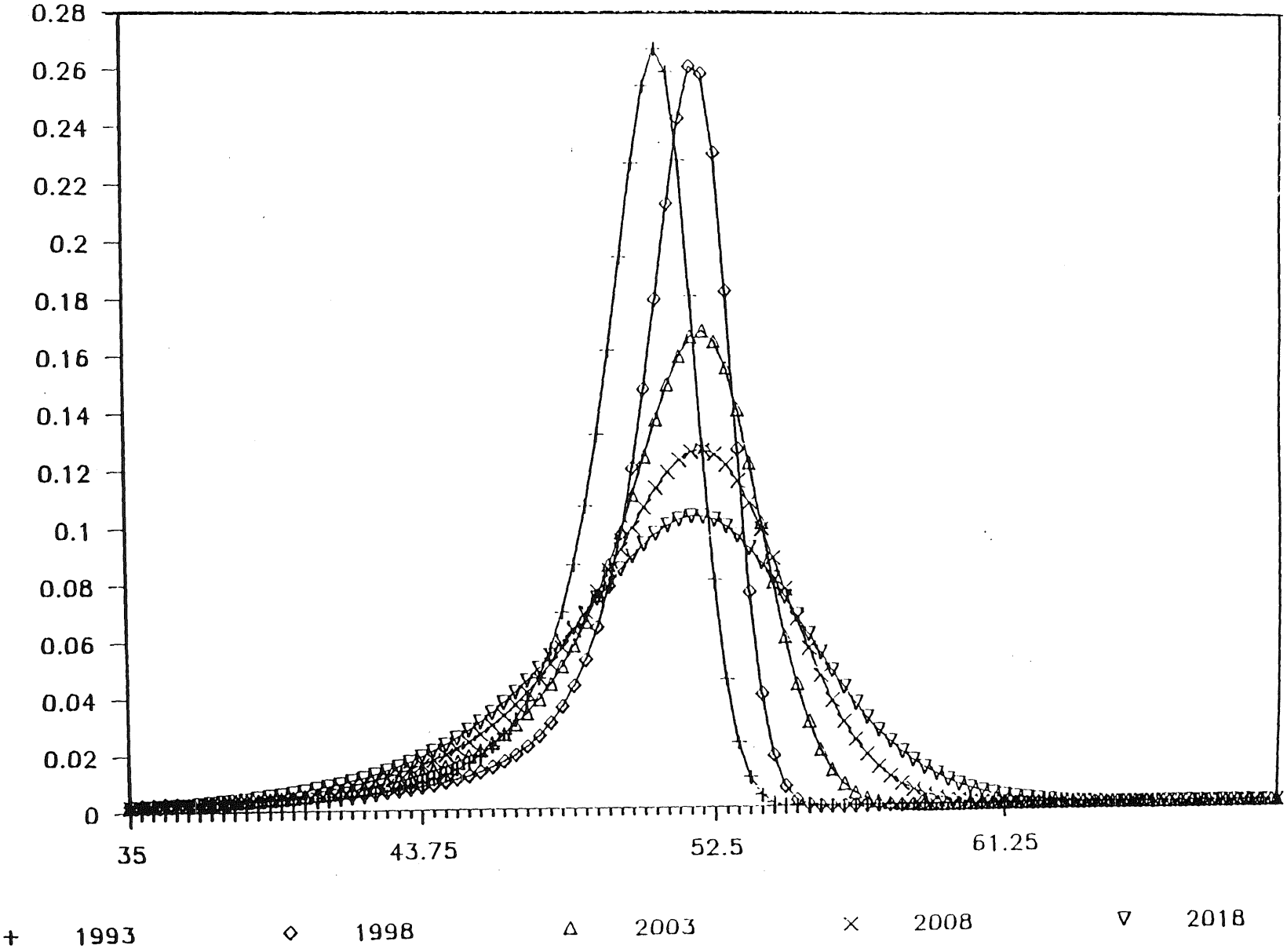
- Anything affecting the ratio of enplanements to originations may also affect the enplaning load factor. If the proportion of enplanements that are not originating rises, it is possible that the proportion of seats of "through" passengers will also rise, reducing the number of empty seats and reducing the enplaning load factor.

- Does the FAA projection fully capture future increases in seat utilization by airlines?


Average Enplaning Load Factor
National and MSP International
Actual
Forecast
Percent
75
70
65
60
55
50
45
40
35
30
1970
1973
1978
1983
1988
1993
1998
2003
2008
National
MSP Int'l

Enplaning Load Factor

Probability Density Function



VARIABLE:
PEAK MONTH OPERATIONS

Description

Peak month operations is the proportion of annual traffic accounted for by the busiest month expressed as a percentage of annual Aircraft Operations (arrivals and departures).

How the Variable Affects Air Traffic

This variable is used in conjunction with hourly traffic data to determine the peak load faced by the airport. This in turn has an important impact on planning, since the size of facilities is governed by the peak load they are expected to handle.

Baseline Assumptions

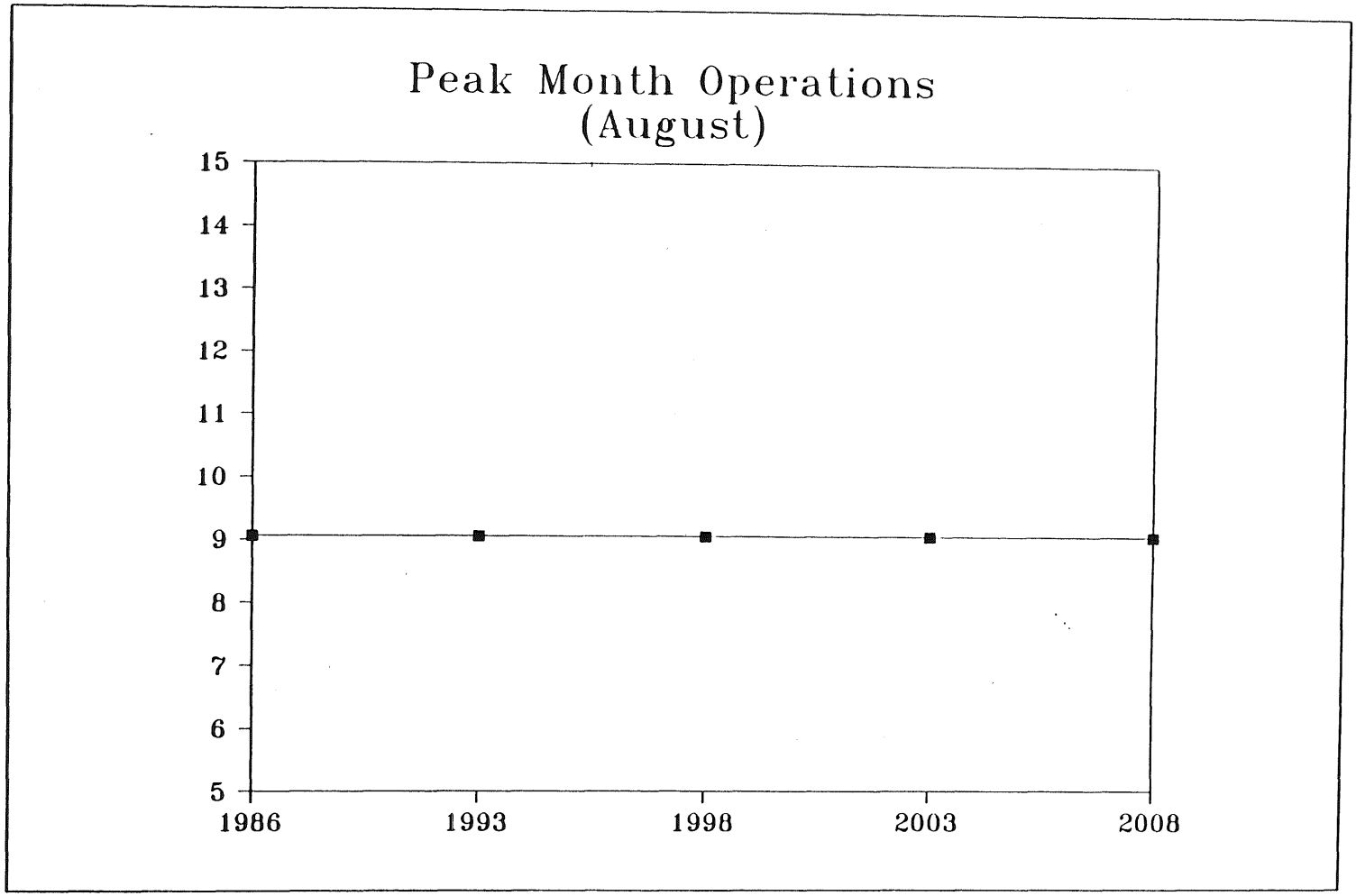
The HNTB model assumes that the current share of the peak month (August) will remain constant at 9.06 percent of annual Aircraft Operations.

Major Uncertainties and Considerations

The key factor is not the identity of the month but the percentage accounted for by the peak month. Some considerations are as follows:

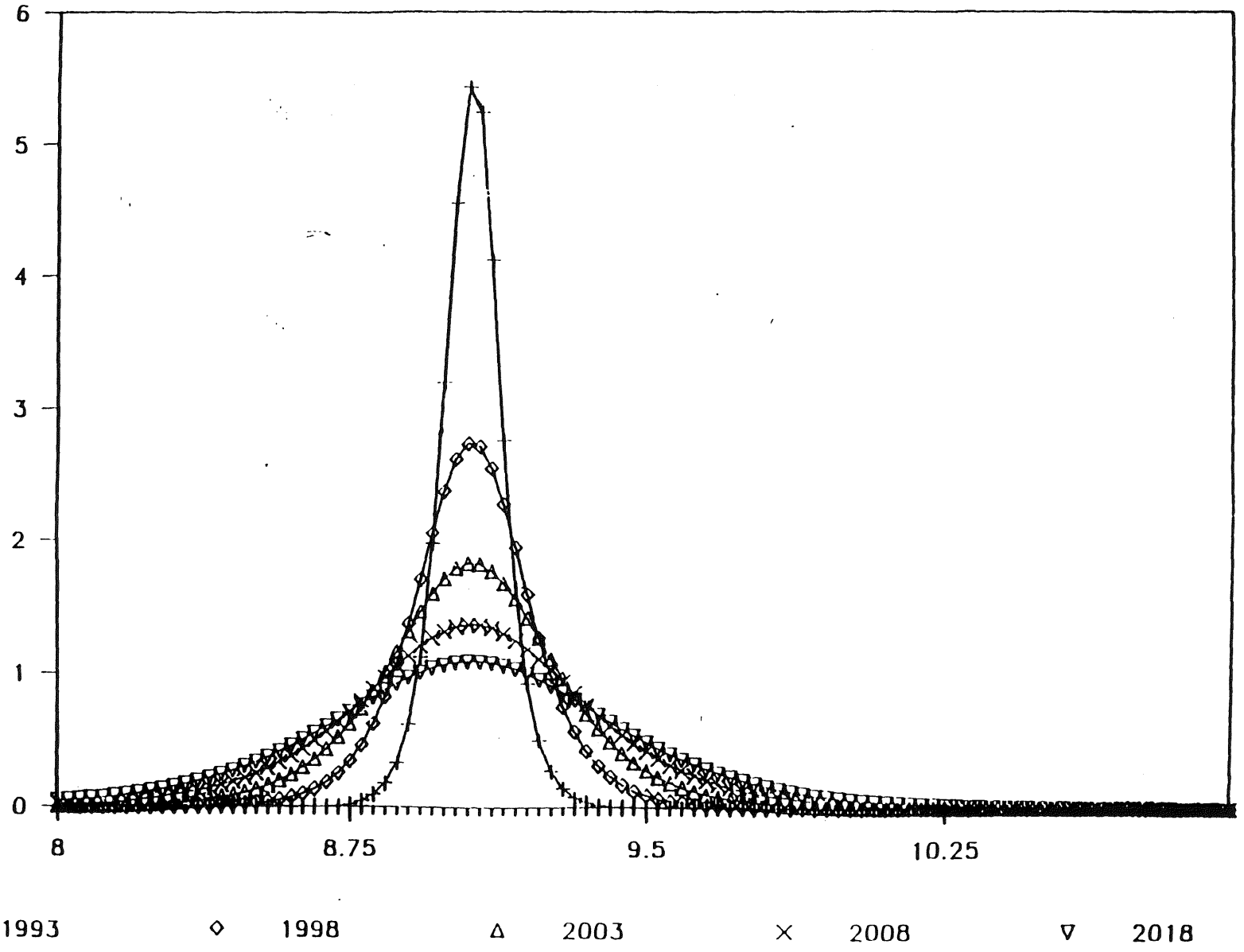
- Will the proportion of enplanements in the peak month caused by vacation travel increase? Will this increase the proportionate share of the peak months? A related concern is the aging demography of the population.

- The peak month cannot have less than one twelfth or 8.33 percent of the annual traffic.


Peak Month Operations
(August)
15
14
13
12
11
10
9
8
7
6
5
1986
1993
1998
2003
2008

Peak Month Operations

Probability Density Function



VARIABLE:
PEAK HOUR PEAK MONTH OPERATIONS

Description

Peak hour peak month operations is the proportion of arrivals and departures occurring during the busiest hour of an average day on the busiest month. It is expressed as a percentage of the daily total of arrivals and departures. The average day is calculated by dividing the busiest month's traffic by the number of days in the month.

How the Variable Affects Air Traffic

The Peak Hour Peak Month Operations identifies the peak load that airport facilities will be expected to handle repeatedly. This will affect planning of the size of facilities. (Note: The peak hour of the peak day is not used since this peak would not occur often. Instead we have the peak hour of the average day in the peak month.)

Baseline Assumptions

The HNTB assumes that the general daily pattern of peaks will continue. The three busiest periods are in the morning before 9:00, in the two hours following 12:00, and from 5:00 p.m. to 5:59 p.m. The evening peak was the biggest in 1987 with 10.2 percent of average daily operations during the peak month. However, it is also assumed that the share of the peak hour will fall over time as operating hours at the airport are extended, and as increased hubbing by Northwest Airline cause more connecting flights. Connecting flights will tend to occur in off-peak hours because their passengers will be departing and arriving at peak hours at other airports.

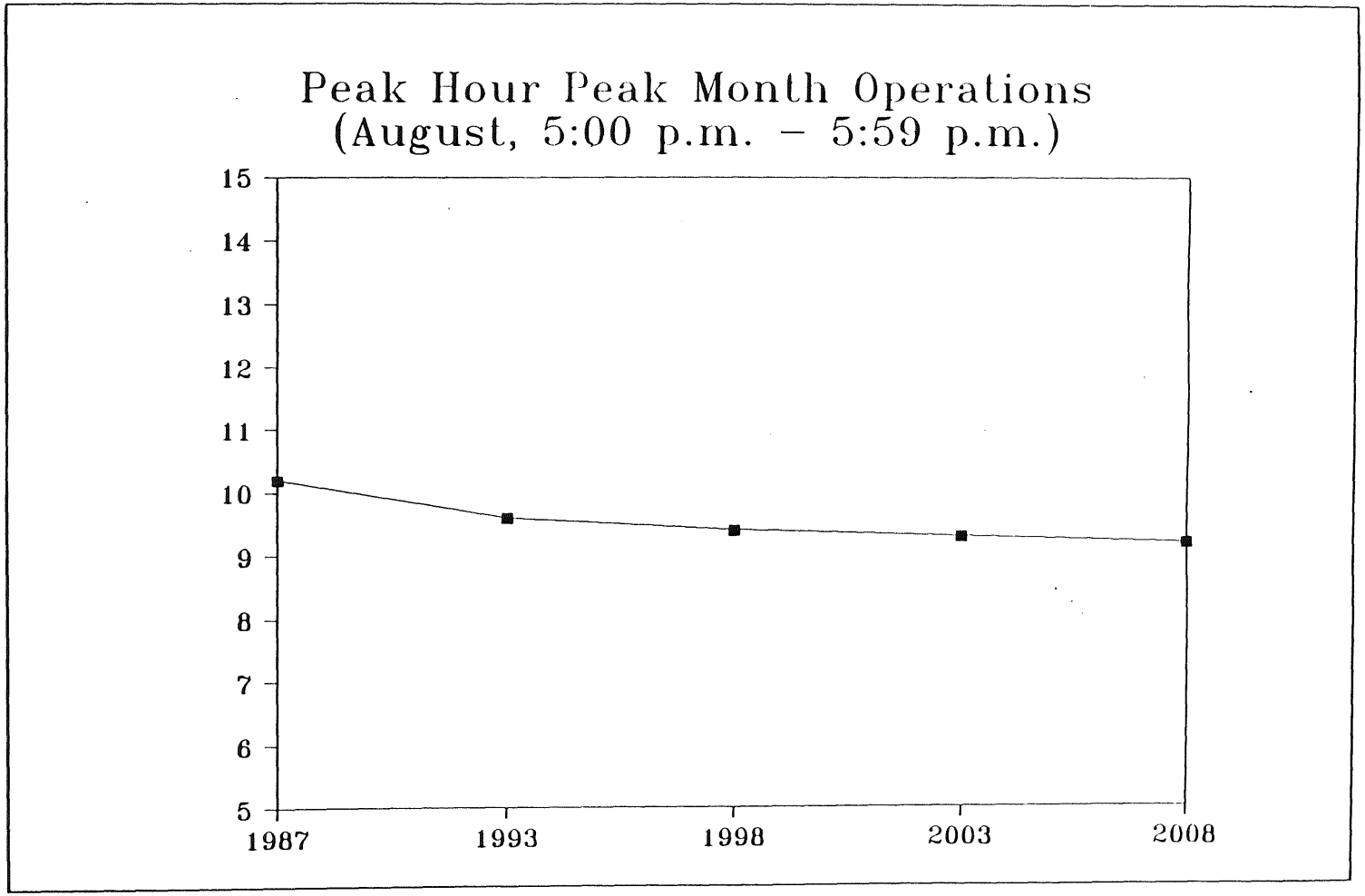
Major Uncertainties and Considerations

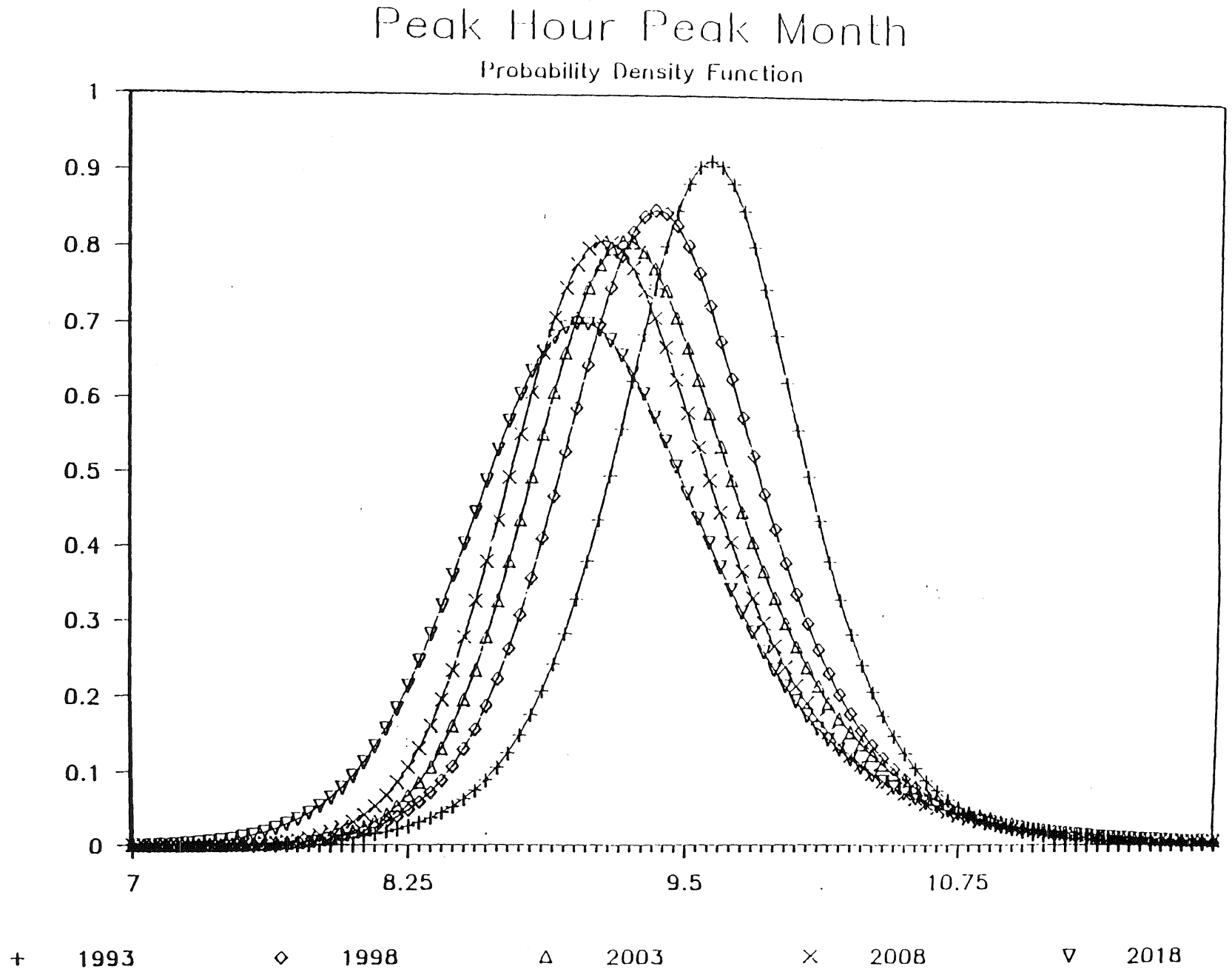
- Is the Minneapolis - Saint Paul International Airport planning future pricing policies to shift operations away from peaks? Have these been accounted for?

- Does the absence of analysis of a weekly cycle have an impact on a systematically recurring peak hour?

- Is there an anticipated change in the mix of business and vacation travel? Will this affect peaks?

- The lower bound on a peak load hour is 1/24 of the day or a little over 4 percent.


Peak Hour Peak Month Operations
(August, 5:00 p.m. – 5:59 p.m.)
15
14
13
12
11
10
9
8
7
6
5
1987
1993
1998
2003
2008


Peak Hour Peak Month
Probability Density Function
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7
8.25
9.5
10.75
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

VARIABLE:
REGIONAL CARRIER ENPLANEMENTS

Description

Regional Carrier Enplanements is the number of passengers boarding regional carriers and air taxis, and carriers which typically serve the small communities within a several hundred mile radius of MSP.

How the Variable Affects Air Traffic

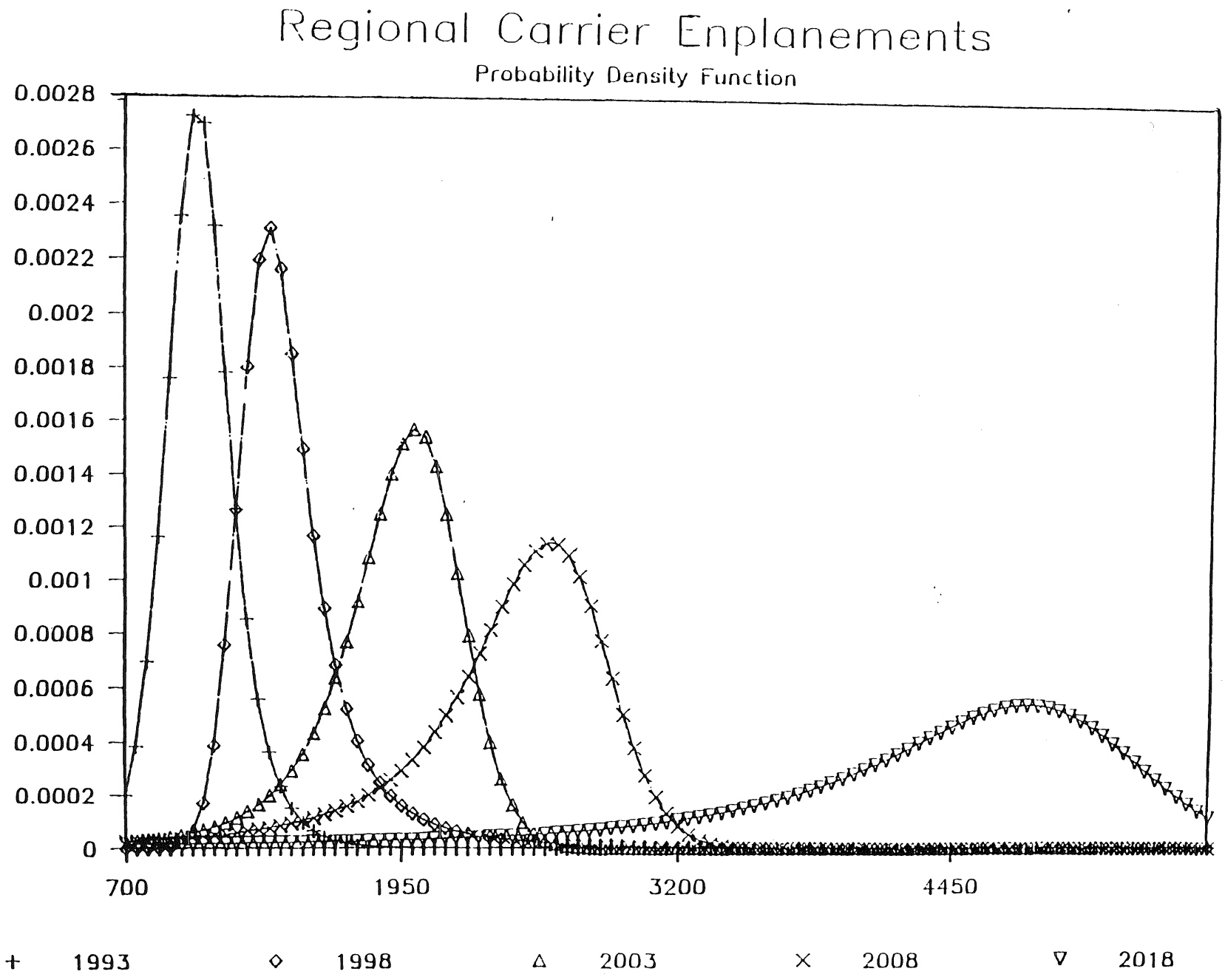
Regional Carrier Enplanements are distinct from enplanements of domestic carriers. They represent a different kind of passenger using a different class of planes. While domestic carrier enplanements are forecast by the HNTB model using several input variables, the smaller volume of Regional Carrier Enplanements is itself an input variable. Enplanements are themselves a measure of the workload of airport facilities. The number of enplanements is used in combination with aircraft size to determine the number of arrivals and departures by regional carriers.

Baseline Assumptions

While the number of carriers has not increased significantly over the last two year (from 6 to 7), many have entered into code-sharing agreements with the major carriers. Under such an agreement, the regional airline uses the air carrier's code in published schedule and reservation systems. As a result, preliminary 1986 data show a 60 percent increase in operations over 1985 levels. Based on discussions with airlines, including NW, HNTB forecast a 15 percent annual growth rate through 1990. After 1990 the growth rate is assumed to diminish to the 6 percent forecast by the FAA for regional carriers in Aviation Forecasts: 1987-1998, 1987.

Major Uncertainties and Considerations

- The local growth rate for regional carriers is projected to be much higher than the national average. Is this justified?
- At some point, the number of passengers carried by the regionals will reach a level which may interest the major carriers in competing for them. The growth rates implicit in this variable should consider this possibility.
- Is the 6 percent national growth rate justified?


Regional Carrier Enplanements
Probability Density Function
0.0028
0.0026
0.0024
0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
700
1950
3200
4450
+ 1993
◇ 1998
△ 2003
× 2008
▽ 2018

VARIABLE:
REGIONAL CARRIER AIRCRAFT SIZE

Description

Regional carrier aircraft size is the weighted average number of seats of regional carrier aircraft departures from MSP. The MSP average, 30.0, is higher than the national average, 21.5.

How the Variable Affects Air Traffic

Arrivals and Departures are a measure of the workload of an airport. The more seats on the average plane, the fewer departures for a given number of passengers (enplanements) by regional carriers.

Baseline Assumptions

Over the next ten years the FAA forecasts a 2.9 percent annual growth in the average size of regional carrier aircraft. Because the MSP average is already higher than the national average, it is assumed that the average aircraft size will increase by only 2.5 percent through 1998. Beyond 1995, growth is expected to be lower, at 1.5 percent annually.

Major Uncertainties and Considerations

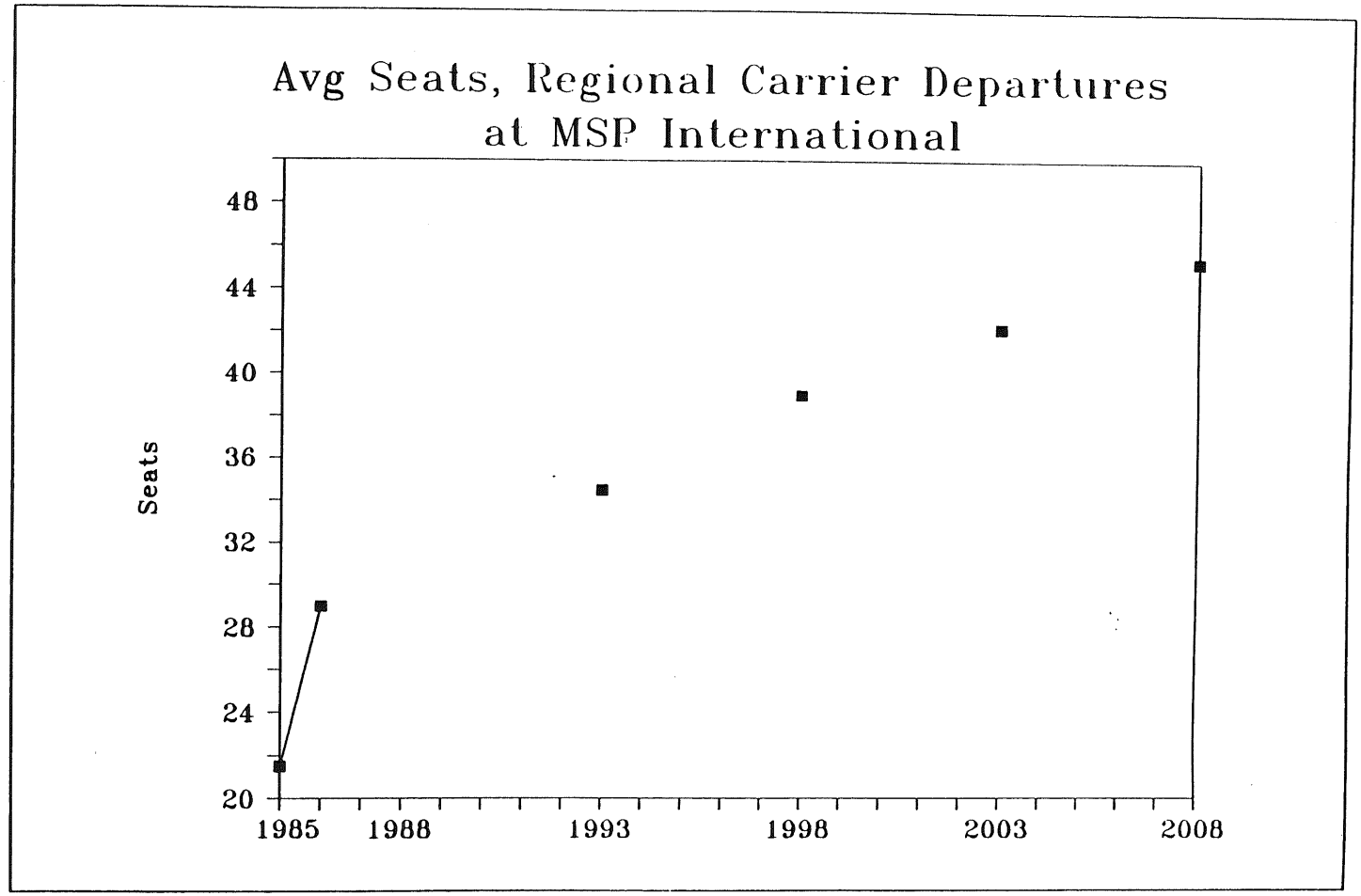
- One of the reasons for the higher than average planes size is the presence of RC/NW CVR's. The current forecast assumes that this fleet will not be expanded. Is this valid?

- Is the high growth forecast for regional enplanements consistent with a low growth in plane size? Will accelerated fleet acquisition change the average aircraft size more than projected?

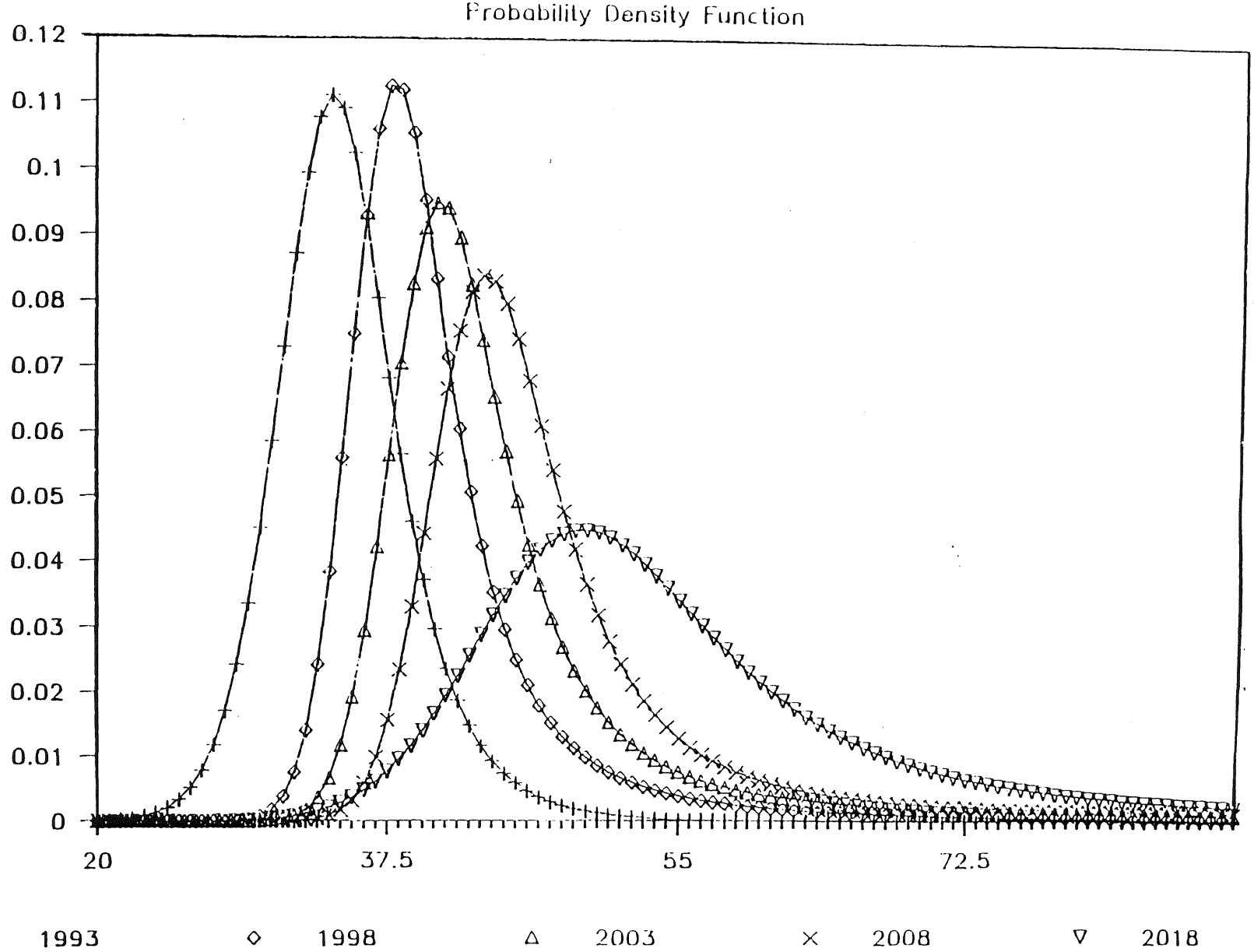
- Higher growth rates of regional carrier markets and the smaller size of those markets will favor small aircraft. On the other hand, capacity constraints at MSP will favor larger aircraft.

- How does uncertainty in the growth of enplanements affect uncertainty in fleet acquisition and plane size?

- Is there some practical upper limit to regional aircraft average size due to the volume of traffic at individual service points?


Avg Seats, Regional Carrier Departures
at MSP International
Seats
48
44
40
36
32
28
24
20
1985
1988
1993
1998
2003
2008

Regional Carrier Aircraft Size



VARIABLE:
REGIONAL CARRIER LOAD FACTOR

Description

The regional carrier load factor is the percentage of seats of departing regional aircraft filled by enplaning passengers. Much as the average number of seats per departure is important to potential passenger capacity, average load factor reflects how effectively that capacity is being used.

How the Variable Affects Air Traffic

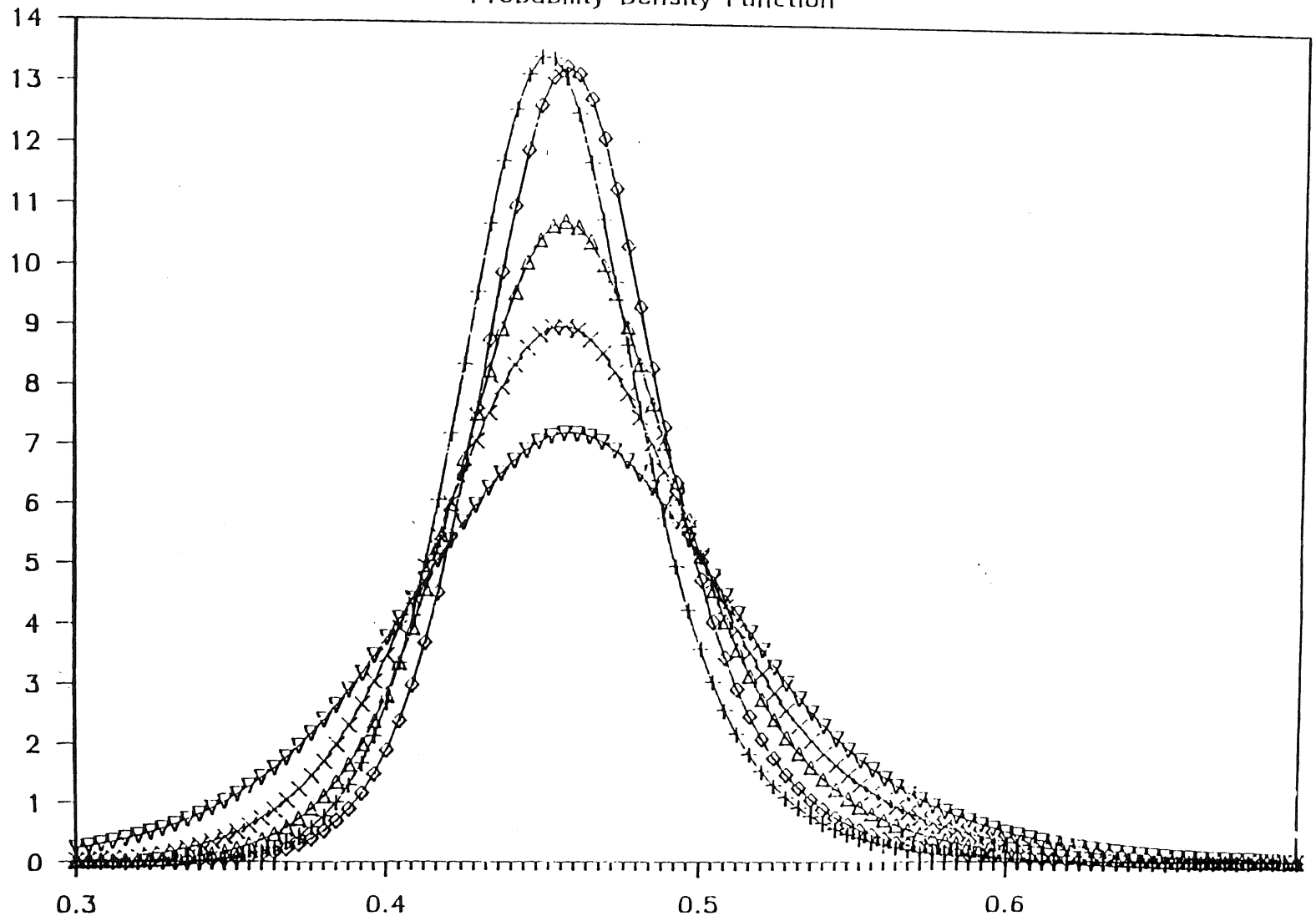
The load factor is used in combination with the aircraft size to convert the number of enplanements to the number of aircraft departures. (Arrivals are assumed to equal Departures.)

Major Uncertainties and Considerations

- Some of the forces that influence commercial load factors may also affect regional carrier loads.
- The strength and nature of regional demand helps determine the fare that can be charged and thus influences the fraction of seats that must be filled in order to cover costs.

Regional Carrier Load Factor

Probability Density Function



VARIABLE:
INTERNATIONAL ENPLANEMENTS

Description

International Enplanements are passengers boarding flights for non-domestic destinations distinct from the domestic enplanements.

How the Variable Affects Air Traffic

Enplanements are a measure of the workload of airport facilities. More passengers may require larger facilities. Enplanements are combined with average plane size of international flights to determine the workload of arrivals and departures.

Baseline Assumptions

Prior to 1980, international activity at MSP International was primarily limited to charter flights with foreign flag carriers. In 1980, however, Northwest began scheduled service to northern Europe. The relatively short history of MSP's international enplanements, combined with the unstable commercial environment of the 1980's, made a conventional statistical forecast using local data impossible. Therefore, FAA forecasts for United States international enplanements were used. These forecasts show an annual average growth of 4.7 percent for 1987-1998.

Major Uncertainties and Considerations

- HNTB notes that the 4.7 percent growth rate in international enplanements exceeds the projected growth rate in domestic originations (people starting domestic trips from the MSP area). They credit the difference to increased hubbing by NW bringing in more passengers to transfer to international flights. Given this, should the growth rate be higher than the national average to account for the increase in locally originating international enplanements as well?

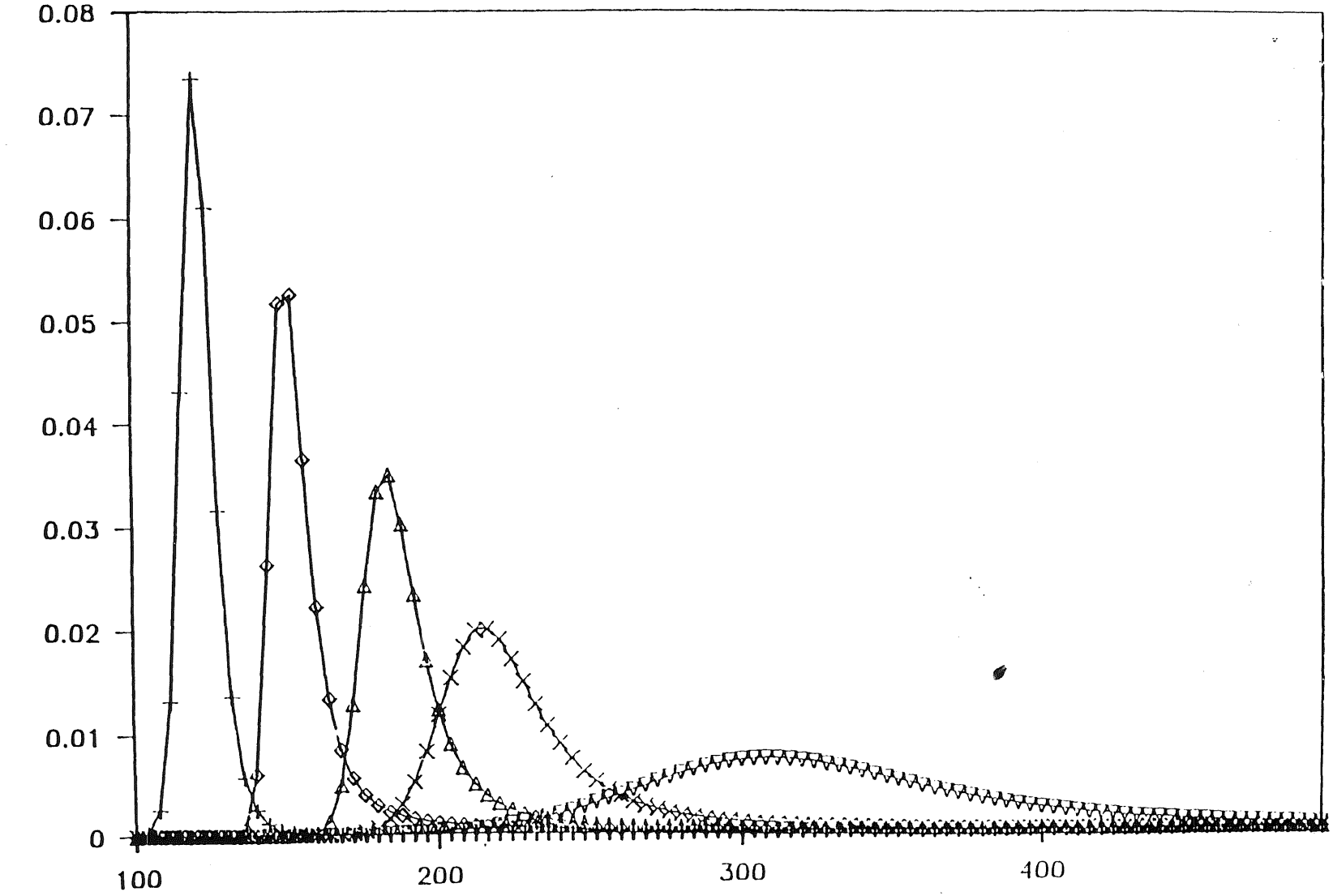
- As NWA's international flight schedule improves, passengers who formerly took domestic flights to other airports to transfer to international flights may take a direct international flight from MSP. This kind of shift is meant to be excluded from this projection. These "divertable" enplanements are estimated separately.

- International activity is tied to Northwest decisions on the use of MSP as a gateway. The rate of growth in international flights may depend on the addition of banks and airfield capacity.

- Is the business/recreation mix of international flights different from domestic flights? Will future changes in the vacation travel stemming from demographic changes affect the international enplanements?

International Enplanements

Probability Density Function



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GH014Q

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

Background Material
for Expert Panel Review:

Capacity Options

March 17, 1988

Prepared By:

APOGEE RESEARCH
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BACKGROUND MATERIAL FOR EXPERT PANEL REVIEW

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ATTACHMENTS

o Detailed Description of Facility Alternatives

o Data on Capacity Impacts

o Graphic Presentation of Alternatives

Introduction and Overview

Public works are both long-lived and far reaching in their influence on a region's eccnomic and social makeup. Decisions on major public investments are rarely straight-forward. Many risks are involved; some of these are technical and involve technical analyses of capacity alternatives, while others reflect value judgments about the most desirable economic and social makeup of the region and about the willingness to bear more noise pollution or increased airport delays.

One thing is certain -- virtually every important forecast will be wrong to some degree. Knowing this, how should decision-makers (and their technical advisors) size-up the pros and cons of their investment choices? For example, how can the Minneapolis-St.Paul region best compare the long-run adequacy of its existing airport facilities with the merit of major expansion or even a new airport given the multitude of uncertainties about future traffic, possible improvements to physical capacity, technological changes, economic interactions, and environmental constraints?

The MSP Adequacy Study recognizes these uncertainties explicitly by using a family of techniques called risk assessment.[1] By attempting to measure the risks of each of the key factors that might influence a major investment decision the result will not be a single "take it or leave it" answer. Rather, the information necessary for an informed decision will be organized and presented in a systematic fashion.

For example, two key parts of the technical portion of the analysis -- the expected amount of traffic and the effective capacity of the airport system -- require long-term forecasts of economic, social, technical, and political forces. In most long-term planning efforts these forces are rolled into a single discrete forecast, or perhaps a set of discrete forecasts. Each of these forecasts result from a series of explicit and implicit decisions about the many variables that influence the forecast. Although this methodology of probable or expected outcomes helps focus the decision making problem, it provides no guidance regarding the likelihood of that outcome, thereby leaving the community and its elected decision-makers with an incomplete view of the future.

A typical variation on the single "expected outcome" is a "high" and "low" case based on high and low variations to the

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[1] For details, see "Working Paper Number Two: Analytical Framework," MSP Airport Adequacy Study, December 1987.

forecast's underlying assumptions. This approach adds little information for decision-making, however, since it gives no indication of how likely it is that these high and low cases will actually materialize.

An equally significant shortcoming of this 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. In reality, of course, the likelihood that all underlying factors shift simultaneously in the same direction is quite remote.

Probability provides a way around the limitations of discrete point estimates outlined above. Probability measures the confidence or "odds" that an expected outcome will actually materialize. To understand how probability aids decision-making, consider a simple example. Before the advent of powerful computers, weather forecasters would simply assert their mean expectations -- "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 few dollars -- not to mention good will and tempers -- were lost.

This style of risk assessment could greatly assist the MSP Region in the decision making process regarding new airport facilities. The success of this analysis, however, hinges on defining accurate probability distributions. This involves three steps:

- o First, record the baseline assumptions for each forecast factor in a probability recording chart;
- o Second, define an initial probability distribution for each entry in the charts; and
- o Third, consult with groups of outside experts and revise initial distributions.

The first two steps have already been completed by the working group. The purpose of this technical memorandum is to consult with expert groups to develop "consensus probability distributions" for each capacity variable identified. In this manner, the working group expects to develop the most accurate probability statistics.

The panel of experts assembled have extensive experience in a range of fields including: economics, aviation technology, engineering, decision making, etc. Although the individual expert may not fully understand or be able to confidently predict values for all these variables, as a group, you can provide accurate estimates for these distributions as well as identify potential areas of interaction. For any variables that you might not fully understand, please begin to think of questions that should be addressed at the panel meeting in order to clarify these variables for you and other panel members.

The Need for Expert Opinion

You, the expert, are best qualified to provide the qualitative information necessary to complete our analysis. Your training, experience, and knowledge of the relevant facts and issues provide a database and analytical process which would be impossible to model. While individually you may not be able to fully predict the impact of demand on future airport utilization, collectively your opinions will enable us to estimate the probabilities associated with expected outcomes.

Attached are data sheets that ask for information concerning a number of factors that will influence the adequacy of the MSP airport in future years. A detailed explanation of how to complete these forms follows below.

Completing the Expert Opinion Survey

When you generate an estimate of a number, whether it be a football score or an economic parameter, there are two important pieces of information which describe that forecast:

- What you think the number will be, and
- How sure you are that you will be right.

If you think the odds are that your team will win, you may place a bet, but the size of the bet will be partially determined by your certainty. Similarly, airport planning depends on the probable future values of parameters affecting capacity.

In general, the potential values of a particular capacity variable will display a central tendency around a particular value, with greater or lesser values of the parameter having a relatively lower chance of occurring. Your predictions can be adequately conveyed to us through the following three numbers:

- Central Value - where your feeling is that the actual value of the parameter has an equal chance of being above or below this value.

- o Upper Limit - where your feeling is that the actual value of the parameter has less than a 10 percent chance of being above this value.

- o Lower Limit - where your feeling is that the actual value of the parameter has less than a 10 percent chance of being below this value.

Please note that the upper and lower limits are not measures of your confidence in your central value prediction, but rather are your feelings about the uncertainty inherent in the prediction of the parameter. Typically, the lower and upper limits will diverge in successive years because forecasting further into the future is always less precise. To assist you in making your predictions, official estimates of the central values have been included for comparison purposes.

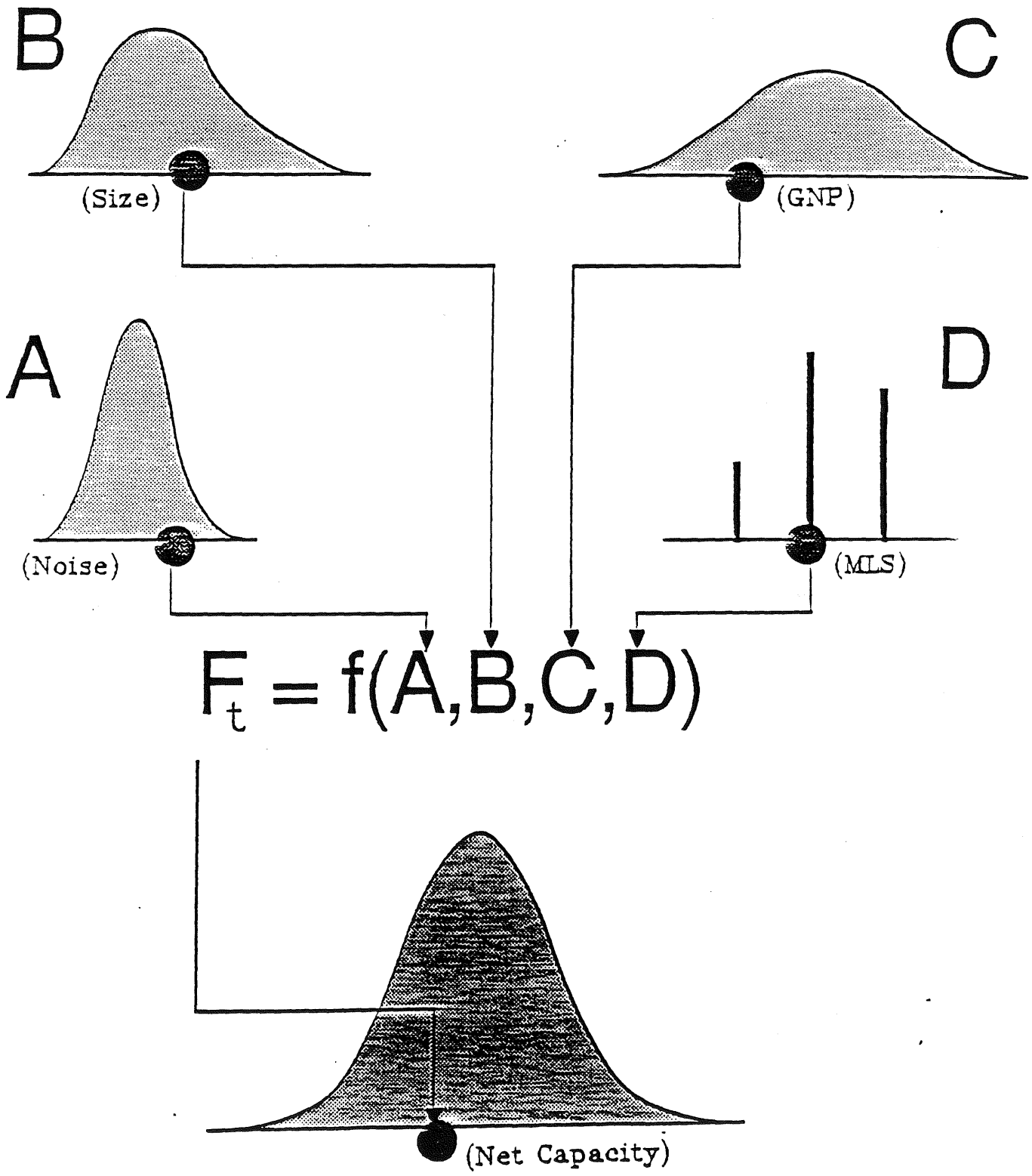
The following example may help to clarify your role in our survey. An estimate of capacity for an ILS runway is 60 operations hourly. However, you feel, as a result of your direct knowledge (or findings from the panel discussions) that this number could be too high because of the high percentage of general aviation aircraft traffic. You think the number is closer to 40. For this reason, you set the upper limit to 60 and the lower limit to 40, with the result that your estimates are stretched toward the lower values.

Statistical Interpretation of the Expert Opinion Survey

The role you are being asked to play is defined by the attached figure from Working Paper II (Figure 1). A forecasting model consists of input values (Size, GNP, Noise, MLS), output values (net capacity), and a model stating a precise relationship between input and output values (Net Capacity = f{Size, GNP, Noise, MLS}). The future values of the inputs must be projected before the model can make a projection of the output. A basic projection takes the single most likely future input values (the black dots) and produces a single number indicating the most likely output value (net capacity). However, under this method there is no indication of the degree of uncertainty associated with the output.

The technique by which you are providing information is firmly grounded in statistical theory. This appendix details the concept behind probability and its relationship to the expert opinion survey.

FIGURE 1: MONTE CARLO SIMULATION:
A WAY TO COMBINE PROBABILITIES



The well known, bell shaped, probability density function for the normal distribution is illustrated in Figure 2. Values of the parameter of interest are indicated along the horizontal axis. The probability of an occurrence between any two values is given by the area under the curve. For example, the probability of a value between -1.28 and 1.28 is 80 percent. This is commonly referred to as the 80 percent confidence interval.

The normal distribution is fully described by two parameters; one indicating the center of the distribution and the other indicating the amount of dispersion about the center. There are three ways of measuring central tendency:

- **Mean** - the average of all possible values, weighted according to probability.
- **Mode** - the value with the highest probability (the peak of the probability density function).
- **Median** - the value which bisects the area under the probability density function such that there is an equal probability of higher and lower values occurring.

In the special case of the normal distribution, the mean, mode, and median are equal. As we will see later, this is not necessarily true for all distributions.

"Dispersion" describes the width of the range of probable values. There are two ways of measuring dispersion about the center:

- **Variance** - is equal to the sum of the squared deviations form the mean divided by one less than the number of observations.
- **Standard Deviation** - is equal to the square root of the variance.

In a standard normal distribution the mean, mode, and median are all equal to zero and the standard deviation is equal to one. Because a great deal is known about the behavior of the standard deviation of a normal distribution, it is a very useful distribution for analysis. Normal distributions with different means and standard deviations can, for example, be easily transformed into a standard normal distribution for analytical purposes.

A variation on the probability density function (PDF) in Figure 2 is the cumulative density function (CDF) of Figure 3. Mathematically, the CDF is the integral of the PDF, and the PDF

Figure 2. Normal Probability Density Function (PDF)

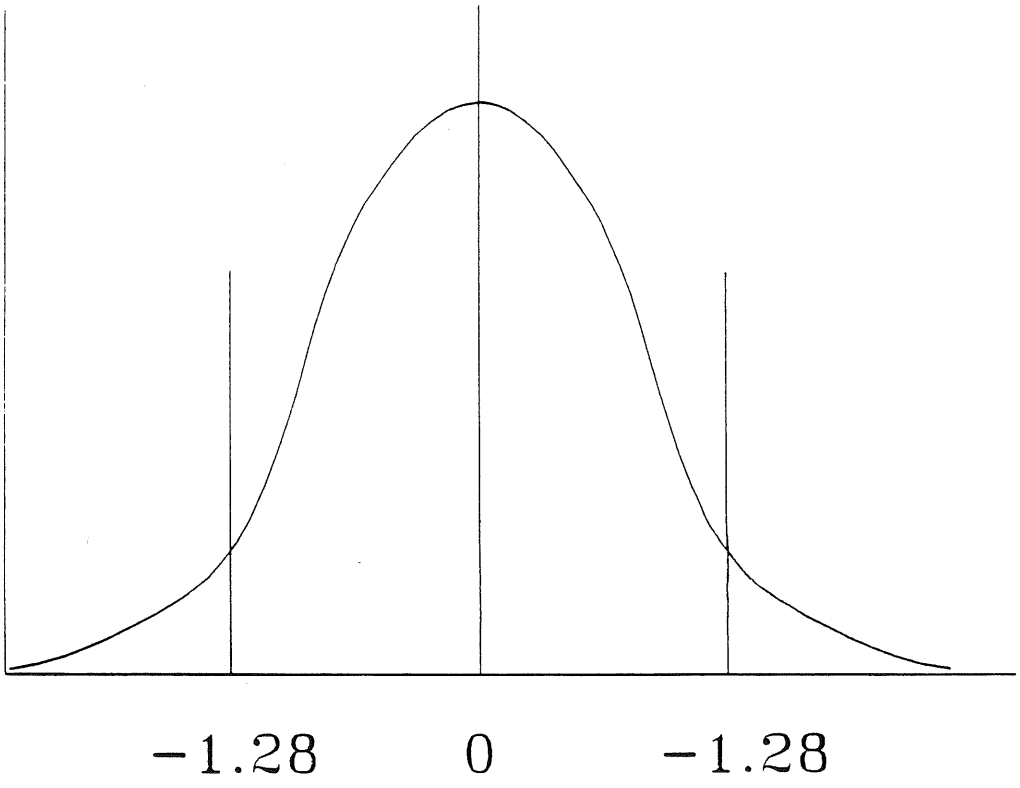
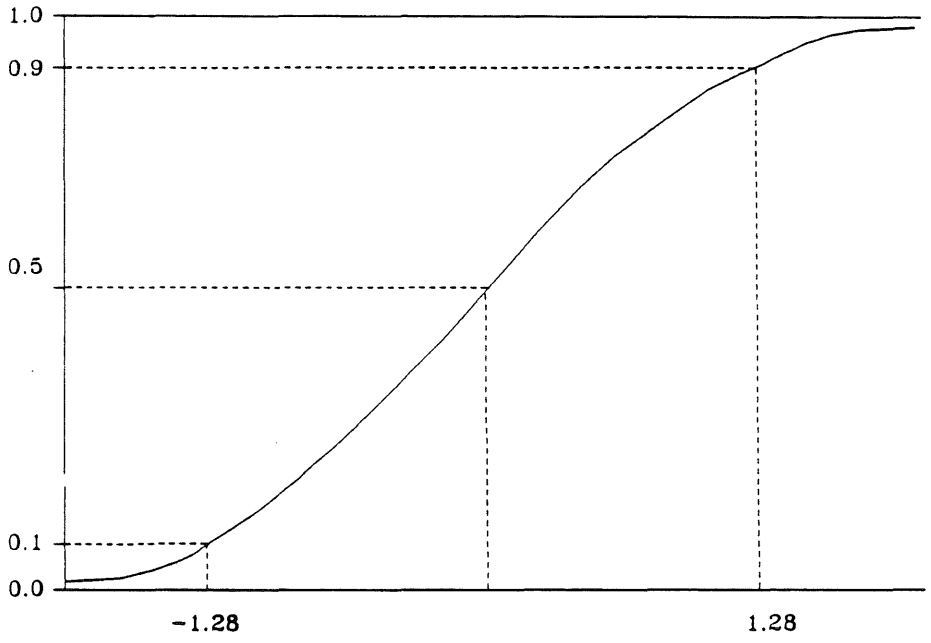


Figure 3. Normal Cumulative Density Function (CDF)



is the derivative of the CDF. This means that a point on the CDF curve represents the area under the PDF curve from negative infinity to that value of the parameter. In other words, the CDF gives the probability of values occurring which is less than or equal to the specified value.

Often probability distributions are assumed to be normal, when they are considered at all. This is partially because the normal distribution does describe a wide range of events, but mostly because the distribution is well understood and easy to apply. In this study we have avoided the assumption of normality because we feel that it is not appropriate for many parameters.

Distributions which are not normal, as shown in Figure 4, are described by two parameters in addition to the measure of central tendency and dispersion. These are:

- o **Skewness** - Measure of the asymmetry of the density function. A high skew indicates that one side is larger than the other.

- o **Kurtosis** - Measure of the shape of the density function. A high kurtosis indicates relatively thin density function heavy tails.

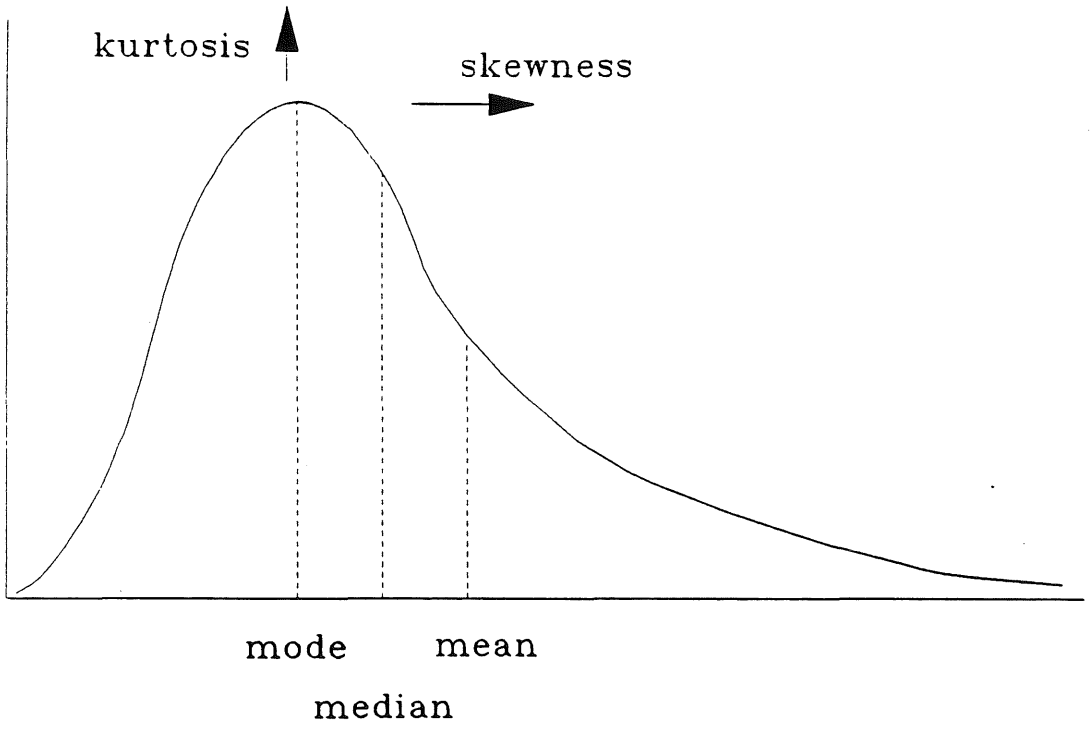
A normal function has a skewness parameter equal to zero and a kurtosis parameter of approximately three.

In distributions which are skewed, the mean, mode, and median are not equal. Therefore, the measure chosen to describe a particular distribution is somewhat arbitrary. For the purposes of the MSP Adequacy study we have asked you to provide estimates of the median in the attached survey, as this measure is best suited to our needs.

Panelists will be able to influence skewness in their choice of the 10 percent upper and lower limits. A larger upper limit will flatten out the upper side of the distribution, skewing the distribution to the lower end. Panelists familiar with statistics should note that because we are using the median for a central value rather than the mean, the probability of the forecast value falling below the central value is always 50 percent, regardless of the skew.

The choices panelists make will not influence kurtosis.

Figure 4. Non-Normal Distribution



Use of the Expert Opinion Survey

The information which you will provide in this survey will allow us to develop an appropriate non-normal PDF and CDF for each parameter in each year. This will be done by plotting your information and fitting a CDF curve to it. A PDF curve can then be developed from the CDF curve. The CDF function will allow uniformly distributed random numbers (which are easily generated by a computer program) to be transformed into random numbers distributed according to the distribution which you have defined for parameters in this survey. These distributions will be used as input to the Monte Carlo analysis described in Working Paper II.

Capacity Variables at MSP International

Alternative operations and airfield layouts for MSP are presented in the attached data sheets. While the potential of implementing each varies considerably, each would enhance overall capacity. These alternatives fall into three distinct categories (Figure 5):

- o Runway and airfield configuration,
- o Air traffic control procedures (and terminal navigation aids), and
- o Demand management techniques that influence the ultimate aircraft mix characteristics.

These options are discussed individually in the data sheets. The effects are not, however, additive. Instead they interact to produce combination-specific results. These interactions are discussed at the end of the attached data sheets.

Runway and Airfield Configuration

As a general rule:

- o parallel runways yield the greatest potential capacity levels, and
- o the capacity available during peak hours is the most critical element in identifying possible constraints for an airport.

In addition, the capacity for each development alternative can vary over time both as a result of changes in aircraft mix and of different degrees of familiarity of air traffic controllers and pilots. At MSP, the present forecasts reflect an increasing share of operations by regional airlines at the expense of general aviation. The percentage of air carrier operations remains fairly constant despite large increases in enplanements.

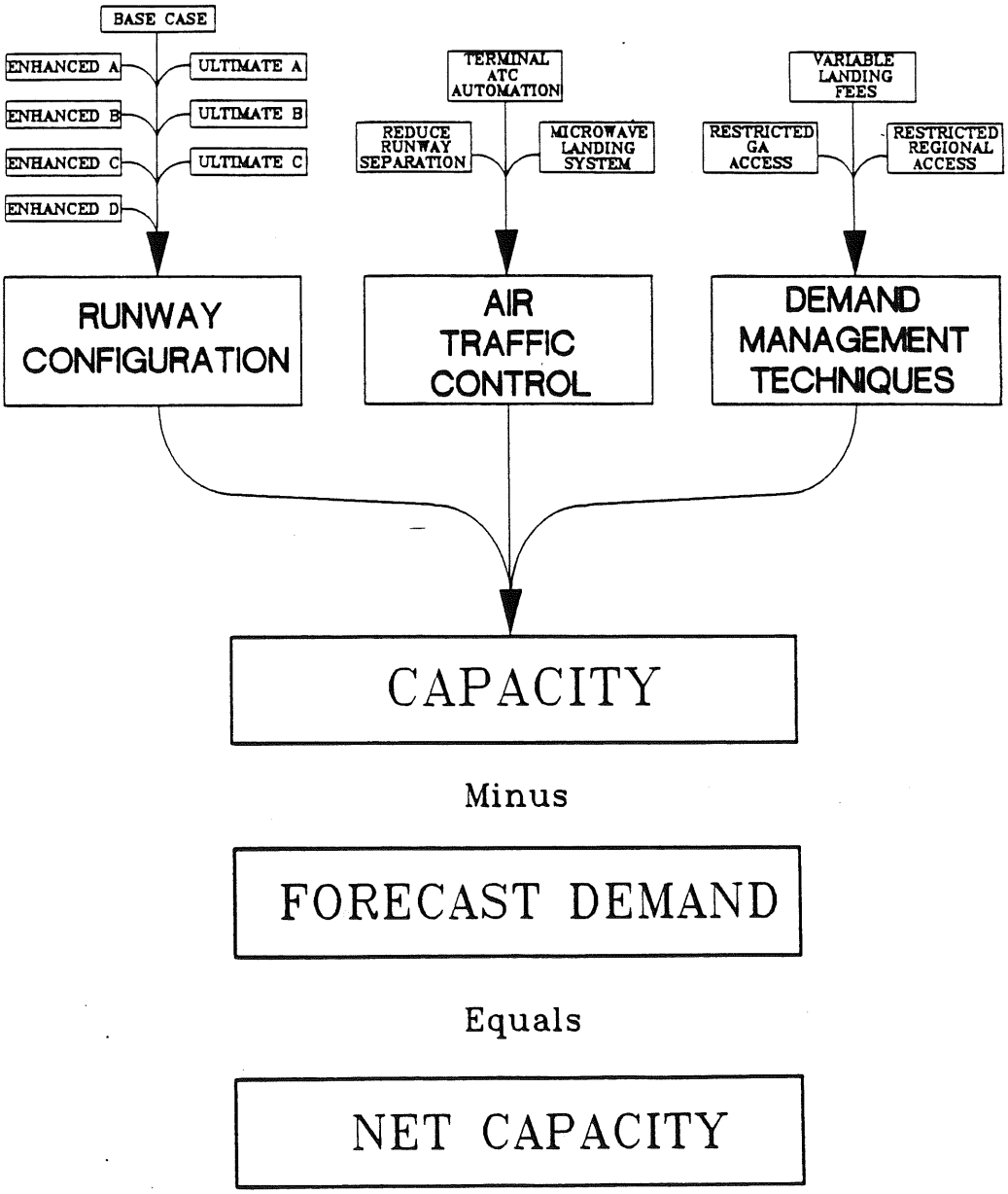
Air Traffic Control Procedures

Changes in air traffic control procedures could have a dramatic affect on capacity at MSP -- and other major airports as well.[2] Important issues for consideration include:

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[2] For examples of airports with similar air traffic control capacity limitations, see Federal Aviation Administration Airport Capacity Enhancement Plan, 1987.

Figure 5:
Inputs to Capacity Analysis



- imposition of special rules, such as preferential runway systems to spread noise impacts, will generally inhibit the airport's ability to meet peak operating demands;

- the introduction of new air traffic control procedures is a time consuming, but necessary, effort involving research and development, testing, iterations of testing evaluation, and training with implementation usually in phases;

- not all users of the airspace/airport system have common goals and priorities; new facilities and procedures need to strike a compromise in order to be implemented.

Those issues in turn raise many questions, including:

- How confident are we that these ATC procedural changes will occur?

- When could they be implemented?

- What are the risks associated with waiting for a change which may not occur?

- How much of a gain in capacity do we realize and how long can that gain serve us until we face a similar decision point?

- What are the tradeoffs between the operating and travel time benefits from reduced delays and the construction costs of additional capacity?

Demand Management Techniques

A third approach to improving net capacity, Demand Management Techniques, involves managing demand to better fit within peak period capacity limits. Recently, many airports have begun to experiment with this concept, most notably and most aggressively Boston's Logan Airport. Because of political and legal considerations, however, the results have been mixed. Thus, while in theory these options hold promise to significantly alleviate congestion problems, political and legal problems can be difficult to overcome. In addition, there may be negative economic impacts on users and commuters that depend on those aircraft shifted to less desireable times or locations.

Background: MSP International

A variety of factors influence the overall effective capacity of MSP including aircraft mix, runway use, time spent under IFR conditions, and wind conditions. Generally, the most important variable is aircraft mix since it ultimately influences both the longitudinal separation of the aircraft and the speed of approach, each of which can be important to capacity.

Aircraft mix

At MSP, the present forecasts reflect an increasing share of operations by regional airlines at the expense of general aviation. However, because the forecast share of air carrier operations remains fairly constant over the period, only falling somewhat from 57 percent of all operations to 51 percent between 1986 and 2008, the types of demands placed on the airfield facilities are not likely to change considerably (See Figure 6).

Runway Use

The intensity of use each runway experiences is expected to remain relatively stable over the next few years, with the distribution of operations focusing primarily on runways 11L, 11R, and 22 during daytime departures and the vast majority on 11R for nighttime departures (Figure 7). Daytime arrivals, on the other hand, are expected to be dispersed more evenly across runways 4, 29R, 29L, 11R, and 11L. Like nighttime departures, nighttime arrivals depend primarily on one runway, in this case 29L.

IFR conditions

Instrument Flight Rules conditions are experienced at, on average, about 8.8 percent of the time at MSP. There is not always a clear distinction between VFR and IFR, however, and modified IFR rules may be used part of the time.

Wind Conditions

During all-weather wind conditions, Runways 11-29 provide 94.7 percent wind coverage based on the standard 15 mile-per-hour crosswind limitation. Because this value is less than 95 percent, FAA standards justify the construction of a crosswind runway (Runway 4-22) at the airport. The addition of Runway 4-22 increases the wind coverage to 99.4 percent. Therefore, the incremental effect of Runway 4-22 is 4.7 percent. The incremental benefit of a crosswind runway during IFR conditions, on the other hand, is slightly greater at 5.9 percent. The overall runway wind coverage at MSP during IFR conditions is 98.7 percent, suggesting that the wind coverage provided by the existing runway configuration is excellent. Interestingly,

Figure 6:
Forecast Distribution of Operations at MSP
by Type of Craft

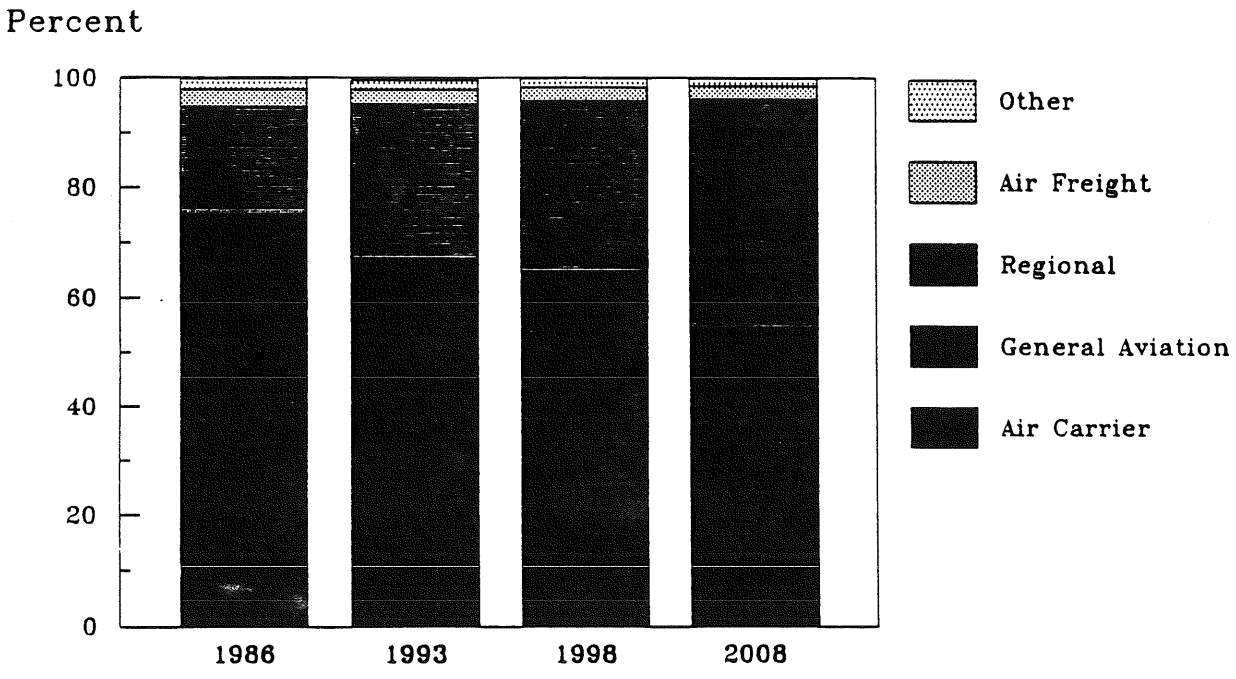
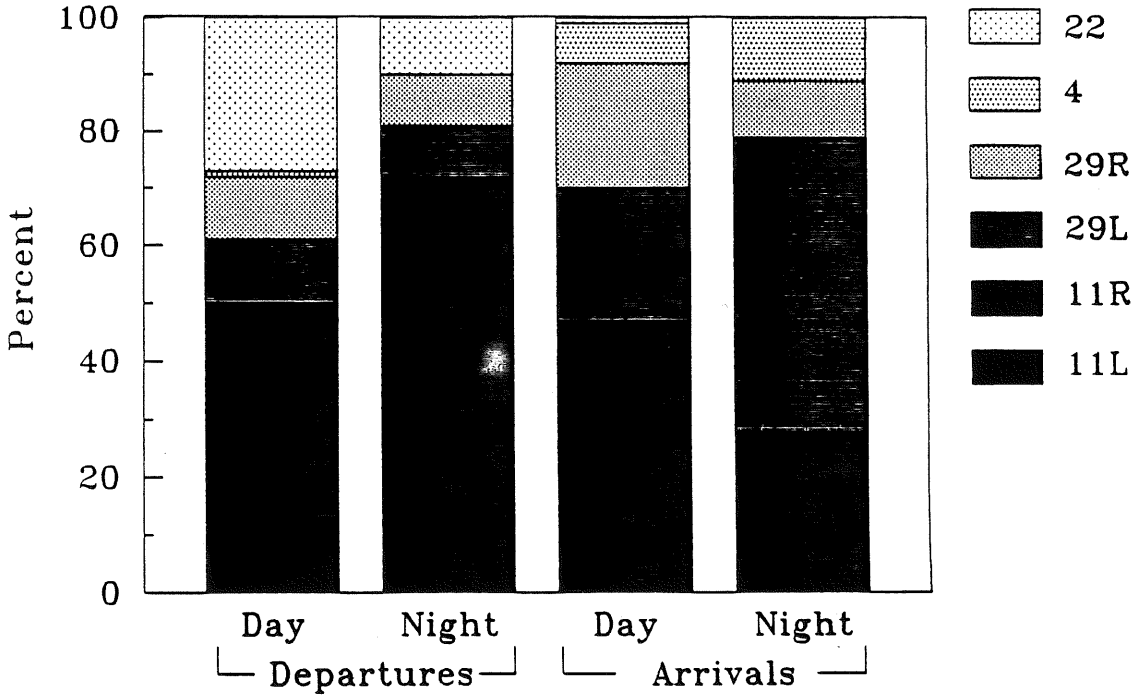


Figure 7:
Distribution of Runway Use
in 1992



Runway 4-22 alone provides 90.0 percent and 93.0 percent coverage during VFR and IFR conditions, respectively.

Terminal Considerations

While this report focuses on modifications to the existing airside capacity, either physically or through operational changes, panelists must remember that landside capacity is also an important factor in determining overall MSP airport capacity. Each airside option discussed will ultimately affect required level of landside capacity -- the capacity of the terminal building, access roads and parking lots. Thus, it is important to consider landside capacity implications while evaluating alternative airside options.

The factors which determine landside capacity fall into two broad categories: physical and managerial. The following sections briefly discuss important areas to consider within these categories which may effect the choice of airside configuration.

Physical Impacts

The physical characteristics of the airport facility is perhaps the most important determinants of landside capacity. They include both the size and layout/configuration of the airport itself. Although the existing terminal offers expansion opportunities that could meet long-term passenger demand, the choice of airside configuration may necessitate changes in the size or layout of the terminal. It is important to consider the possible impact of these changes on the efficiency and cost-effectiveness of landside and airside operations.

For example, one airside option under consideration includes additional parallel runways outboard of the existing MSP runways. Given the current terminal configuration, aircraft would have to taxi the additional distance from the terminal to the runway--an option that could prove costly as well as time consuming. One alternative would be to add an additional terminal closer to the new runways. As regional carriers are expected to experience high growth, perhaps this terminal could be dedicated to regional carrier service.

Management

The management of the existing facility can have a powerful impact on whether or not new capacity is necessary. Increased efficiency in the management of existing resources can, for example, increase airport capacity. There are two types of management decisions which effect airport capacity: resource management and operational.

Operational Factors

Hubbing characteristics of one or more airlines can dictate the demands made on landside facilities at any given time. In particular, the timing of hubbing airline operations is an important consideration. For example, if a hubbing airline's peak deplaning traffic coincides with peak traffic from other airlines, the peak demands on landside facilities will be greater than if the peak deplaning times for the airlines are staggered. Because MSP is located in the middle of the country, there is may be greater flexibility in this regard.

Contractual factors that may affect landside capacity include gate allocation and control as well length and timing of lease agreements. The allocation of gates among airlines can affect the efficiency of the airport itself. The most efficient allocation of gates would match the number of gates with demand. If an airline is allocated more gates than it actually needs, landside capacity could be increased simply by reallocating gates to other airlines. The extent to which the airport is locked into an allocation pattern by lease agreements, will determine the airport's flexibility in this area.

Resource Management

Efficient management of resources can effect the capacity of the facility. Management issues which might be affected by airside configuration include: land resource management, marketing the airport to desired airlines based on their aircraft fleet and route structure, and maximizing gate and range space utilization and efficiency.

APPENDIX
Flight Path Savings Under MLS: Preliminary Analysis for MSP

This appendix reviews the major elements that must be considered in estimating the possible gains from using MLS at Minneapolis.

GENERAL

Radar Guidance

Aircraft are provided standard instrument arrivals into the Minneapolis airport by the en route controllers. Radar vectors are issued to the pilot by the approach controller to bring the aircraft to the best point for initiating the approach. This point is optimized for each approach. That is, for an ILS approach it will be the best point for commencing the ILS navigation; for an MLS approach it will be a different point, optimize for best use of MLS navigation.

Arrival Direction

Arrival directions are divided into three main categories. Arrivals from a direction leading straight in to the runway can be vectored for a "straight-in" approach using either ILS or MLS. For this analysis, arrivals from within plus or minus 30 degrees of the runway heading are considered straight-in. Arrivals from the opposite direction are referred to as "opposite direction" arrivals. The remaining arrivals will range in direction from just outside the straight-in cone through 90 degrees to the runway heading to just outside the opposite direction cone.

The estimates for MSP assume that arrivals are distributed as follows: 10 percent are straight-in, 10 percent are opposite direction and 80 percent are 90-degree arrivals.

Ground Speed

Aircraft ground speed varies considerably according to aircraft type, with the greatest variation in the earlier portions of an approach. Estimates of average ground speed used here are 200 knots on the downwind leg, reducing in stages to 140 knots on final approach. These figures are biased somewhat toward the higher speeds and thus would be representative of larger air carrier aircraft for which most of the benefits would be gained.

Minneapolis Terminal Environment

ILS Procedures

Straight-In

Aircraft arriving from within the straight-in cone will be vectored directly onto final approach with little or no maneuvering.

90- Degree Arrival

Arrivals in this zone will normally be radar vectored to final by a series of maneuvers whose dimensions are critical to an analysis of MLS. For consistency, a radar vectoring aim point 5 n.m. laterally from the approach center line will be assumed for both ILS and MLS. Analysis commences at the threshold and works backward to establish the longitudinal location of the radar vectoring point, the length of the flight path and the time required to cover that distance.

The total time for a radar/ILS 90-degree procedure is estimated to require 6.3 minutes.

Aircraft being vectored to the ILS from the forward quadrant, meaning those arriving from between 30 degrees and 90 degrees from approach heading, would not necessarily all be vectored through the same aim point. Rather, they would be vectored to join the routing at the most convenient point in each case.

Opposite Direction

Opposite direction traffic was analyzed from a point opposite the runway threshold to arrival over the threshold, maintaining a distance of 5 n.m. laterally from the approach center line. The procedure follows a pattern similar to the 90-degree pattern on the final portions of the 90-degree arrival.

Total time for a radar/ILS opposite direction procedure is estimated to require 9.7 minutes.

MLS Procedures

Straight-In

Radar vectors will bring the aircraft straight in on an MLS approach exactly as in the ILS approach. Flight paths and time will be the same.

90-degree Arrival

As in the ILS case, radar vectors will guide the aircraft to the optimum position from which it can commence the MLS procedure. In this case, the procedure is assumed to follow a

curved path from an arrival vector at 90 degrees to the final, 5 n.m. laterally from the approach path and at the optimum longitudinal distance from threshold.

Total time for the radar/MLS 90-degree procedure is estimated at 3.7 minutes.

Opposite Direction

Opposite direction arrivals on MLS will normally carry out a 180-degree curved approach. Glide path will be intercepted before commencing the curved leg, so the entire curved and final portions will be flown at final approach speed.

Total time for the radar/MLS opposite direction procedure is estimated at 5.2 minutes.

Flight Path Time Savings

Straight-In

Flight paths will be identical for ILS and MLS. Time savings will be zero.

90-degree Arrival

Time saving will be: 6.3 - 3.7 = 2.6 minutes

Opposite Direction

Time saving will be: 9.7 - 5.2 = 4.5 minutes

Total

Weighting these estimates according to traffic direction, total time savings would be:

Straight-In		0.00
90 degree	2.6 x .80 = 2.08	
Opposite Direction	4.5 x .10 = 0.45	
Total, weighted, is:		2.53 minutes

Conclusions

The theoretical hourly instrument rate for Minneapolis airport is stated as 85 per hour. If we assume that half, or 42.5, of these are arriving aircraft, then an aircraft will be arriving on dependent parallel runways every 2.8 minutes, or every 7.3 miles in trail on runway 11 and 29. Based on the above analysis, 42.5 times 2.53, or 107.5 minutes of flying time are saved. If arrival spacing is maintained at 7 miles in trail and 50 per cent of the flying time saved is available for arrivals then 19.1 arrivals can be added with the implementation of MLS.

This amounts to a 45 per cent increase in arrivals with the addition of MLS and a total increase of 22 percent.

Some analysts argue that an instrument rate of 85 per hour may be optimistic for Minneapolis and that a more realistic rate may be as low as 60 an hour, with about 35 being arrivals. Under these conditions, aircraft will be arriving every 3.4 minutes or every 9 miles in trail on runway 11 and 29. Using these numbers the savings would represent 91 minutes of flying time. If arrival spacing is maintained at 9 miles in trail and 50 per cent of the flying time saved is usable for arrivals then 13.4 arrivals can be added with the implementation of MLS. This amounts to a 38 per cent increase in arrivals with the addition of MLS.

The exact amount of increase will be determined by the ability of the flight crews and the air traffic controllers to make effective use of the flying time saved by using MLS. Since most estimates of MLS productivity indicate a maximum increase of 15 per cent then it seems unreasonable to expect Minneapolis to achieve the 38 per cent increase. On balance, it is likely that Minneapolis airport arrival capacity could be increased by 10 arrivals per hour when both runways have MLS and are available for landing.

ATTACHMENT:

Detailed Description of Alternatives

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APPENDIX

Flight Path Savings Under MLS: Preliminary Analysis for MSP

INTRODUCTION

The generic heading "Capacity Alternatives," includes three sets of options:

- Runway alternatives focuses on new or extended runways in addition to the Base Case or present runway configuration;
- Changes to air traffic control procedures describes scenarios under which the current FAA rules may be relaxed as a result of new technologies or improved operating procedures; and
- Demand management techniques cover pricing and regulatory methods that can alleviate long-term facility constraints by shifting the mix of aircraft using MSP International.

This document focusses on these types of options, presenting each in terms of detailed verbal descriptions and data sheets that summarize the working estimates currently being used by the consulting team. The descriptive section provides the following:

- A description of the option, both in terms of physical modifications and procedural changes;
- A summary of how the option affects capacity, which explains (a) the key factors contributing to the change in capacity, (b) general advantages and disadvantages, and (c) major uncertainties regarding its effectiveness, and
- A discussion of the likely time frame in which the project could be implemented.

The second section, Data Sheets, provides quantitative detail for each option first by graphically summarizing (if possible) key components, such as physical changes to the airport runway configuration. Second, the section provides tabular detail on the operational benefit of each option, relative to the Base Case. Most options have two tables covering estimates of (a) the increment in hourly operations that could be expected as a result of implementing the option and)b) the probability distribution of how soon the option might be implemented (both include sample upper and lower 10 percent limits for each distribution -- see discussion in the enclosed Panel Review document).

A Note About Capacity Estimates

Estimates of airport capacity are by no means fixed. In fact, each series is vulnerable to a wide variety of influences,

including aircraft mix, runway configuration and use, number and type of exit taxiways, frequency of Instrument Flight Rules (IFR) weather conditions, and decisions made on the spot by air traffic controllers. Many of these difference may reflect contrasts between what may be predicted by simulation models and the effect of local conditions. Consequently, estimates provided by one agency or group may not coincide with those of another. At MSP, this point is illustrated by analyses of the Federal Aviation Administration (FAA) and of the consultants to the Metropolitan Airports Commission, Howard Needles Tammen and Bergendoff (HNTB) (see Table 1).

Table 1
Capacity Estimates of MSP International
(Mixed Traffic in IFR, Hourly Basis)

Type of Operation[a]	FAA Estimate	HNTB Estimate[b]
Dependent Parallel	72	85
Independent Parallel	98	98

Notes: (a) Runways 11L, 11R
(b) HNTB estimate adjusted to reflect facility layout similar to FAA's.

Sources: MSP 2000+ Airport Development Plan, February 1988 and Airport Capacity Enhancement Plan, 1987.

The difference between the two estimates is difficult to attribute, since each group used different models to develop estimates of capacity. Nonetheless, the fact is that the estimates diverge -- and this variance, as it would for other variables, should be weighed carefully in approximating capacity. Again, the risk assessment approach being used in the MSP AIrport Adequacy Study is one way to incorporate this natural range of uncertainty.

It must be stressed that the specific capacity estimates presented for each of the capacity options as well as the 10 percent limits are **for illustrative purposes only.** They were developed using only materials at hand and are intended solely as a starting point for discussion.[1] Panelists are encouraged to

[1] In most cases, the median estimate reflects estimates prepared by HNTB (Howard, Needles, Tammen, and Bergendoff) for the MAC as part of the ongoing Master Plan process.

alter estimates of capacity and/or 10 percent limits as they deem appropriate. It will be particularly useful to the process if panel members can identify any specific factors missing from the analysis.

A technical possibility that some panelists may wish to consider in developing estimates of upper and lower limits deals with "skewness." Some of the examples on the data sheets place one of the 10 percent confidence boundaries further from the median than the other. This indicates a greater chance that the actual result will occur on one side of the distribution -- the distribution is "skewed" in that direction. (If the upper boundary is further from the median, the skew is towards the upper boundary.) Panelists may prefer to move the median in a direction they think more probable or revise the boundaries so that they are even on both sides and the distribution is shaped more symmetrically.

To simplify the presentation, estimates are made for each option independent of the others. A later section will discuss some of the possible effects of combining options -- changes in air traffic control procedures along with new runway layouts. Most of the runway options, however, are built up incrementally, so that Ultimate Case 4 combines four other options.

Unless stated otherwise, capacity estimates assume current FAA rules; that is independent operations are allowed on the parallel runways only under VFR conditions. Also, changes are expressed relative to the Base Case, or the airport modified only for changes already approved by the MAC board.

Definitions

Parallel runways have the same directional alignment. The FAA considers runways separated by at least 4,300 feet to be capable of accommodating independent (simultaneous) operation during IFR conditions. That is, each runway may be utilized independent of operations on the other. During VFR conditions, the lateral separation requirement for independent operations is reduced to 700 feet. Runway operations which are not independent are categorized as dependent. That is, use on one runway depends on the activity being conducted on the other. For example, the takeoff clearance may be withheld until an aircraft had assured a safe landing on the other runway and would therefore pose no threat to the aircraft awaiting its takeoff clearance.

Crosswind runways are constructed to facilitate operations when surface wind conditions exceed safe limits on the primary runway. Thus, crosswind runways are always at an angle to the primary runway. At MSP, crosswind conditions pre-dominate only about 6 percent of the time.

Approaches to both primary and crosswind runways may be termed converging when aircraft headings intersect either in their approach paths, on the airfield pavement, or along their missed approach paths. Based on where this potential intersection occurs, converging runways may be categorized as either independent or dependent. During converging approaches, controllers must provide a greater margin for error in setting aircraft separations. Current FAA air traffic control procedures restrict converging approaches to what are essentially VFR conditions.

In the analysis which follows, capacity levels have been identified for mixed operations. This implies that each runway is utilized equally for arrivals and departures. Because of hubbing, however, most peak periods at MSP have 60 percent of the traffic in one direction (arrivals or departures). As a result of the current MSP airfield configuration and air traffic control procedures, capacities are reduced when 60 percent of peak-period operations are arrivals -- this reduction can be as great as 20 percent. This is largely due to separation standards during approaches. Conversely, separation requirements are reduced during departures, so that capacity is higher when 60 percent of the operations are departures. The variances between mixed and arrival or departure peaking is more pronounced during IFR than VFR conditions. In order to limit the number of options presented, the capacity estimates presented here are for mixed (50-50) operations only.

RUNWAY ALTERNATIVES

This section details a range of alternative runway layouts for MSP International. These range from some that appear likely in the near future to more speculative ideas that need additional study. Options are grouped under the headings "Enhanced" and "Ultimate." Enhanced includes options that can either be completed in the near future or that impose relatively smaller legal or political burdens. "Ultimate" includes alternatives that can make significant additions to the capacity of the existing site but which may require considerable debate and examination before they could be implemented.

There are several sets of objectives of considering new runway layouts. Most obviously, these include the need for additional 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: 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. The specific options discussed here are:

Base Case

Enhanced A	Extend Runway 4-22 Add taxiway improvements
Enhanced B	Enhanced A Short "close" parallel
Enhanced C	Enhanced A Long "close" parallel
Enhanced D	Enhanced A New North-South Runway
Ultimate A	Enhanced A Long "far" parallel
Ultimate B	Ultimate A New North-South runway (Enhanced D)
Ultimate C	Enhanced A Long "close" parallel (Enhanced B) Long "far" parallel (Ultimate A) New North-South runway (Enhanced D)

BASE CASE

Description

The base case includes the existing runway and taxiway network at MSP, airfield improvements already approved for the period 1988 to 1989 as well as normal maintenance and rehabilitation in the future. 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[2] 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 convergent runways, it can only be used in conjunction with one of the parallel runways during VFR conditions.

Impacts on Capacity

The roughly 3,400 foot distance between the two parallel runways is more than the 2,500 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 -- 85 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

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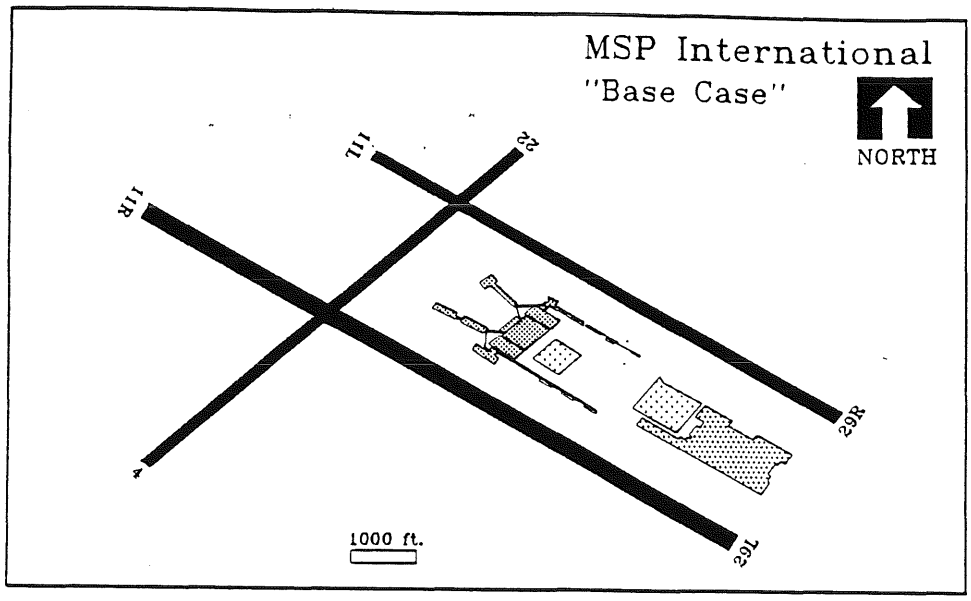
[2] The full physical length of this runway is 1,000 longer, but because of limits imposed by the nearby VA hospital, the current operating threshold has been shifted toward the Southwest. This additional length might be available under special and infrequent circumstances.

the parallels at about 72 operations per hour in mixed arrivals and departures.[3]

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. As a crosswind runway

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



Procedures: Current Rules.

Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Lower 10%	Upper 10%
Parallels	103	85	85	72
Preferential Runway System	60	0		

Procedures: Assumes independent parallels can be operated under IFR with 3,400 foot separation.

Change in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Lower 10%	Upper 10%
Parallels	+5	+19	+10	+30
Preferential Runway System				

ENHANCED CASE A

Description

Enhanced Case A combines the Base Case with a 2,750 foot extension of Runway 4-22 (toward the southwest) and new taxiways and taxiway exits. The extension allows for a shift in normal Runway 22 landing threshold to the southwest, thereby allowing certain non-convergent operations on Runway 22 and 11L-29R. The active portion of 4-22 would still cross 11R-29L, however, thus restricting simultaneous operation of these two runways. This option also includes additional exit taxiway on Runways 11L-29R and 11R-29L which could decrease runway occupancy time, thus making it safer to increase the number of operations in the process.

This change would also create an 11,000 foot runway, the longest one at MSP. Because the full length of 4-22 crosses both parallels, however, use would have to be carefully coordinated. Further, the northern-most 1,000 feet has legal restrictions under an agreement with the VA Hospital.

Effect on Capacity/Operations

The new taxiways could reduce runway occupancy time for arrivals, thus permitting somewhat closer longitudinal separations. This in turn will increase capacity. HNTB estimates the increase from this change at about 7 percent or seven operations per hour. The FAA capacity enhancement plan has an average gain of 3 percent from improved longitudinal separation, and Lebron estimates the potential gain from reduced runway occupancy time at 8 to 9 percent.[4] Our base estimates use 7 percent.

An extended Runway 4-22 would not affect the capacity of the two parallel runways. It would, however, make it possible, in theory, to use the preferential runway system (PRS) for perhaps 8 or 9 hours daily, versus the present 5 to 6 hours a day. As traffic increases, however, this level of use might have to be reduced because of the lower capacity of the PRS/Crosswind runway.

Shifting the operating threshold for Runway 22, will eliminate the intersection with 11L-29R. This will improve the capacity of 22 when it is dedicated to departures and 29R is

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[4] John E, Lebron, Mitre Corp., Estimates of Potential Increases in Airport Capacity, prepared for FAA, (October 1987).

dedicated to arrivals. Because the threshold point for arrivals has not been shifted, the effective increase when Runway 4 is used for arrivals, may be negligible.

A key factor limiting the capacity of this configuration is that FAA air traffic control procedures currently restrict approaches on converging runways to times of VFR. Thus, even an extended 4-22 cannot be used in IFR conditions in conjunction with 11L-29R.

A longer 4-22 also creates an 11,000-foot runway for occasional use by heavy aircraft on long-haul stage lengths--747-400s bound for Europe, for example. This would require temporary limits on the use of the parallels, but there should be little if any effect on traffic delays because of the infrequency of such flights and because the schedule for international flights usually does not coincide with domestic peaks.

While much interest is focussed on 4-22 because of the noise benefits it provides, it is also important as a crosswind runway when winds are such that the two parallels are unsafe. While this occurrence is relatively rare, the reduced capacity in this direction can be constraining during peak periods. One option might be to build a parallel to 4-22 toward the north. This might be a short (5000 foot) runway dedicated to regional carriers and other smaller aircraft (mentioned as a possibility by HNTB). A longer parallel runway would add significantly to the crosswind capacity during VFR weather. There is inadequate space however to create a parallel that has the separation (4,300 feet) necessary for independent IFR use.

Implementation/Timing

The 4-22 extension is actively under discussion by the Metropolitan Airports Commission (MAC) and other interested parties. An environmental impact assessment has been prepared.[5] Approval appears probable because it represents one of the few means by which existing noise impacts can be spread among other neighborhoods. For these environmental benefits to be realized, however, the FAA must implement channelized departure tracks for Runway 22, and in all likelihood, for Runway 4 departures as well. Also, most construction work could be completed during the planned reconstruction of Runway 4-22, thus adding little new disruption.

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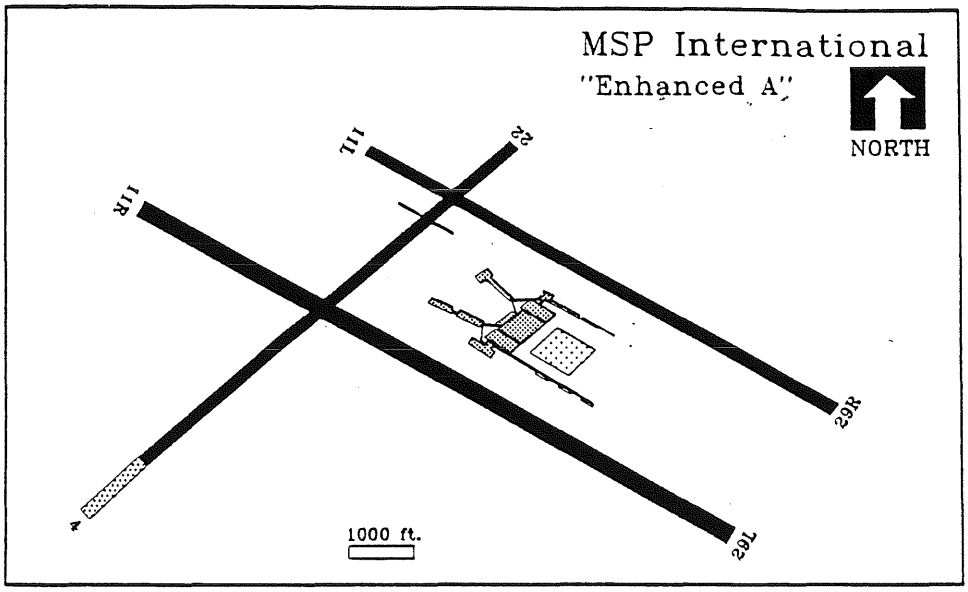
[5] Reference

In sum, it appears favorable that the 4-22 extension could be completed within four or five years so that the probability of its being in place by 1993 is high.

At present, the FAA does not permit the use of converging runway approaches during IFR conditions. While such procedures could be added, this is unlikely before the turn of the century. Even when these changes are made, however, they are likely to add capability for indirect converging runways before changes are approved for direct convergents such as 4-22 and 11R-29L. As a result, the extension of 4-22 will offer no significant addition to MSP's peak period capacity without a change in FAA regulations. Such a change in air traffic procedures, could increase capacity by about 20 percent however.[6]

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[6] FAA, Airport Capacity Enhancement Report, 1987.



Procedures: Current rules

Change in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Lower 10 %	Upper 10 %
Parallels Preferential Runway System	+12	0	+0	+5

EXPECTED AVAILABILITY OF ENHANCED A

Date	Expected Outcome	Lower 10%	Upper 10%
1993	80%	60%	100%
1998	95%	94%	100%
2003	98%	95%	100%
2008	98%	95%	100%
2018	98%	95%	100%

ENHANCED CASE B

Description

This case includes the extension of Runway 4-22 (Enhanced Case A) together with a close parallel Runway (the new 11L-29R) 700 feet north of the existing 11L-29R (renamed here as 11C-29C). This new runway is assumed to be 8,000 feet in length and have instrument landing systems on both ends.

The current FAA minimum for dependent operation of parallel runways in VFR conditions is 700 feet. Therefore, any third parallel must be separated by at least 700 feet -- in fact this is one option mentioned by HNTB in its work on the MSP Master Plan. A related option would be for a slightly wider separation (920 feet), also creating a triple parallel system, but with the outer parallels 4,300 feet apart. Land use impacts in Fort Snelling State Park are greater under this options.

Effect on Capacity

Capacity should be increased during VFR conditions because the Center Runway 11-29 can be used to handle arrivals or departures in concert with the outboard runways. A 700-foot separation is the minimum currently allowed by the FAA for dependent operations during VFR conditions. Gains from the third runway would have less effect during IFR weather conditions, however.

If, however, the new third runway were to be built 920 feet away, the two outside runways -- the new runway and existing Runway 11R-29L -- would have a lateral separation of 4,300 feet, the minimum currently allowed by the FAA for independent IFR operations. Because of this, they could be operated independently during IFR conditions rather than dependently. This would eliminate the need to observe diagonal separations between aircraft using the parallel runways, so that IFR capacity for the existing parallels would be close to what is now possible under VFR (about 100 operations an hour with mixed traffic).

Uncertainties

A practical problem with adding a third parallel is the limited space within the current boundaries of MSP. Thus, some land, but probably a minimum of public structures, would have to be obtained from Fort Snelling State Historical Park.

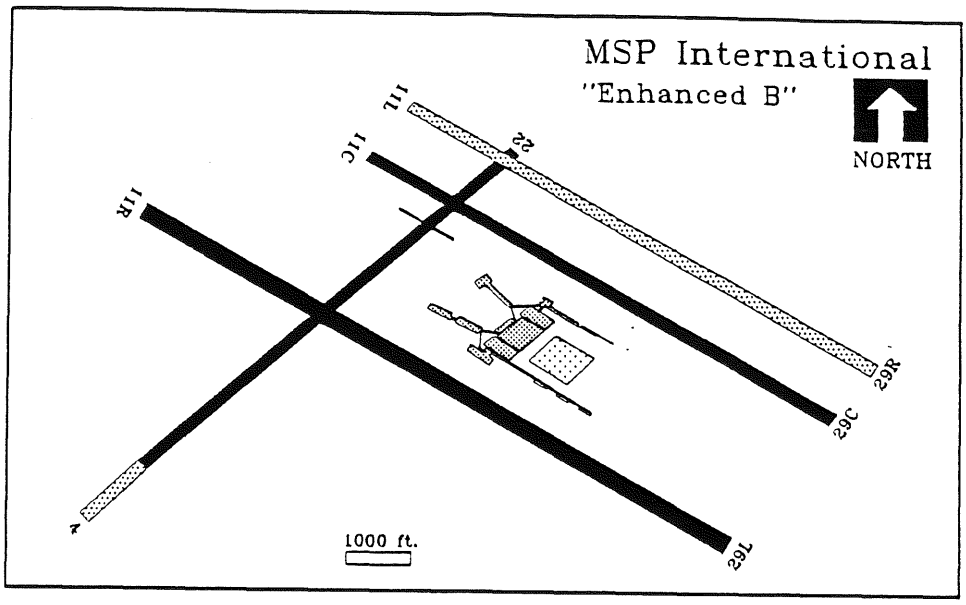
Under either option (700 or 920 foot separation) a full-length runway would require the use of land and the removal of structures now used by the Minnesota Air National Guard, the U.S. Air Force Reserve, and miscellaneous other government agencies in the area north of existing Runway 11L-29R. Several options may exist for these facilities, including consolidation and relocation to another location at MSP or moving them to another airport.

A triple parallel system could continue aircraft noise on those communities that are most affected today, while moderating impacts on other areas. There are two reasons for this, both closely related to the motivation behind adding the new runway--the need to serve expected future traffic efficiently. First, because a triple system is likely to be implemented to meet continued growth in air traffic, it will be more difficult to switch traffic from the parallels to Runway 4-22. The limited capacity of Runway 4-22 as well as the operating problems in changing the direction at which traffic approaches MSP both argue for making greater use of the parallel system than at present. Second, because of their proximity to each other, departure turns on the outboard Runways (11L-29R and 11R-29L) will be restricted, thereby concentrating noise impacts along extended runway centerlines.

While adding a third, close parallels should make an important improvement to capacity under VFR rules, the closeness of the two northern runways is such that they cannot both be used during IFR weather. In fact, current air traffic control procedures for triple approaches and converging runway approaches are essentially limited to VFR operations.

Implementation/Timing

Construction of a close parallel is not likely to occur in the immediate future, in large part because of the need to negotiate a new site for the U.S. Air Force and related operations and to reach an agreement concerning Fort Snelling Park. The noise implications of a triple runway operation during VFR weather will require some analysis and could create controversy. On balance, it appears unlikely that such a new runway would be in place sooner than ten years.



Procedures: Current rules.

Change in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Upper 10%	Lower 10%
Parallels Preferential Runway System	+22	0	0	0

EXPECTED AVAILABILITY OF ENHANCED B

Date	Expected Outcome	Lower 10%	Upper 10%
1993	0%	0%	10%
1998	50%	10%	80%
2003	70%	30%	100%
2008	80%	40%	100%
2018	95%	50%	100%

ENHANCED CASE C

Description

This option is similar to Enhanced Case B in that, in addition to the 2,750 foot extension of Runway 4-22, it requires a close parallel Runway 700 feet north of existing Runway 11L-29R. However, under this option, the new runway would be intended to serve small aircraft only, and thus could be limited to 5,000 feet (with instrument landing systems on each end). This would create a runway dedicated to regional carriers and the remaining general aviation.

A related option would be to add a similar short parallel to the cross-wind runway 4-22. This would serve similar purposes when wind conditions prevented landings and takeoffs in the direction of the parallels. If the 5,000 foot runway could be placed so that it did not cross 11R-29L, however, it might be possible to dedicate it to smaller aircraft, thus adding to the capacity of the parallels to handle larger commercial aircraft (this option might also be possible with an extended Runway 4-22). Such use, however, would provide only very limited benefits in terms of redistributing noise impacts.

Effect on Capacity

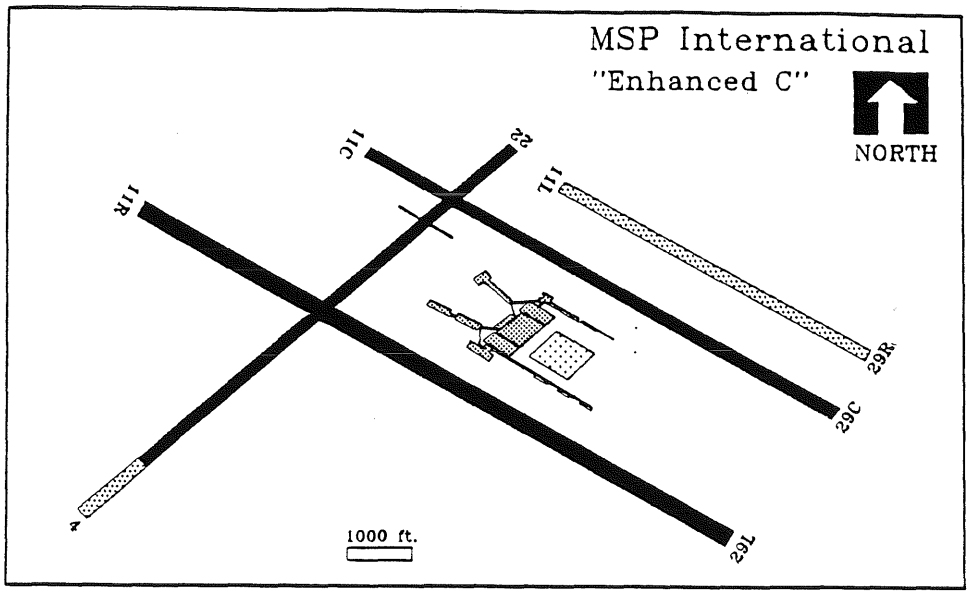
Because the new runway would be restricted to small aircraft, the effect on overall capacity might be smaller during peak periods, when larger commercial aircraft dominate, than that described above. On the other hand, by segregating smaller aircraft on a single runway, aircraft using each runway would have more similar speed and size characteristics. This could enhance safety as well as improving capacity somewhat. Capacity improvements on the existing runways would result both from reduced longitudinal separation and from less variability in these separations.

Of course, these gains in safety and capacity would be limited to VFR weather conditions, since the close parallel could not be used in conjunction with its nearby sister during IFR conditions.

Because of the closeness of the two northern parallels, there could be some safety concerns over effects that the wake vortex from larger aircraft on Runway 11C-29C might create for lighter planes using the new runway.

Implementation/Timing

There are no significant differences in the timing with which this option could be accomplished relative to that of Enhanced B. Because it would be significantly shorter, however, it may not intrude as much into the U.S. Air Force site, thus lessening one of the land use problems that has to be solved. Thus, on balance, it may be possible to implement this options slightly sooner than Enhanced B.



Procedures: Current Rules

Change in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Upper 10%	Lower 10%
Parallels Preferential Runway System	+5	+0	0	0

EXPECTED AVAILABILITY OF ENHANCED C

Date	Expected Outcome	Lower 10%	Upper 10%
1993	10	0	20
1998	60	20	50
2003	80	40	100
2008	90	60	100
2018	98	80	100

ENHANCED CASE D

Description

Enhanced Case D combines Enhanced Case A (the 4-22 extension) together with a new 8,000-foot north-south runway (called 18-36) on the west side of the Airport (with instrument landing systems on each end). No new parallel runways are added.

Construction of this runway involves some land use considerations. It is likely to require relocation of the air freight forwarders near its southern end. More importantly perhaps, is the location of office buildings on the other side of the freeway at the airport's southern boundary. One partial solution to this problem might be to shift the southern threshold to the north.

While there is adequate land to place this runway on airport property, it would move operations much closer to some of the residential areas to the East of Cedar Avenue. A more important consideration may be the continued commercial development along the airport's southern border.

Major benefits of this configuration are the creation of additional opportunities to distribute noise impacts more widely than at present and the ability to complement the existing parallel runways.

Effect on Capacity

The major capacity gains are likely to be in conjunction with the two parallels during VFR weather. Landings or takeoffs on Runway 18 would create limited interference with operations at the two parallels. Operations to the north, however, would have to be carefully coordinated with the parallels, limiting capacity gains.

It could add to crosswind capacity, again if careful coordination were made with Runway 4-22.

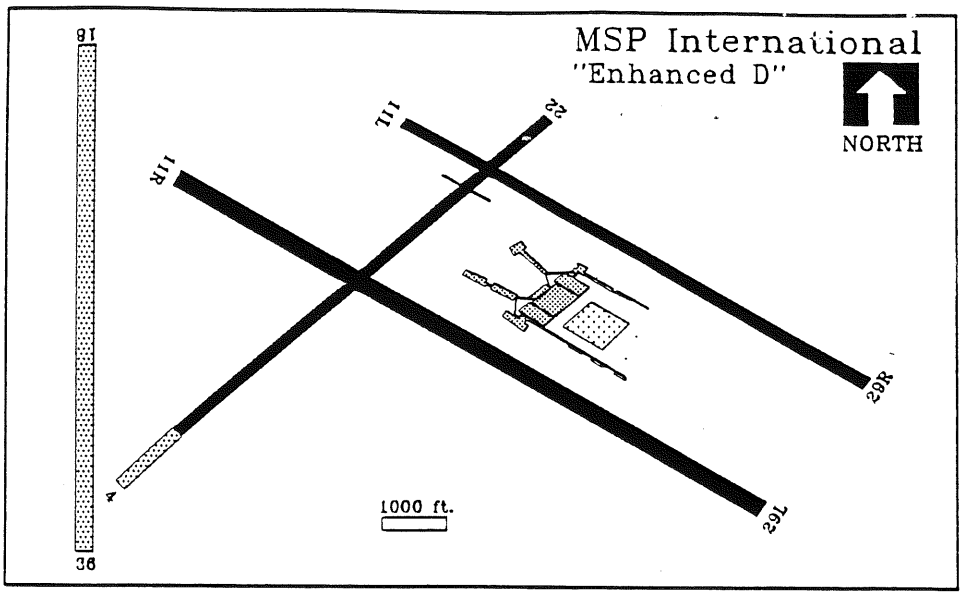
The proposed new runway would be somewhat removed from the present terminal, adding to direct airline costs because of increased taxiing and indirect costs because of passenger delays between the time of leaving the gate and the time of actual takeoff. One option to consider, however, would be to construct a new terminal building closer to the new runway. Such a building could be used for regional carriers, perhaps at the site of the proposed West Terminal. This would fit in with current discussions about the need for additional gates for regional

operations.

Larger capacity gains are dependent on new air traffic control procedures for converging runways during IFR conditions.

Implementation

Residential land use concerns may mean development of this runway should be phased in over time, perhaps restricting use to smaller aircraft at first and completing the full 8,000 foot runway later. Full operations are unlikely to occur before ten years.



Procedures: Current Rules

Change in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Upper 10%	Lower 10%
Parallels Preferential Runway System	+5	0	0	0

EXPECTED AVAILABILITY OF ENHANCED D

Date	Expected Outcome	Lower 10%	Upper 10%
1993	50	0	80
1998	80	20	90
2003	90	40	95
2008	95	60	98
2018	95	60	98

ULTIMATE CASE A

Description

Ultimate Case A combines Enhanced Case A (Runway 4-22 extension 2,750 feet to the Southwest) 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). This new runway differs from Enhanced Case B primarily in that the new parallel is located 2,000 feet from the current northern parallel rather than just 700 feet away.

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 consideration 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 might need to be consolidated/relocated elsewhere at MSP or some other site or some combination.

Effect on Capacity

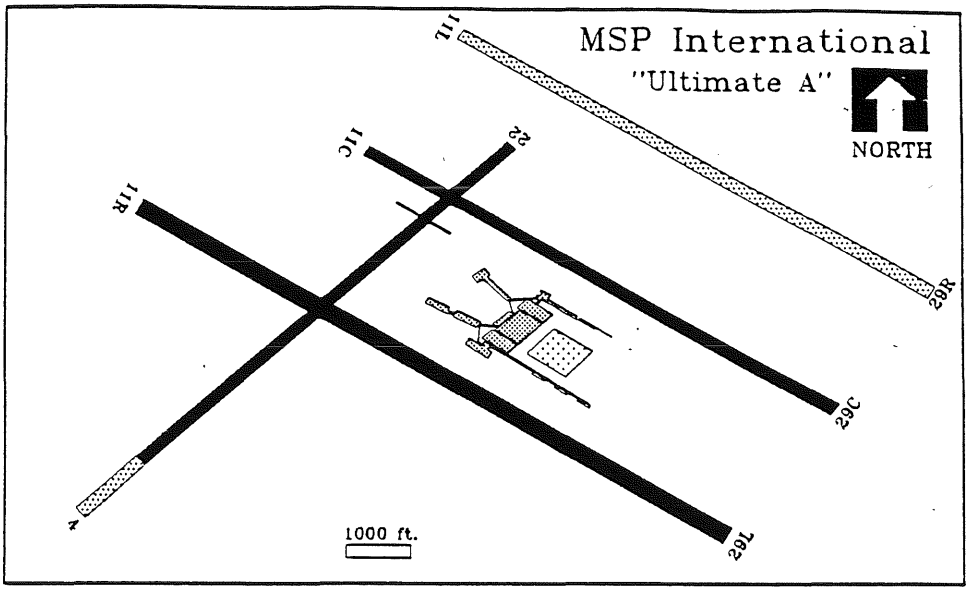
In contrast to Enhanced Case B, the two outboard runways would have a lateral separation of about 5,380 feet, thereby permitting independent IFR operations even if current FAA rules are not relaxed. Given that the possible timing for these rule changes is speculative, this runway provides good insurance 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..

The hourly capacity of the PRS runway could be increased due to the lack of 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.

This option also create opportunities for a new terminal location near the two northern parallel runways. An efficient ground transportation system would be needed to connect with the existing terminal. Again, this new terminal could be used either for regional carriers or as one way to reduce access times to the new runway.

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.



Changes in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Lower 10%	Upper 10%
Parallels Preferential Runway System	+22	+19	+22	+10

EXPECTED AVAILABILITY OF ULTIMATE A

Date	Expected Outcome	Lower 10%	Upper 10%
1993	0	0	0
1998	40	10	0
2003	60	20	20
2008	80	30	90
2018	80	40	90

ULTIMATE CASE B

Description

Ultimate Case B adds a new 8,000-foot north-south runway (18-36) on the Western edge of the airport (Enhanced D) to Ultimate A (4-22 extension and new 8,000 foot "far" parallel). All new runways would have instrument landing systems on each end.

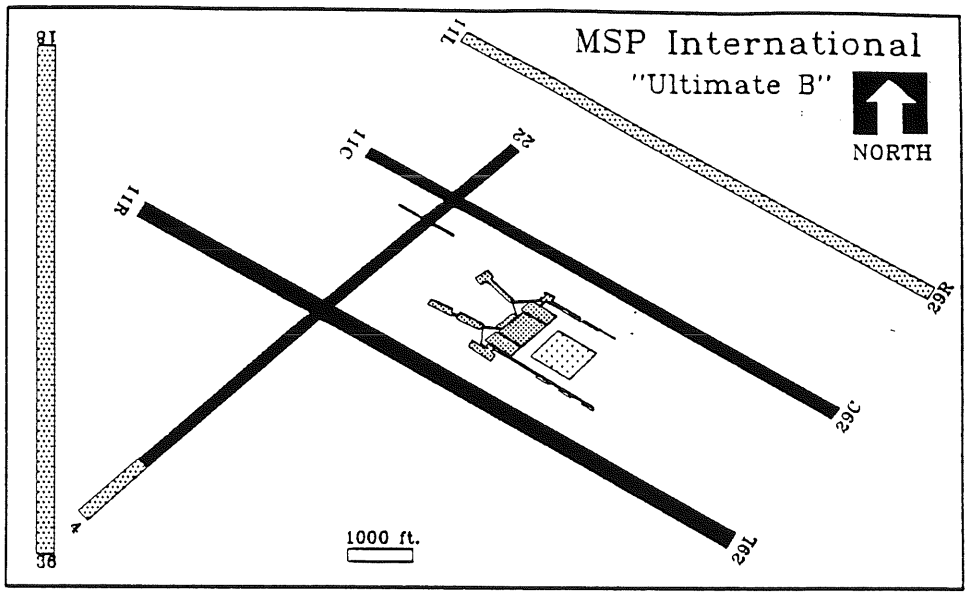
In addition to the problems discussed under Ultimate A for the "far" parallel, there are local land use implications regarding the new runway both on and off the airport site (see discussion of Enhanced Case D).

Effect on Capacity

The major capacity effects have been described already under Ultimate A for the far parallel, under Enhanced D for Runway 18-36, and under Enhanced A for the extension of Runway 4-22. However, adding the new North-South Runway would increase the capacity of the PRS or crosswind runway system, thus increasing the likelihood that it will be used as capacity grows. Without this addition, it would be difficult to spread noise impacts to areas other than those adjacent to the parallel runway system.

Implementation/Timing

Full implementation of this option will take more than ten years because of the additional study required in order to solve some of the site-related problems.



Procedures: Current rule

Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Lower 10%	Ranges for IFR Upper 10%
Parallels Preferential Runway System	+22	+19	+22	+10

EXPECTED AVAILABILITY OF ULTIMATE B

Date	Expected Outcome	Lower 10%	Upper 10%
1993	50	0	80
1998	80	20	90
2003	90	40	95
2008	95	60	98
2018	95	60	98

ULTIMATE CASE C

Description

Ultimate Case C combines Ultimate A and Ultimate B with Enhanced A and Enhanced B, plus adding a crossover taxiway linking the ends of Runways 29L, 29C (formerly 29R). Enhanced B features a close parallel positioned 700 feet north of current 11L-29R as well as the extension to 4-22 that was first mentioned in Enhanced A. Ultimate Case A added a new 8,000 foot "far" parallel runway and Ultimate B a new 8,000 foot North-South runway). In effect, this creates a quadruple parallel runway system with separations of 3,380, 700, and 1,300 feet respectively and 5,380 feet between the outside parallels. The crossover taxiway would make it easier to move aircraft from the south side of the existing terminal to the triple runways toward the north.

Because of the concentration of airport capacity to the north of the existing terminal, it might make sense to consider adding a new terminal between the "far" and "close" parallels both to minimize taxi time and to serve the higher levels of traffic that MSP would be serving under this configuration.

As with Ultimate A and Ultimate B, there are important land use problems that must be solved. In addition, construction of the crossover taxiway would be a complicated and expensive construction job around the only land access to the main terminal. Further, it would require moving Northwest's current hangars elsewhere on the site -- one possible location might be to the west of the new North-South runway.

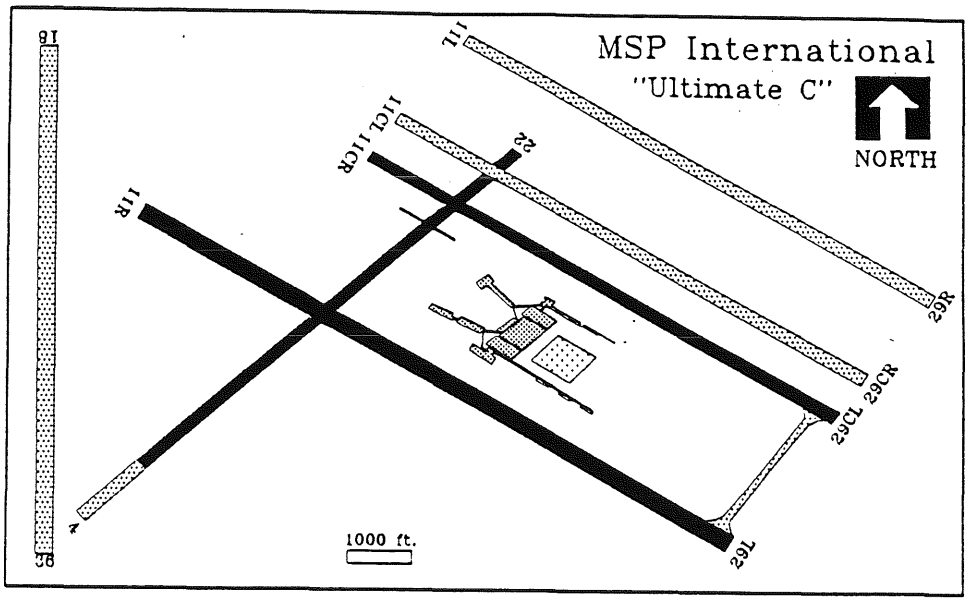
Effect on Capacity

The major addition here is the ability to use all four parallel runways during VFR weather. During IFR, however, only two runways could be used independently -- either the two outside runways under current FAA rules, or two of the southern three runways if the rules for independent parallel operations are relaxed. Thus, the existence of the four parallels provides little additional capacity during IFR conditions over what is possible under Ultimate A with current rules.

The crossover taxiway will not add to overall capacity of MSP to handle operations, but will make it less expensive for airlines and their passengers to use the new parallel runways.

Implementation/Timing

As with Ultimate Case B, completion of this option is unlikely in the near future.



Change in Hourly Capacities for Mixed Operations

Configuration	VFR	IFR	Ranges for IFR Lower 10%	Ranges for IFR Upper 10%
Parallels Preferential Runway System	+77	+35	+27	+50

EXPECTED AVAILABILITY OF ULTIMATE C

Date	Expected Outcome	Lower 10%	Upper 10%
1993	0	0	0
1998	40	10	0
2003	60	20	20
2008	80	30	90
2018	80	40	90

AIR TRAFFIC CONTROL PROCEDURAL MODIFICATIONS

Air Traffic Control procedures and equipment are continually changing to keep up with greater demand and technological advancements. This section describes those modifications that can be reasonably expected to occur in the forecast period, their impact on operations, and likelihood. Each is compared to the Base Case, or the "no change" alternative. A later section discusses possible interactions between changes in runways and air traffic control procedures.

Introduction

Over time, major improvements in the efficiency of airspace control procedures can have a direct impact on airside capacity. To a large extent, such improvements will stem from the development and deployment of new equipment and systems for terminal areas. Table 1 lists key procedural improvements and related equipment and system requirements.

The Federal Aviation Administration has conducted a number of capacity task forces at individual airports and simulated a range of improvements using its Airfield Capacity Model and Runway Capacity Model. The FAA also estimates the capacity improvements possible with various procedures and technologies on the basis of research prepared by others. Using these data, the FAA has published average percentage changes for a range of procedural options.[7] Although care was exercised to ensure that IFR capacity is never allowed to exceed each site's original or VFR capacity, the figures -- shown in Table 2 -- can only be used as a very rough guide to possibilities at MSP. Actual results at MSP will depend upon traffic mix, runway occupancy times and so on. The figures do provide a useful summary of recent analytic studies.

The FAA has also analyzed the applicability of various ATC procedure improvements at individual airports. According to the FAA's 1987 Airport Capacity Enhancement Plan, terminal ATC automation and independent close-parallel IFR approaches are the most likely to apply at MSP. For example, reduced longitudinal separation was not judged applicable under the existing airside layout since runway occupancy times are too low to permit reduced longitudinal separation. However, reduced longitudinal separation is likely to be applicable under certain approach configurations and under some of the airside expansion options under consideration in this study.

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[7] See, Federal Aviation Administration, Airport Capacity Enhancement Plan, 1987.

Table 1: Improved Airspace Control Procedures and Related Improvements in Equipment and Systems

Improved Airspace Control Procedures	Additional Equipment and System Requirements
Simultaneous IFR Approaches to Converging Runways	Microwave Landing System (MLS)
Improved Independent Parallel IFR Approaches	Instrument Landing System (ILS
Improved Dependent Parallel IFR Approaches	Next Generation Weather Radars
Triple IFR Approaches	Wind Measuring Equipment (LLWA
Improved IFR Longitudinal Separation Standards	Weather Sensor Development
	RVR Establish/Upgrade
	Wind Shear Detection
	Wake Vortex Avoidance and Forecasting
	Departure Flow Metering
	Upgrade Arrivals/Demand Algorithms
	Automated Airport Capacity Calculations
	Terminal Radar Enhancements
	Airport Surface Detection Equipment (ASDE-3)
	Mode S Data Link Applications Development
	Runway Configuration Managemen System
	Terminal ATC Automation

Table 2:
Effect of Projects on IFR Hourly Capacity

Project Capacity	Percent Change in IFR
Reduced Longitudinal Separation	3
Terminal ATC Automation	8
Simultaneous IFR Converging Approaches	100
Independent Close-Parallel IFR Approaches	39
Dependent Close-Parallel IFR Approaches	39

Source: Federal Aviation Administration, Airport Capacity Enhancement Plan, 1987.

The key questions in conducting the MSP adequacy study are;

- o **When** can capacity improvements through enhanced procedures and equipment be expected come about? and
- o **How much** additional capacity can be expected?

These questions are addressed next assuming the existing airside configuration.

INDEPENDENT PARALLEL APPROACHES

Description

Reduction in lateral separation standard from 4300 feet to around 3000 feet.

How the Factor Affects Traffic

The arrival separation values specified by the ATC handbook are as follows:

- o 3-nmi radar separation requirement and 4, 5 and 6-nmi wake vortex separations between aircraft on the same approach;
- o 2-nmi diagonal between aircraft on adjacent approaches for runways spaced 2500 to 4200 ft. This is rule applying today at MSP.

Capacity will increase if the required lateral separation between aircraft on parallel runways is decreased, removing the stagger between aircraft and allowing independent parallel operations.

Forecast of Timing and Availability

A number of factors will influence the timing and availability of independent parallel over dependent parallel operations. Currently, FAA regulations require parallel runways spaced between 2500 and 4299 ft. in order to operate as dependent parallels under IFR conditions. The FAA is exploring the possibility of changing the specifications to about 3000 ft. for independent IFR parallel operations. Two technologies, now in the research and development phase, could permit smaller separation requirements. One is back-to-back Mode S Radar which has a 2 second update rate (double the current rate) and higher accuracy. The other is a TCAS-like radar antenna which would update every second. As reflected in Table 3, there is a great deal of uncertainty about the near or medium-term availability of either technology. Interviews with FAA officials suggest that at least three years stands between state of the art radar and the hardware/software requirements of close parallel operations; and a further 7-8 years before individual sites can expect installation of the equipment. These estimates are reflected in Table 3 which suggests the turn of the century before the probability of close parallels at MSP approaches 75 or 80 percent.

Baseline Capacity Forecasts and Their Sources

The baseline forecasts reflect FAA and Mitre Corp. estimates of about 39 percent additional hourly capacity at MSP in moving to independent parallels over dependent parallels. This value is not unlike results from simulation experiments at other airports and has been chosen to reflect the expected outcome following a five year learning curve (Table 4).

Major Uncertainties

The major uncertainties associated with these baseline forecasts occur in two categories: controller and pilot acceptance on the one hand and political acceptance. If the controllers and/or the pilots are not willing to take full advantage of the opportunities for increased capacity then the forecasted values could be too high. Political acceptance could also play a part in reducing possible capacity increases. If the new procedures are perceived to increase noise or reduce safety to politically unacceptable levels, then there may be barriers to achieving the full capacity potential of IFR independent parallel operations.

The lower 10 percent limits are further from the projected expected outcome to indicate a skewness towards the improvements being lower rather than higher than the expected outcome. The limits decrease over time to indicate increased certainty in achieving the mean. The upper 10% limit is constrained by the present VFR capacity.

Table 3: Availability of IFR Capacity Improvements Due to Independent Parallel Approaches

Percent Probability of Availability

MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
1993	0	0	0
1998	0	0	0
2003	10	0	15
2008	80	50	85
2018	99	80	100

Table 4: IFR Capacity Improvements Due to Independent Parallel Approaches

PERCENT IMPROVEMENT IN HOURLY OPERATIONS

Five Year Learning Curve	Expected Outcome	Lower 10%	Upper 10%
t	7	2	10
2	12	6	16
3	16	9	22
4	33	23	39
5	39	30	44

t = First Year of Availability

Note: The current IFR capacity upon which these increases are based is 71 operations/hour which is the arrival peak (60%).

TERMINAL ATC AUTOMATION

Description

This represents a group of projects (included in Table 2, but excluding MLS) designed to improve the performance of air traffic controllers and pilots and in so doing improve the rate at which aircraft operation can occur under IFR conditions (some VFR improvements are also envisaged, though considerably smaller).

How the Factor Affects Traffic

Improved performance stems from reductions in the size and variability of aircraft separations from the metering fix to the runway threshold.

Forecasts of Timing and Availability

Under the National Airspace System Plan, terminal ATC automation is not expected to be operational until the mid-1990s. This is reflected in Table 5 which also reflects the judgement that availability is more likely to be later than expected than earlier.

Baseline Capacity Forecasts and Their Sources

As shown in Table 2, the FAA forecasts an 8 percent improvement in IFR hourly capacity as a result of terminal automation. Other estimates of the impact of improved inter-arrival variability are in the 12-16 percent range The estimates given in Table 6 assume an expected outcome of 8 percent at MSP, the lower of the various available estimates.

Major Uncertainties

Full implementation and impact is heavily dependent upon controller and pilot skill levels and acceptance. The 10 percent limits given in Table 6 reflect a slow learning and acceptance curve and, in the initial years, a greater likelihood of falling beneath the expected outcome.

Table 5:
Availability of Full Terminal ATC Automation

	PERCENT PROBABILITY OF AVAILABILITY		
MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
1993	0	0	0
1998	50	30	60
2003	75	65	80
2008	90	80	95
2018	95	90	99

Table 6: IFR Capacity Improvements Due to Full ATC Terminal Automation

PERCENT IMPROVEMENT IN HOURLY OPERATIONS

5-Year Learning Curve	Expected Outcome	Lower 10%	Upper 10%
t	1	0	0
2	3	1.5	4.0
3	4	2	5
4	6	4	8
5	8	4	12

t = First Year of Availability

MICROWAVE LANDING SYSTEM

Description

Next generation precision landing system.

How the Factor Affects Traffic

Because MLS uses a beam that scans a wide volume of airspace, rather than the pencil beam of ILS, in theory it permits aircraft to fly any of several approach angles (including two-step glide slopes) and, in the horizontal plane, to approach along curving paths that intersect the extension of the runway centerline at any chosen point. In effect, MLS offers a degree of freedom in using the airspace that is closer to that enjoyed under conditions of good visibility.

Forecasts of Timing and Availability

According to preliminary investigations and conversations with the FAA, five MLSs are to be installed at MSP with two years. Use of the system will take substantially more time however since aircraft will equip with the associated avionics at a slower -- and very uncertain -- rate. Since the ICAO deadline for fully operational MLS is 1998, many observers do not foresee its broad application until that time. This view is reflected in Table 7.

Baseline Forecasts

According to the Office of Technology Assessment, estimates by the FAA indicate that the gains could range up to 10-15 percent at some airports under IFR conditions. No estimates specific to MSP are available and we have treated the 15 percent as an upper limit. The baseline forecast has been taken at one half that level with a five year learning curve after full MLS implementation (see Table 8).

Major Uncertainties

The chief motive for FAA in seeking to develop and deploy MLS is not the potential capacity benefits but rather operational advantages. These include more precise guidance, ease of installation, improved reliability, less susceptibility to electro-magnetic interference and greater number of transmission channels. The capacity benefits are secondary and highly dependent upon controller and pilot acceptance of radically new procedures. Since theoretical limits are rarely achieved even under current conditions, many believe that the capacity gains from MLS may be smaller than theoretical estimates suggest. The

ranges given in Table 8 thus suggest a greater likelihood of lower rather than higher results compared with the baseline forecast.

Further preliminary analysis of the prospective capacity impacts of MLS at MSP is presented in the appendix to this report.

Table 7:
Availability of Fully Operational MLS

PER CENT PROBABILITY OF AVAILABILITY

MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
1993	40	20	60
1998	95	85	100
2003	100	100	100
2008	100	100	100
2018	100	100	100

Table 8: Increased IFR Capacity Due to Fully Operational MLS

PER CENT IMPROVEMENT IN HOURLY OPERATIONS

MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
t	1	0	1.5
2	2	0.5	3
3	3	0.5	4.5
4	6	3	8
5	7	4	9

t = First Year of Availability

DEMAND MANAGEMENT TECHNIQUES

The two sets of options discussed so far focus on improving the physical capacity of MSP either through greater runway capacity or relaxed air traffic control procedures. A third approach -- called demand management -- requires no physical modification to the existing airside configuration. Rather, they 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 capacity. All three approaches have the same end goal, however, to reduce the expected gap between capacity and peak-period demand.

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.

LIMIT GENERAL AVIATION ACTIVITY AT MSP

Description

Typically, the term general aviation (GA) applies to small private planes and includes a wide variety of aircraft from corporate multi-engine jet aircraft to single-engine piston aircraft built by amateurs. Technically, GA includes all civil aircraft except air carrier aircraft certified in accordance with FAR Parts 121, 123, 127, and 135.

How the Variable Affects Capacity

General aviation aircraft currently represent more than 18 percent of all operations at MSP. Due to the required separations for landings and takeoffs, the variety of GA planes places operational constraints on the use of terminal airspace and airport facilities. Restricting the availability of MSP facilities to the relatively large and faster air carrier and regional carrier aircraft would have the immediate benefit of increasing the number of commercial service passenger aircraft without requiring any additions to existing facilities.

In the short term, eliminating all GA operations at MSP could allow other aircraft operations to increase by as much as 25 percent. Because of the much higher number of passengers in commercial aircraft, the number of travelers able to use MSP would increase by much more than the number of operations. This improvement in capacity would probably not be concentrated at peak times of day.

Baseline Assumptions

Operations by GA at MSP aircraft are expected to drop precipitously over the period through 2008, from 18.1 percent of total operations in 1986 to 3.8 percent in 2008. This is substantially below the lowest levels found at major U.S. airports today. The annual number of GA operations would decline from 71,000 today to 22,000 by 2008. Remaining general aviation operations at MSP are projected to be almost exclusively corporate business jets.

The data sheet assumes takes 70 percent of GA traffic as a target for shifting to other airports or to off-peak times of day at MSP. The distribution is strongly skewed toward lower numbers based on the difficult history that such efforts have had in the past.

Major Uncertainties

Key questions concern whether or not this dramatic decline in GA traffic will actually occur. What role can regulations and/or landing fees have in speeding up this trend or ensuring that it takes place?

Historical data indicate that small aircraft use of major airports declines as capacity becomes constrained (as delays increase) and as the number of larger, heavier aircraft increase. These two forces provide a "natural" incentive to use less-crowded reliever facilities and other general aviation airports. The current low end of this trend is about 10 percent of operations at major congested airports such as La Guardia.

The HNTB forecast for MSP surpasses this trend in predicting a considerable decline in the number of GA operations at MSP. FAA forecasts, in contrast, suggest a very slow increase nationwide. This implies a dramatic shifting of GA demand at MSP to outlying airports. Is this shift realistic without other incentives?

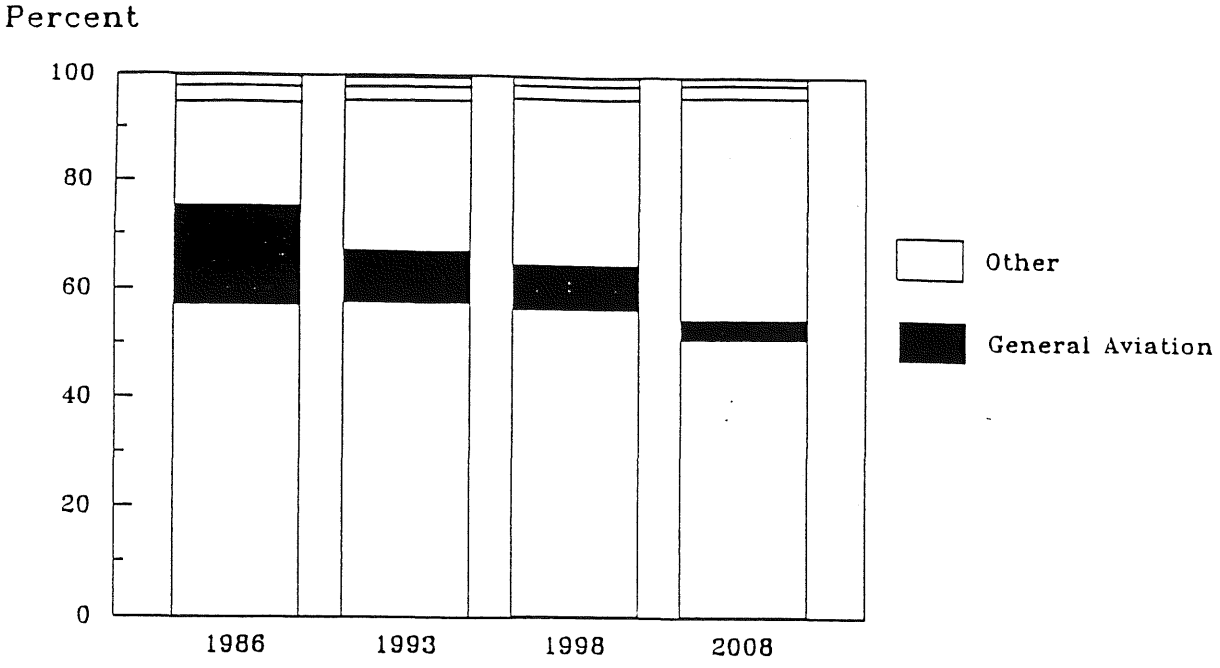
In restricting GA aircraft from access -- whether this occurs "naturally" or due to regulations -- considerable attention should be paid to the needs of so called corporate jets. Otherwise there may be an unintended affect of reducing the attractiveness of the Twin Cities region to business. (The National Business Aircraft Association adamantly opposes these restrictions).

Reliever airports may require additional facilities to accommodate higher levels of general aviation activity. In addition to airport improvements, land access to regional business centers must usually be improved. Further, the environmental impacts associated with such actions may be unacceptable to area residents.

The timing of any restrictions could be critical, since it will not be for some time that such restriction would be necessary.

Forecast Share of Operations at MSP:

General Aviation Versus All Others



PERCENT DECREASE IN OPERATIONS DUE TO SHIFT IN GA TRAFFIC

Year	Base Estimate	Lower 10 Percent	Upper 10 Percent
1993	7	2	12
1998	6	2	11
2003	4	2	10
2008	3	0	9
2018	2	0	8

PROBABILITY OF IMPLEMENTING THIS OPTION BY GIVEN YEAR

Year	Base Estimate	Lower 10 Percent	Upper 10 Percent
1993	10	0	20
1998	15	0	25
2003	20	0	30
2008	25	0	35
2018	35	0	45

RESTRAINTS ON REGIONAL CARRIER ACTIVITY

Description

Regional carriers is a broad term that includes air taxis, commuter carriers as well as local airlines that operate larger aircraft -- sometimes up to 100 seats. They provide the feeder service to the major airlines from smaller, less trafficked airports. They are by far the fastest growing class of aircraft at MSP and could account for more than 40 percent of total operations by the year 2008. Even though their aircraft are smaller, regionals can place demands similar to those of air carrier aircraft on an airport. Because they provide feeder service, there is considerable interest in coordinating the schedule of reliever carriers with those of the hub airline.

One option would be to designate a reliever airport--perhaps the new reliever that will be located to the Northwest of Minneapolis -- for the exclusive use of regional traffic. Such a facility would require greatly improved ground access both to the major business centers in the Twin Cities area and to MSP for connections to longer distance flights.

How the Variable Affects Capacity

Regional carrier operations currently comprise nearly 20 percent of all aircraft operations at MSP. Encouraging regionals to land at one of the area's reliever airports could, therefore, increase the capacity of MSP for air carrier aircraft operations by up to 20 percent today and even more in the future. Much as it is for GA aircraft, the required separations for landings and takeoffs can place nearly the same requirements on the terminal airspace and airport facilities. Encouraging the use of reliever facilities by these aircraft could, therefore, free up capacity for aircraft with higher passenger capacities.

Baseline Assumptions

Due to the increased use of "code-sharing" agreements, or contractual agreements between regionals and major air carriers, the number of regional carrier flights is expected to increase rapidly. Regional carrier operations as a percent of all operations at MSP are, therefore, forecast to rise from its current level of 19.5 percent to 41.5 percent in 2008. This tremendous growth could, by itself, determine the capacity additions needed at MSP and perhaps even the question of whether or not a new airport is needed.

The estimates shown in the attached table take slightly less than one half of all regional carrier operations as a target for shifting to off-peak periods at MSP. As with general aviation, this distribution is strongly skewed toward lower levels, reflecting some skepticism about the ability to implement such a plan.

Major Uncertainties

Some considerations are as follows:

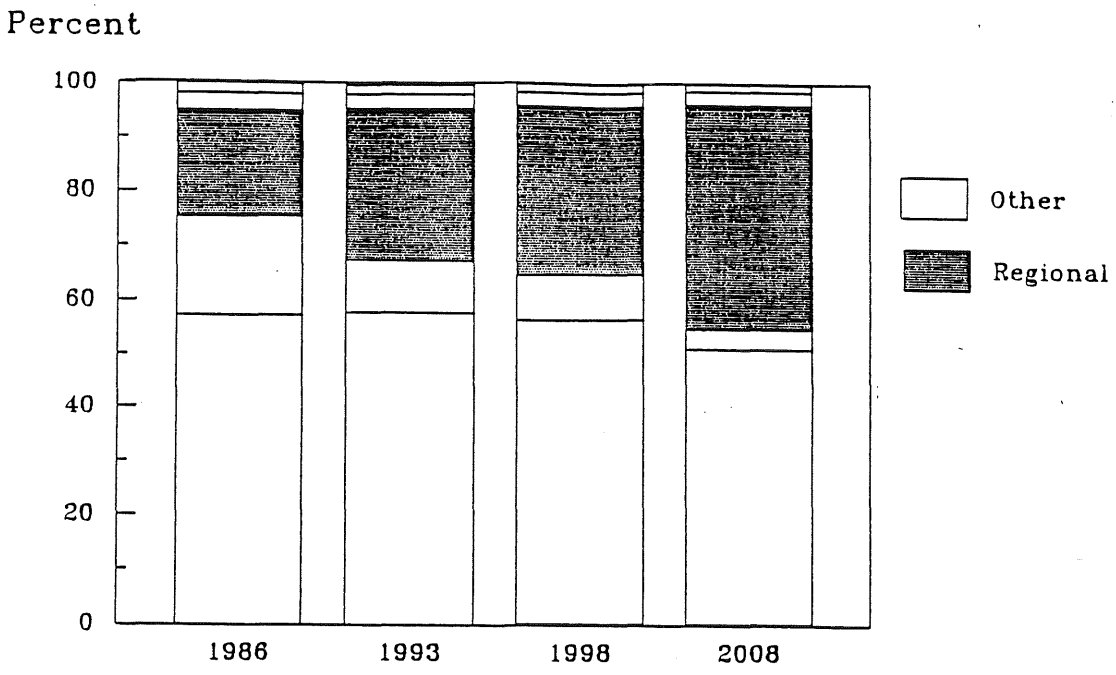
- The ability to reduce regional airline service would be determined in part by the availability of alternative transportation to MSP to make connecting flights and, if available, the time requirements of transfers.

Not all regional airline service to MSP involves passengers transferring to connecting flights -- many are starting or ending their travel in the Twin Cities. Shifting only these passengers to a new site would cause much less inconvenience. However, is the volume of this origin and destination traffic enough to justify non-connecting flights that could provide service to and from one of the relievers. At present, the market does not appear to be large enough to justify creating such dedicated flights. If, however, regional traffic grows to beyond 4 million passengers a year as shown in the most recent MAC forecast, traffic volumes may be large enough to justify such exclusive service between certain city pairs.

Forcing all regional service away from MSP would effectively reduce the accessibility to and from communities served solely by regional carriers. The negative economic effects on these communities could be significant.

Forecast Share of Operations at MSP:

Regional Carriers Versus All Others



PERCENT DECREASE IN OPERATIONS DUE TO SHIFT IN REGIONAL TRAFFIC

Year	Base Estimate	Lower 10 Percent	Upper 10 Percent
1993	14	6	16
1998	15	7	18
2003	20	8	22
2008	20	9	23
2018	20	10	25

PROBABILITY OF IMPLEMENTING THIS OPTION BY GIVEN YEAR

Year	Base Estimate	Lower 10 Percent	Upper 10 Percent
1993	10	0	20
1998	15	0	25
2003	20	0	30
2008	25	0	35
2018	35	0	45

VARIABLE LANDING FEES

Description

A commonly considered alternative for reducing aircraft activity levels, particularly during peak travel times, is a variable landing fee. Higher landing fees typically affect smaller aircraft such as general aviation aircraft and air taxis most directly. If these higher fees are focused on peak periods hours, the net effect is to encourage smaller aircraft to use other airports or shift operations to off-peak periods. Some form of peak period fees are in use at the three New York airports, Miami and Boston as well as European airports. Boston's Logan Airport has a controversial proposal to greatly expand its fee structure.

Fees need not be very large for an impact to be seen. Differential landing fees of under $50 had a significant effect at the three New York airports in the late 1960s and still serve to keep almost all GA traffic except for corporate jets away.

How the Variable Affects Capacity

While the degree to which variable landing fees will affect capacity varies depending on the nature of demand, and how the fees are imposed. Some estimate of the potential benefit can be estimated by comparison to a similar situation at Boston's Logan Airport. As proposed by the Massachusetts Port Authority, variable landing fees are expected to reduce aircraft operations by 5 percent. Because Logan is already capacity-constrained, the estimated benefit is considerable, reducing delays by 80 percent for most of Logan's passengers. Similar effects were found at La Guardia in the late 1960s.

No such peak period fees are in use at MSP.

The capacity gains could be substantial, in the extreme, even approaching the effects of the two previous options. The numbers shown in the attached table represent a rough average of the gains from the two previous options.

Major Uncertainties

Variable landing fees have traditionally met with considerable opposition on the part of small aircraft owners. Consequently, Logan's plan for increased fees -- in addition to the existing peak-period landing fee -- was released two months late in order to "perfect its legal position."

As with the previous two demand management options, a key question is whether or not the benefits from reduced peak-period delays are seen as offsetting the reduced service that smaller communities and users of general aviation are likely to receive

These fees, however, can be quit flexible, with adjustments made according to shifts in demand and the level of net capacity that exists at any time. For example, fees might be reduced after a new runway addition or major change to air traffic control rules. Fees can also be used as a source of revenues in order to help add new capacity. Proposals have been made to use peak-period fees as "cross-subsidies" to reduce costs for airport users who shift to off-peak periods. Thus, the same fee schedule could provide a "double" incentive, allowing air taxi operator's, for example, to offer reduced fares as one means of offsetting the greater inconvenience.

Variable fees, if structured properly, are also one way to assign scarce peak-period capacity to those travelers who receive the greatest benefit from travelling at that time.

Percent Decrease in Operations Due to Variable Fees

Year	Base Estimate	Lower 10 Percent	Upper 10 Percent
1993	11	4	14
1998	11	4	15
2003	11	5	16
2008	11	5	16
2018	11	5	16

Probability of Implementing This Option by Given Year

Year	Base Estimate	Lower 10 Percent	Upper 10 Percent
1993	10	0	20
1998	15	0	25
2003	20	0	30
2008	25	0	35
2018	35	0	45

INTERACTION AMONG OPTIONS

Each option identified above is subject to variation due to changes in aircraft mix, weather characteristics, the variability of human efficiency, etc. Beyond these, however, is a separate level of variability -- one brought on as a direct result of the combination of capacity enhancement options employed whose primary areas of improvement may overlap. In short, it may be misleading to add the total capacity gains estimated for one option with the gains from another. In order to make the panel's work more manageable, we have not attempted to model each of the multi-option capacity permutations.

For demonstrative purposes, Table 1 indicates how a sampling of variables (detailed in the attachments) would result in benefits which could not have been arrived at through the addition of incremental options. For example, one can compare the impact of implementing MLS to that of independent parallel runways (under ILS conditions) for "Enhanced Case A." While the incremental benefit of these might be 28 operations and 19 operations hourly, respectively, the benefit of both is clearly not going to be the sum, 47, but instead may be some number closer to 35 or 40.

Table 1 also illustrates the benefits in improving airfield capacities utilizing non-capital intensive alternatives. For example, air traffic control procedural changes in lateral separation requirements for independent IFR operations results in an IFR hourly capacity equivalent to that associated with the extensive airfield development associated with "Ultimate Cases A and B."

It is interesting to compare the resultant estimated hourly capacities with the corresponding Year 2008 demand levels as presented in the MSP Master Plan prepared by HNTB. The forecasts for VFR and IFR peak-hour operations are equivalent given the nature of demand during peaking conditions, and the far majority of the demand is comprised of scheduled airline operations. The general aviation component of the demand values is relatively small and represents the more sophisticated elements of the general aviation fleet; that is, corporate jets whose approach speeds are similar to those of the relatively larger air carrier aircraft.

The comparison indicates that only "Ultimate Case C" can generate the VFR and IFR hourly capacities to match or exceed the projected demand levels, and in the case of IFR hourly demand, only with the implementation of MLS capability on all runways and with the associated enhancements to air traffic control procedures.

Table 1
Facilities and ATC Procedures Impact on Airside Capacity

Airside Configuration	Highest Hourly Capacity W/ Facilities Improvements Alone		Increased Highest Hourly Capacity With Implementation of ATC Procedures Changes:				
			CASE A (MLS)		**CASE B** (Independent Runways)		**CASE C** (Terminal ATC Automation)
	VFR	IFR	VFR	IFR	VFR	IFR	IFR
Base Case	103	85	N/A	N/A	N/A	N/A	92
Enhanced Case A	115	85	126	93	115	104	92
Enhanced Case B	125	85	137	93	125	104	92
Enhanced Case C	118	85	129	93	118	104	92
Enhanced Case D	108	85	118	93	108	104	92
Ultimate Case A	125	104	137	114	125	104	112
Ultimate Case B	125	104	137	114	125	104	112
Ultimate Case C	180	120	198	132	180	120	130

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

CAPACITY ESTIMATES AND PRELIMINARY FINDINGS

May 1988

Prepared By:

APOGEE RESEARCH
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Introduction

One need not be an airport planner or systems analyst to appreciate the problem of the nation's system of airports. Anyone who has travelled by air or read a newspaper in recent years is painfully aware of the problem in aviation today. In a word, that problem is capacity.[1] The problem is most apparent during peak travel periods, when delays have become the norm.

Delays cost money. Late arrivals or departures can cost both the businessmen and the airlines several billion dollars a year in terms of missed meetings or increased operational costs. Persistent delays also can cause serious long-term costs to a region's economy. Frequent delays will ultimately alter the attractiveness of a given location and, in the long run, may even induce businesses to consider alternative locations.

Nationally, more and more airports have reached -- or exceeded -- their physical capacity, indeed, it could even be argued that the national system of airports already exceeds its capacity during peak hours. By 1994, air carrier delays are predicted to reach 1.6 million hours, a 39 percent increase in eight years.[2] Worse, the opportunities for expansion are limited at many of the busiest airports and only one or two are actively responding to that problem through the construction of new airports.[3]

Since adequate capacity provides reliable service and a minimum of travel delays, it can be a significant force as businesses make locational decisions. The question is which cities will be able to respond to that need and how soon? Cities or regions that can continue to increase their airport capacity will clearly have an economic development advantage.

What is Capacity?

Capacity sounds like a simple concept, but in practice it

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[1] The National Council on Public Works Improvement, Airports and Airways, (May 1987).

[2] Federal Aviation Administration, Airport Capacity Enhancement Plan, 1987, p. 2-12.

[3] These airports include Austin, Texas, and Denver, Colorado, although even these may take up to a decade to add significant amounts of capacity.

has a variety of meanings and nuances.[4] 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 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 constraints, the mix of aircraft

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

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.

Although most people understand capacity in terms of the time he or she was delayed at the airport, the fact is that airport capacity has different parts. For example, in its broadest sense capacity can be defined to include the airfield (runways), terminal, and landside facilities (roads, parking, and ground transportation).

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.[5] 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. This report (1) provides a brief overview of the capacity analysis and analytical approach being used in the MSP Adequacy Study, (2) describes the types of airfield improvements possible at the MSP, and (3) discusses the findings and their policy implications.

The Analytical Process[6]

The analytical process used in the MSP Airport Adequacy Study builds on what has traditionally been a stumbling block for capacity analyses. That is that while explicit alternatives can be identified for each category of capacity options, the exact magnitude of operational improvements attributable to a given option can vary widely. Aircraft mix, runway configuration and use, number and type of exit taxiways, frequency of Instrument Flight Rule (IFR) weather conditions, and decisions made on the spot by air traffic controllers can each influence the actual capacity yield of an existing or proposed runway configuration.

Many of the differences between estimates may reflect contrasts between what may be predicted by simulation models and

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

[6] 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.

the effect of local conditions. Consequently, estimates provided by one agency or group may not coincide with those of another. At MSP, this point is illustrated by analyses of the Federal Aviation Administration (FAA) and of the consultants to the Metropolitan Airports Commission, Howard Needles Tammen and Bergendoff (HNTB) (Table 1).

Table 1
Capacity Estimates of MSP International
(Mixed Traffic in IFR, Hourly Basis)1

Type of Operation[a]	FAA Estimate	HNTB Estimate[b]
Dependent Parallel	72	85
Independent Parallel	98	98

Notes: (a) Runways 11L, 11R
(b) HNTB estimate adjusted to reflect facility layout similar to FAA's.

Sources: MSP 2000+ Airport Development Plan, February 1988 and Airport Capacity Enhancement Plan, 1987.

Specific reasons for the divergence of the two estimates are difficult to define, since judgement is key in applying any set of engineering relationships. Nonetheless, the fact is that estimates vary -- and variance, as for other inputs to the analysis, should be weighed carefully in approximating capacity. In most traditional analyses it is not.

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 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.

In addition to applying the judgments of the study team members and available analytic techniques, a panel of experts on airport capacity was assembled to review options and to suggest alternatives. This panel included national and local experts on airfield, air traffic control and terminal capacity questions as

well as members of the Task Force (Appendix lists the members of the panel). The options presented here reflect discussions with these individuals.

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.

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

Each set of options is discussed below, with most detail focused on the runway alternatives. Additional details are provided in Appendices B, C, and D.

Runway Configurations

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

While nine separate options were considered, the four presented here offer a range of potential improvements, including what may be the maximum possible without going beyond the Ring Roads. Some options, particularly what is called Ultimate A, do however, involve taking land now not controlled by the MAC and would require the purchase of nearby residential areas and

perhaps part of Fort Snelling Park as well as the relocation of certain nearby land uses, perhaps including the Air National Guard and Air Force operations.

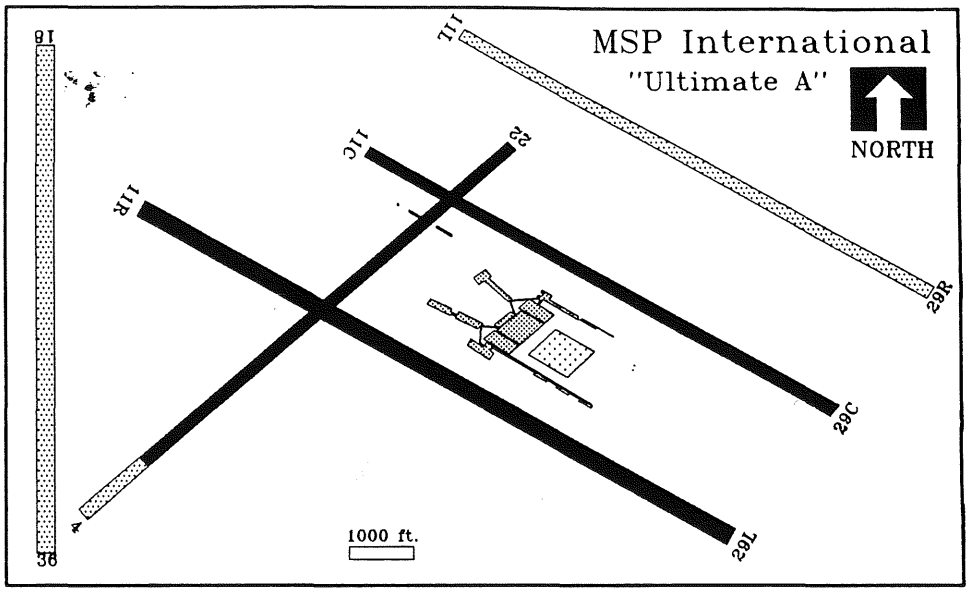
Table 2 summarizes the runway and taxiway additions contained in these options. The first, or Base Case, is a "no change" case where the current runway layout and options to improve already underway remain unchanged. The inclusion of this option allows the capacity analysis to consider the air traffic and economic ramifications of inaction on the part of airport planners and developers. It is the case against which all others can be compared.

Table 2.
Runway Configuration Options

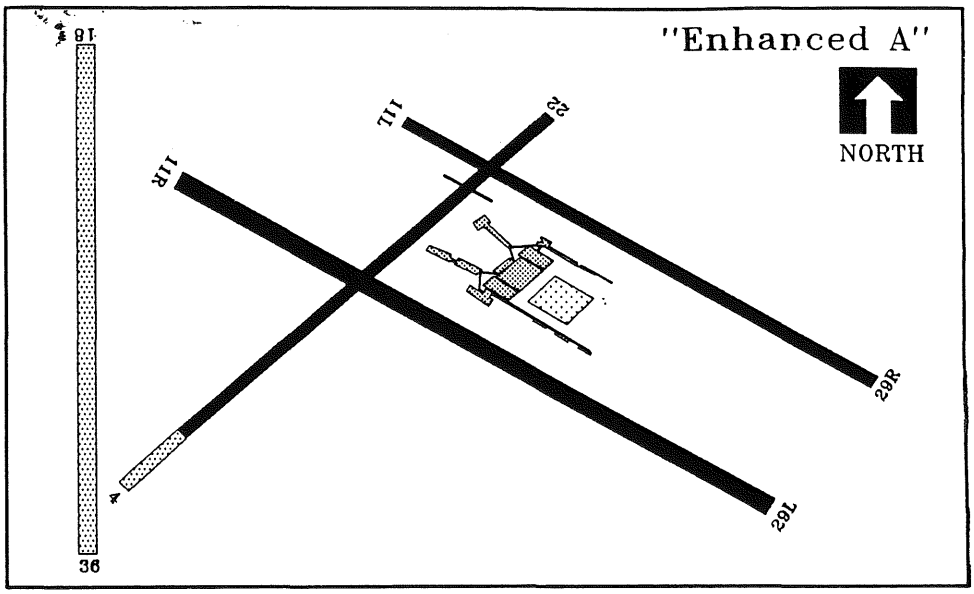
Option	Description
Base Case	No change to the current runway configuration
Enhanced A	Extend Runway 4-22 Add taxiway improvements New North-South Runway
Enhanced B	Extend Runway 4-22 Add taxiway improvements New North-South runway "Close" parallel
Ultimate A	Extend Runway 4-22 Add taxiway improvements 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 what is called Ultimate A (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 Ultimate A.

These IFR estimate are misleading for long-term projections


MSP International
"Ultimate A"
NORTH
11L
29R
11C
2R
11R
29C
29L
1000 ft.

"Enhanced B"
NORTH
18
36
11L
11CL 11CR
25
29CL 29CR
29L
1000 ft.


"Enhanced A"
NORTH
18
36
11L
29R
11R
29L

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 3 provides detail on the base line 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 3
Summary of Average Hourly Capacities

Airside Configuration	Hourly Capacity IFR	Hourly Capacity VFR
Base Case	78	103
Enhanced Case A		
Base	78	103
New North South Runway	18	32
Total	96	135
Enhanced Case B		
Enhanced Case A	96	135
Add Close Parallel Runway	0	20
Total	96	155
Ultimate A		
Widely Spaced Parallels[7]	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,

[7] Assumes addition of new "far" parallel at least 920 feet from 11L-29R, creating two widely spaced parallels.

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 the Ultimate A option. 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.

Technical Summary of Alternatives

The technical description of each alternative includes:

- A description of the option, both in terms of physical modifications or procedural changes;
- A summary of how the option affects capacity, which explains (a) the key factors contributing to the change in capacity, (b) general advantages and disadvantages, and (c) major uncertainties regarding that option's effectiveness; and
- A discussion of the likely time frame in which the project could be implemented.

Base Case

Description

The base case includes the existing runway and taxiway network at MSP, airfield improvements already approved for the period 1988 to 1989 as well as normal maintenance and rehabilitation in the future. 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[8] 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.

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[8] 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.

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 of 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 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.

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.[9]

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).

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

ENHANCED CASE A

Description

This case includes the extension of Runway 4-22, taxiway improvements, and a new north-south runway (18-36) on the west side of the airport parallel to Cedar Avenue. This runway is assumed to be at least 8,000 feet in length and have an instrument landing system on both ends. 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

New runway 18-36 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.

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 debated over this option, limiting the ability to implement it quickly.

Enhanced Case B

Description

This case includes the extension of Runway 4-22, taxiway improvements, and a new north-south runway (18-36) (Enhanced Case A) together with a close parallel Runway (the new 11L-29R) 700 feet north of the existing 11L-29R (renamed here as 11C-29C). This third parallel runway is assumed to be 8,000 feet in length and have instrument landing systems on both ends. A runway length less than 8,000 feet could present operational constraints, especially for departures, thus limiting the maximum gain from the parallel runway system. While this runway's location would make it logical for use with arriving aircraft, its ability to serve departing aircraft without restriction is desirable. A shorter runway might, however, reduce some of the noise and land use impacts on adjoining property.

The current FAA minimum for dependent operation of parallel runways in VFR conditions is 700 feet. Therefore, any third parallel must be separated by at least 700 feet -- in fact this is one option mentioned by HNTB in its work on the MSP Master Plan. A related option would be for a slightly wider separation (920 feet), also creating a triple parallel system, but with the outer parallels 4,300 feet apart. Land use impacts in Fort Snelling State Park are greater under this options.

Effect on Capacity

Capacity could be increased to as much as 160 operations during VFR conditions because the Center Runway 11-29 can be used to handle arrivals or departures in concert with the outboard runways. Gains from this third closely-spaced parallel runway would have no effect during IFR weather conditions, however, unless the FAA were to change the current 4,300 foot separation required for independent parallel operations during IFR. With a separation of 4,100 feet, however, a change in this rule would be much more likely than a switch to permit a 3,400 foot separation. The increased probability of this happening during the next decade, is incorporated into the summary probability estimates presented below.

Uncertainties

A practical problem with adding a third parallel is the limited space within the current boundaries of MSP. Thus, some land, but probably a minimum of public structures, would have to be obtained from Fort Snelling State Historical Park.

A full-length third parallel runway would require the use of land and the removal of some of the structures now used by the Minnesota Air National Guard, the U.S. Air Force Reserve, and

miscellaneous other government agencies in the area north of existing Runway 11L-29R. Several options may exist for these facilities, including consolidation and relocation to another location at MSP or moving them to another airport.

A triple parallel system could continue aircraft noise on those communities that are most affected today, while moderating impacts on other areas. There are two reasons for this, both closely related to the motivation behind adding the new runway--the need to serve expected future traffic efficiently. First, because a triple system is likely to be implemented to meet continued growth in air traffic, it will be more difficult to switch traffic from the parallels to Runway 4-22. The limited capacity of Runway 4-22 as well as the operating problems in changing the direction at which traffic approaches MSP both argue for making greater use of the parallel system than at present. Second, because of their proximity to each other and to the center parallel runway, departure turns on the outboard Runways (11L-29R and 11R-29L) will be restricted, thereby concentrating noise impacts along extended runway centerlines.

While adding a third, close parallel and a new north-south runway should make an important improvement to capacity under VFR rules, the closeness of the two northern parallels is such that they cannot both be used during IFR weather. In fact, current air traffic control procedures for triple approaches and converging runway approaches are essentially limited to VFR operations.

Implementation/Timing

Construction of a close parallel is not likely to occur in the immediate future, in large part because of the need to negotiate a new site for the U.S. Air Force and related operations and to reach an agreement concerning Fort Snelling Park. The noise implications of a triple runway operation during VFR weather will require some analysis and could create controversy. On balance, it appears unlikely that the new runways would be in place sooner than ten years.

Ultimate Case A

Description

Ultimate Case A 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). This new runway differs from Enhanced Case B primarily in that the new parallel is located 2,000 feet from the current northern parallel rather than just 700 feet away. (To achieve the IFR gains from independent parallel, it must be at least 920 feet from 11L-29R.

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 might need to be consolidated and/or relocated elsewhere at MSP or some other site or some combination.

Effect on Capacity

In contrast to Enhanced Case B, the two outboard runways would have a lateral separation of about 5,380 feet, thereby permitting independent IFR operations even if current FAA rules require a 4,300 foot separation are not relaxed. 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 offers an important advantage over Enhanced Case B 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.

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 an 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.

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. 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.

Unless stated otherwise, capacity estimates assume current FAA rules; that is independent operations are allowed on the parallel runways only under VFR conditions. Also, changes are expressed relative to the Base Case.

Findings and Policy Implications

A wide range of physical, technical, and operational changes for MSP have been presented here. An assessment of these alternatives is not easy and depends on several factors:

- the expected level of future demand for aviation services (total enplanements, annual operations and peak-hour operations). The focus heres is on peak-hour demand for aircraft operations.

- what is the desired level of service; how well and how much of the demand should be served.

Alternative traffic forecasts were presented in an earlier report.[10] While there are different ways to measure the level of service, the approach used in this study uses the probability of

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[10] Forecast Methodology and Findings, (May 1988), prepared for Metropolitan Council, MSP Airport Adequacy Study.

being able to meet the expected future demand. A low probabiliyt will result in a low quality of service. A high probability, however, runs the risk of over-investing 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.[11]

The costs of additional capacity are not insubstantial. Any decision about the level of aviation service that a community wishes to provide -- and thus about the related costs and benefits -- depends to a large degree on its view about the purpose of the airport. If the airport is viewed primarily as a tool to stimulate future economic growth, a relatively high level of service may be called for. However, if it is viewed as meeting the current needs of the community, less robust assurance may be all that is required.

The following two figures combine the baseline forecasts already reported with the capacity options discussed here.[12] That is, the numbers reflect not only each of the alternative runway layouts, but also the likelihood of future air traffic control improvements and the full range of variables that affect future demand. While the charts use expected IFR capacity estimates for each option, because the focus is on the year 2008 and 2018, the difference between these estimates and the VFR capacity numbers shown in Table 2 above are quite small.

Each figure shows the expected net capacity 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 shows 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.

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[11] The "Forecast" paper, for example, discusses the desirability of setting an 80 percent chance of meeting demand versus a 50 percent probability.

[12] 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.

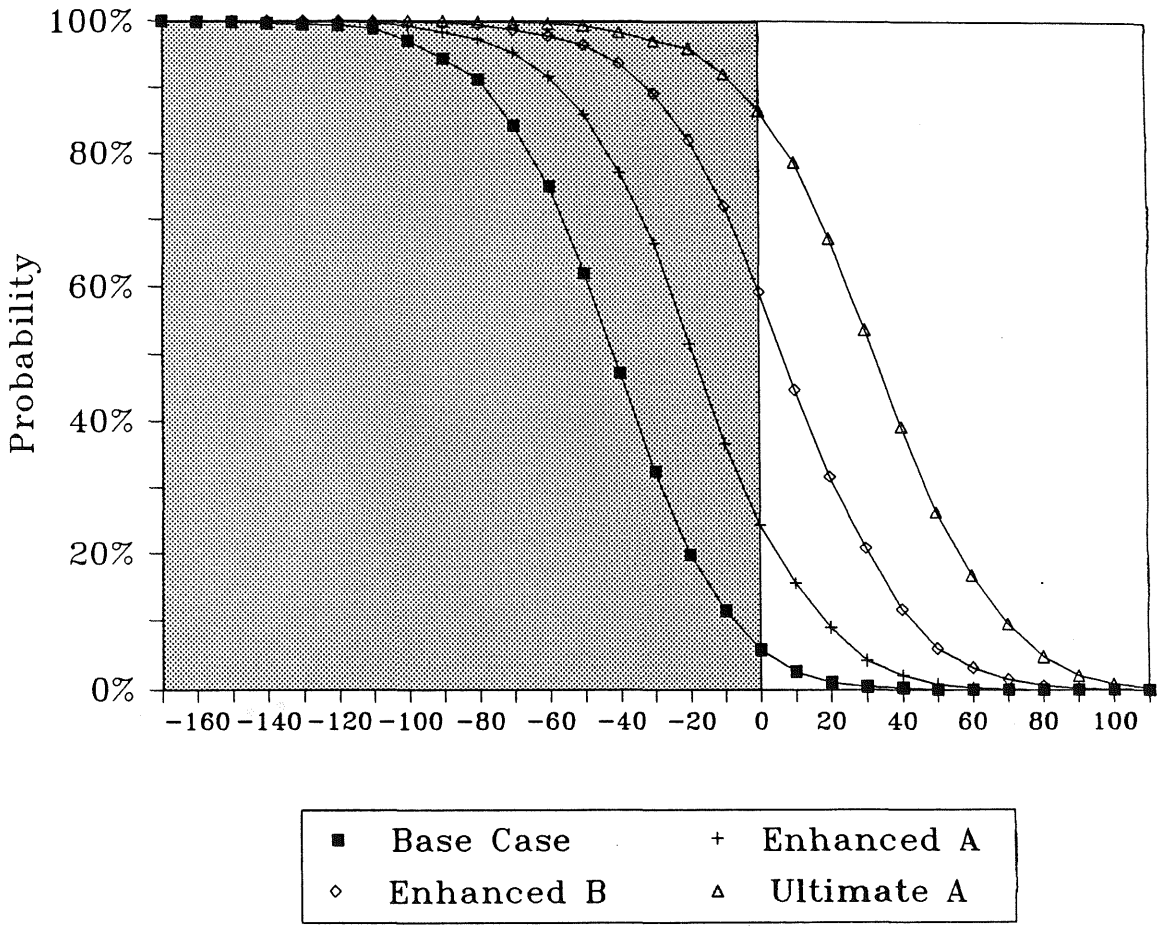
In the year 2008, the simulations show there is a 23 percent chance that Enhanced A (adding a North-South runway) will be adequate, roughly a 60 percent chance that Enhanced B will be adequate and a more than 85 percent chance for Ultimate A. Thus, if there were no costs attached to these choices, Ultimate A would be preferable to Enhanced B. Enhanced B, however, does represent a reasonable option.

By the year 2018, the choices are more limited. At this point (see second figure) Enhanced B offers only about a 20 percent chance of being able to meet expected demand, while Ultimate A shows an almost 45 percent probability of meeting demand. Our analysis indicates that Ultimate A probably represents close to the maximum operating capacity that can be achieved at the current site and within the Ring Road boundary.

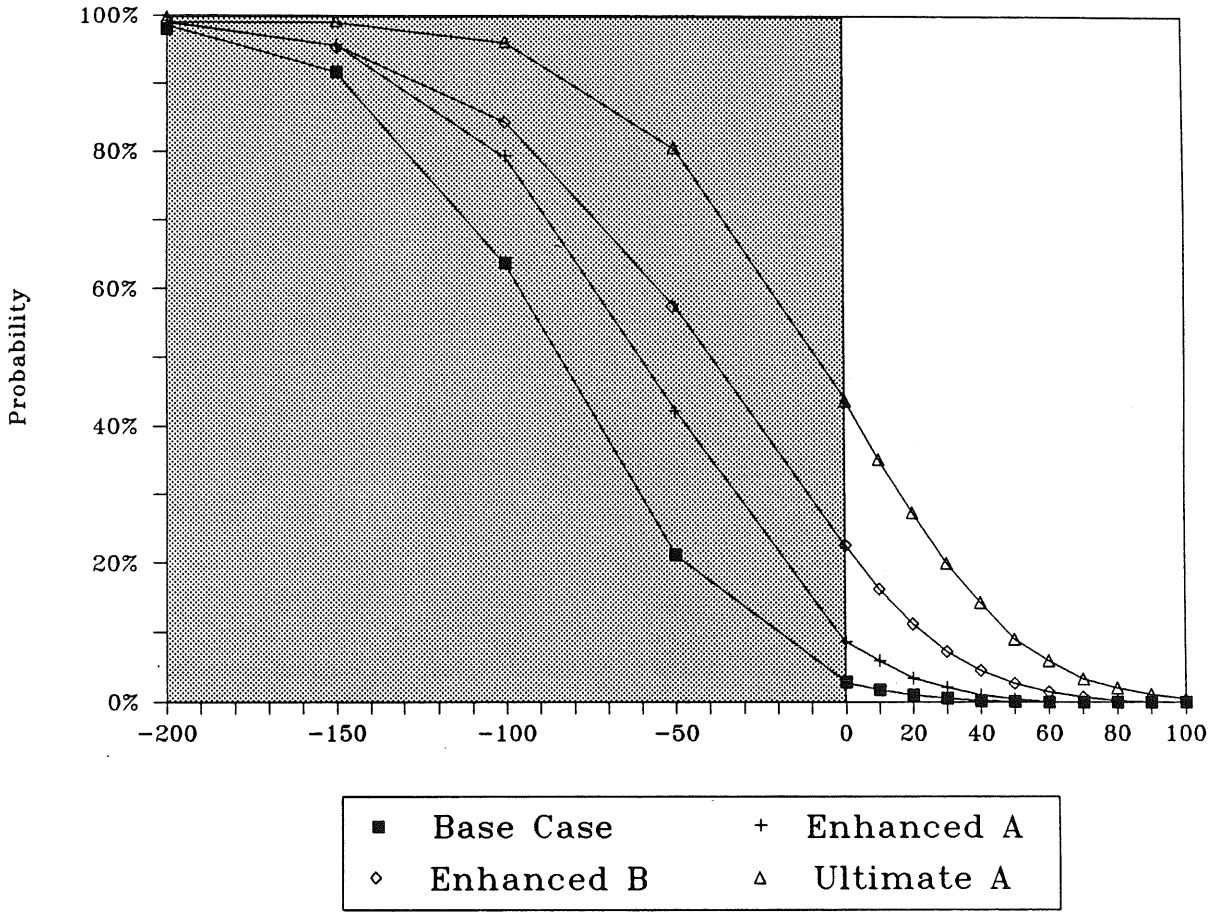
Of course there is no requirement that all the expected demand must be served. If inadequate capacity exists, as is the case for many airports today, airlines will shift traffic to other airports (often other, less congested hubs), traffic will be shifted to off-peak times (imposing longer travel times), and delays will increase. All these factors will impose a direct and indirect cost on the community.

The next step in the MSP Adequacy Study is to examine the expected costs and benefits of different levels of service. In sum, we will address the question of what does the community risk losing if capacity is inadequate?

Net Capacity Probabilities at MSP International (2008)



Net Capacity Probabilities at MSP International (2018)



APPENDIX A:
KEY DEFINITIONS

Parallel runways have the same directional alignment. The FAA considers runways separated by at least 4,300 feet to be capable of accommodating independent (simultaneous) operation during IFR conditions. The two parallels at MSP are separated by 3,380 feet. That is, each runway may be used independent of operations on the other. During VFR conditions, the lateral separation requirement for independent operations can, in theory, be reduced to 700 feet. Because of potential conflicts between arriving and departing aircraft, however, actual operations are often below what is technically allowed by the FAA except when separation are much greater. Runway operations which are not independent are categorized as dependent. That is, use on one runway depends on the activity being conducted on the other. For example, the takeoff clearance may be withheld until an aircraft had assured a safe landing on the other runway and would therefore pose no threat to the aircraft awaiting its takeoff clearance.

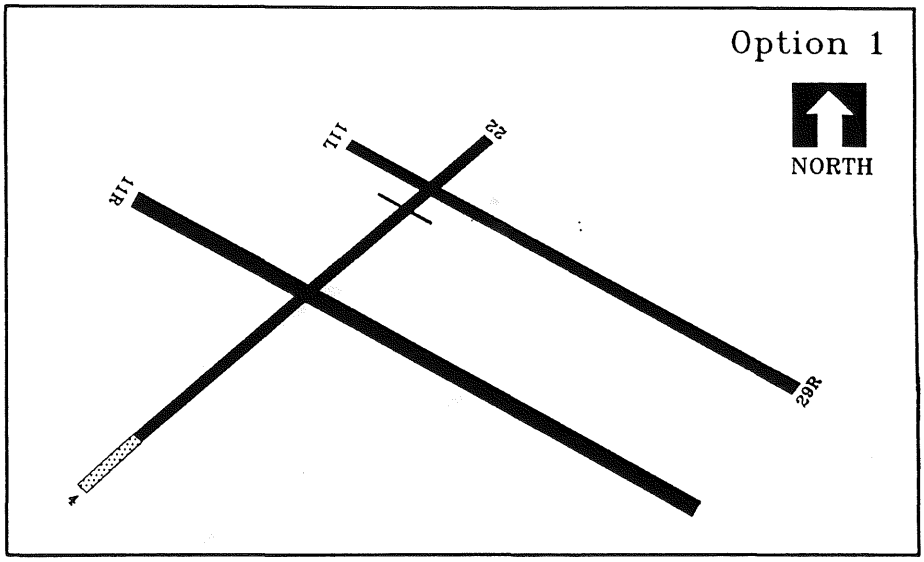
Crosswind runways are constructed to facilitate operations when surface wind conditions exceed safe limits on the primary runway. Thus, crosswind runways are always at an angle to the primary runway. At MSP, crosswind conditions pre-dominate only about 6 percent of the time.

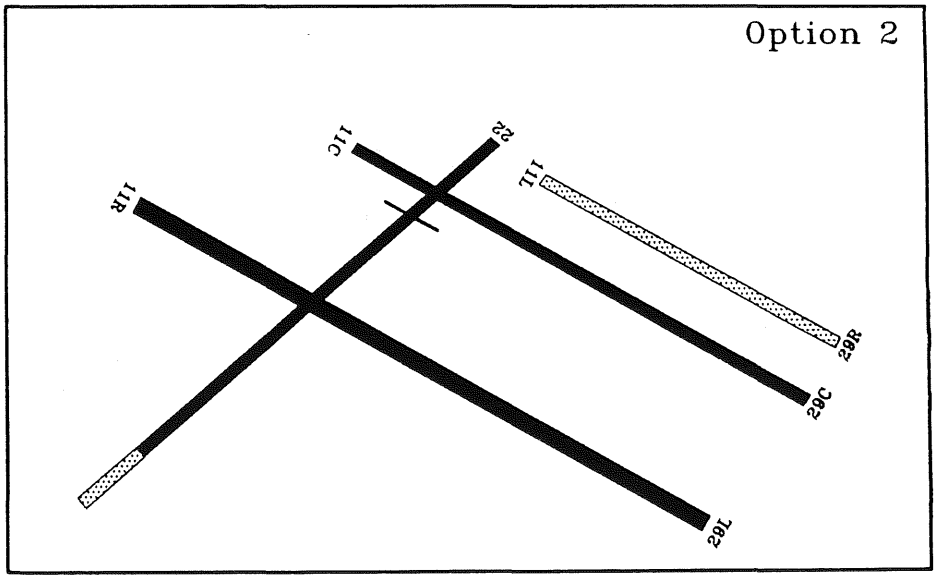
Approaches to both primary and crosswind runways may be termed converging when aircraft headings intersect either in their approach paths, on the airfield pavement, or along their missed approach paths. Based on where this potential intersection occurs, converging runways may be categorized as either independent or dependent. During converging approaches, controllers must provide a greater margin for error in setting aircraft separations. Current FAA air traffic control procedures restrict converging approaches to what are essentially VFR conditions.

In the analysis that follows, capacity levels have been identified for mixed operations. This implies that each runway is utilized equally for arrivals and departures. Because of hubbing, however, most peak periods at MSP have 60 percent of the traffic in one direction (arrivals or departures). As a result of the current MSP airfield configuration and air traffic control procedures, capacities are reduced when 60 percent of peak-period operations are arrivals -- this reduction can be as great as 20 percent. This is largely due to separation standards during approaches. Conversely, separation requirements are reduced during departures, so that capacity is higher when 60 percent of the operations are departures. The variances between mixed and

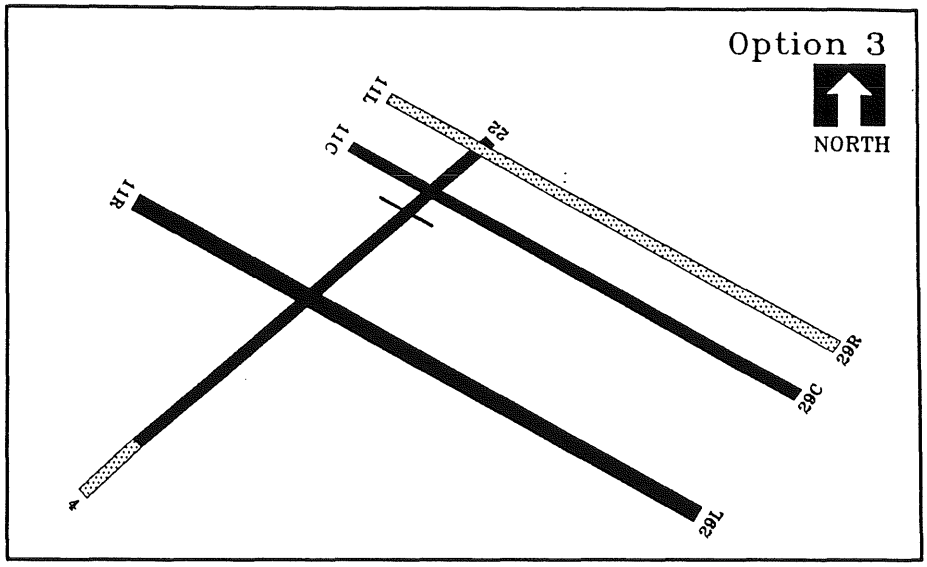
arrival or departure peaking is more pronounced during IFR than VFR conditions. In order to limit the number of options presented, the capacity estimates presented here are for mixed (50-50) operations only.

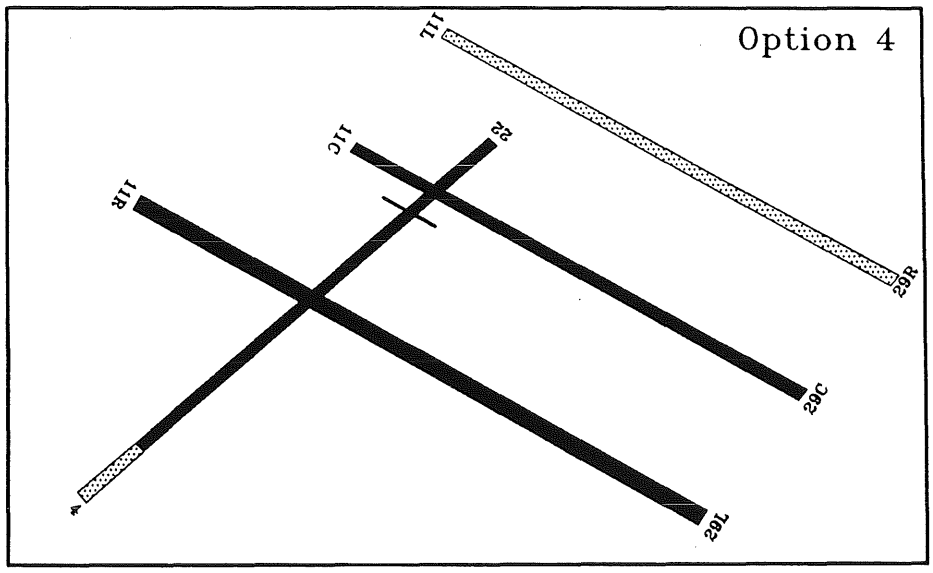
Other Runway Options Considered at MSP International



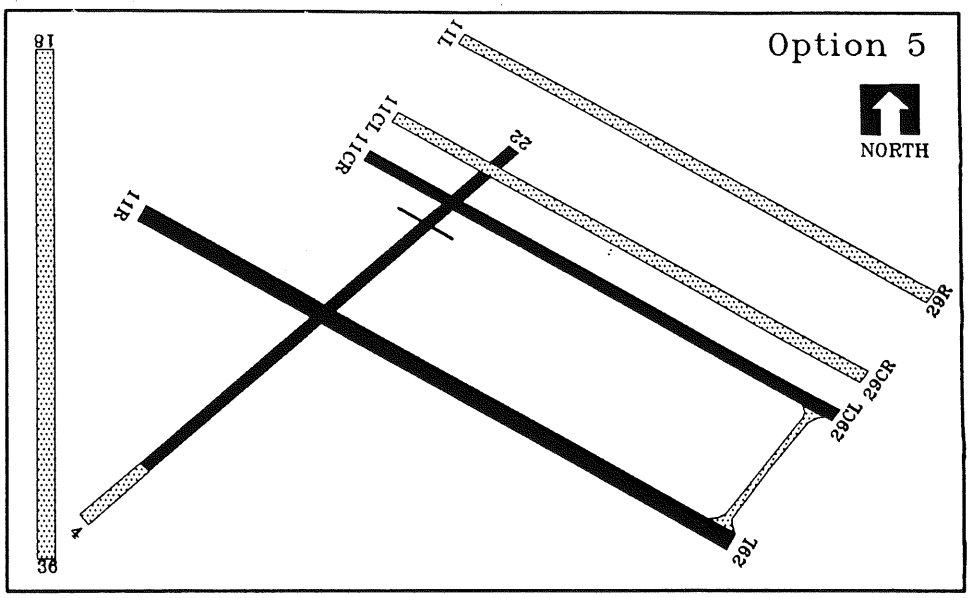


Other Runway Options Considered at MSP International (Cont'd)





Other Runway Options Considered at MSP International (Cont'd)



APPENDIX C:AIR TRAFFIC CONTROL PROCEDURAL MODIFICATIONS

Air Traffic Control procedures and equipment are continually changing to keep up with greater demand and technological advancements. This section describes those modifications that can be reasonably expected to occur in the forecast period, their impact on operations, and likelihood. Each is compared to the Base Case, or the "no change" alternative.

Introduction

Over time, major improvements in the efficiency of airspace control procedures can have a direct impact on airside capacity. To a large extent, such improvements will stem from the development and deployment of new equipment and systems for terminal areas. The Table lists key procedural improvements and related equipment and system requirements.

The Federal Aviation Administration has conducted a number of capacity task forces at individual airports and simulated a range of improvements using its Airfield Capacity Model and Runway Capacity Model. The FAA also estimates the capacity improvements possible with various procedures and technologies on the basis of research prepared by others. Using these data, the FAA has published average percentage changes for a range of procedural options.[13] Although care was exercised to ensure that IFR capacity is never allowed to exceed each site's original or VFR capacity, the figures -- shown in Table 2 -- can only be used as a very rough guide to possibilities at MSP. Actual results at MSP will depend upon traffic mix, runway occupancy times and so on. The figures do provide a useful summary of recent analytic studies.

The FAA has also analyzed the applicability of various ATC procedure improvements at individual airports. According to the FAA's 1987 Airport Capacity Enhancement Plan, terminal ATC automation and independent close-parallel IFR approaches are the most likely to apply at MSP. For example, reduced longitudinal separation was not judged applicable under the existing airside layout since runway occupancy times are too long to permit reduced longitudinal separation. However, reduced longitudinal separation is likely to be applicable under certain approach configurations and under some of the airside expansion options under consideration in this study.

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[13] See, Federal Aviation Administration, Airport Capacity Enhancement Plan, 1987.

Table 1: Improved Airspace Control Procedures and Related Improvements in Equipment and Systems

Improved Airspace Control Procedures	Additional Equipment and System Requirements
Simultaneous IFR Approaches to Converging Runways	Microwave Landing System (MLS)
Improved Independent Parallel IFR Approaches	Instrument Landing System (ILS)
Improved Dependent Parallel IFR Approaches	Next Generation Weather Radars
Triple IFR Approaches	Wind Measuring Equipment (LLWAS)
Improved IFR Longitudinal Separation Standards	Weather Sensor Development
	RVR Establish/Upgrade
	Wind Shear Detection
	Wake Vortex Avoidance and Forecasting
	Departure Flow Metering
	Upgrade Arrivals/Demand Algorithms
	Automated Airport Capacity Calculations
	Terminal Radar Enhancements
	Airport Surface Detection Equipment (ASDE-3)
	Mode S Data Link Applications Development
	Runway Configuration Management System
	Terminal ATC Automation

Table 2:
Effect of Projects on IFR Hourly Capacity

Project Capacity	Percent Change in IFR
Reduced Longitudinal Separation	3
Terminal ATC Automation	8
Simultaneous IFR Converging Approaches	100
Independent Close-Parallel IFR Approaches	39
Dependent Close-Parallel IFR Approaches	39

Source: Federal Aviation Administration, Airport Capacity Enhancement Plan, 1987.

The key questions in conducting the MSP adequacy study are;

- o **When** can capacity improvements through enhanced procedures and equipment be expected come about? and
- o **How much** additional capacity can be expected?

These questions are addressed next assuming the existing airside configuration.

INDEPENDENT PARALLEL APPROACHES

Description

Reduction in lateral separation standard from 4300 feet to around 3000 feet.

How the Factor Affects Traffic

The arrival separation values specified by the ATC handbook are as follows:

- o 3-nmi radar separation requirement and 4, 5 and 6-nmi wake vortex separations between aircraft on the same approach;
- o 2-nmi diagonal between aircraft on adjacent approaches for runways spaced 2500 to 4200 ft. This is rule applying today at MSP.

Capacity will increase if the required lateral separation between aircraft on parallel runways is decreased, removing the stagger between aircraft and allowing independent parallel operations.

Forecast of Timing and Availability

A number of factors will influence the timing and availability of independent parallel over dependent parallel operations. Currently, FAA regulations require parallel runways spaced between 2500 and 4299 ft. in order to operate as dependent parallels under IFR conditions. The FAA is exploring the possibility of changing the specifications to about 3000 ft. for independent IFR parallel operations. Two technologies, now in the research and development phase, could permit smaller separation requirements. One is back-to-back Mode S Radar which has a 2 second update rate (double the current rate) and higher accuracy. The other is a TCAS-like radar antenna which would update every second. As reflected in Table 3, there is a great deal of uncertainty about the near or medium-term availability of either technology. Interviews with FAA officials suggest that at least three years stands between state of the art radar and the hardware/software requirements of close parallel operations; and a further 7-8 years before individual sites can expect installation of the equipment. These estimates are reflected in Table 3 which suggests the turn of the century before the probability of close parallels at MSP approaches 75 or 80 percent.

Baseline Capacity Forecasts and Their Sources

The baseline forecasts reflect FAA and Mitre Corp. estimates of about 39 percent additional hourly capacity at MSP in moving to independent parallels over dependent parallels. This value is not unlike results from simulation experiments at other airports and has been chosen to reflect the expected outcome following a five year learning curve (Table 4).

Major Uncertainties

The major uncertainties associated with these baseline forecasts occur in two categories: controller and pilot acceptance on the one hand and political acceptance. If the controllers and/or the pilots are not willing to take full advantage of the opportunities for increased capacity then the forecasted values could be too high. Political acceptance could also play a part in reducing possible capacity increases. If the new procedures are perceived to increase noise or reduce safety to politically unacceptable levels, then there may be barriers to achieving the full capacity potential of IFR independent parallel operations.

The lower 10 percent limits are further from the projected expected outcome to indicate a skewness towards the improvements being lower rather than higher than the expected outcome. The limits decrease over time to indicate increased certainty in achieving the mean. The upper 10% limit is constrained by the present VFR capacity.

Table 3: Availability of IFR Capacity Improvements Due to Independent Parallel Approaches

Percent Probability of Availability

MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
1993	0	0	0
1998	10	0	30
2003	40	0	70
2008	80	50	85
2018	99	80	100

Table 4: IFR Capacity Improvements Due to Independent Parallel Approaches

PERCENT IMPROVEMENT IN HOURLY OPERATIONS

Five Year Learning Curve	Expected Outcome	Lower 10%	Upper 10%
t	7	2	10
2	12	6	16
3	16	9	22
4	33	23	39
5	39	30	44

t = First Year of Availability

Note: The current IFR capacity upon which these increases are based is 71 operations/hour which is the arrival peak (60%).

TERMINAL ATC AUTOMATION

Description

This represents a group of projects (included in Table 2, but excluding MLS) designed to improve the performance of air traffic controllers and pilots and in so doing improve the rate at which aircraft operation can occur under IFR conditions (some VFR improvements are also envisaged, though considerably smaller).

How the Factor Affects Traffic

Improved performance stems from reductions in the size and variability of aircraft separations from the metering fix to the runway threshold.

Forecasts of Timing and Availability

Under the National Airspace System Plan, terminal ATC automation is not expected to be operational until the mid-1990s. This is reflected in Table 5 which also reflects the judgement that availability is more likely to be later than expected than earlier.

Baseline Capacity Forecasts and Their Sources

As shown in Table 2, the FAA forecasts an 8 percent improvement in IFR hourly capacity as a result of terminal automation. Other estimates of the impact of improved inter-arrival variability are in the 12-16 percent range The estimates given in Table 6 assume an expected outcome of 8 percent at MSP, the lower of the various available estimates.

Major Uncertainties

Full implementation and impact is heavily dependent upon controller and pilot skill levels and acceptance. The 10 percent limits given in Table 6 reflect a slow learning and acceptance curve and, in the initial years, a greater likelihood of falling beneath the expected outcome.

Table 5:
Availability of Full Terminal ATC Automation

MSP Forecast Years	PERCENT PROBABILITY OF AVAILABILITY Expected Outcome	Lower 10%	Upper 10%
1993	0	0	0
1998	50	30	60
2003	75	65	80
2008	90	80	95
2018	95	90	99

Table 6: IFR Capacity Improvements Due to Full ATC Terminal Automation

PERCENT IMPROVEMENT IN HOURLY OPERATIONS

5-Year Learning Curve	Expected Outcome	Lower 10%	Upper 10%
t	1	0	0
2	3	1.5	4.0
3	4	2	5
4	6	4	8
5	8	4	12

t = First Year of Availability

Table 7:
Availability of Fully Operational MLS

PER CENT PROBABILITY OF AVAILABILITY

MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
1993	40	20	60
1998	95	85	100
2003	100	100	100
2008	100	100	100
2018	100	100	100

Table 8: Increased IFR Capacity Due to Fully Operational MLS

PER CENT IMPROVEMENT IN HOURLY OPERATIONS

MSP Forecast Years	Expected Outcome	Lower 10%	Upper 10%
t	1	0	1.5
2	2	0.5	3
3	3	0.5	4.5
4	6	3	8
5	7	4	9

t = First Year of Availability

MICROWAVE LANDING SYSTEM

Description

Next generation precision landing system.

How the Factor Affects Traffic

Because MLS uses a beam that scans a wide volume of airspace, rather than the pencil beam of ILS, in theory it permits aircraft to fly any of several approach angles (including two-step glide slopes) and, in the horizontal plane, to approach along curving paths that intersect the extension of the runway centerline at any chosen point. In effect, MLS offers a degree of freedom in using the airspace that is closer to that enjoyed under conditions of good visibility.

Forecasts of Timing and Availability

According to preliminary investigations and conversations with the FAA, five MLSs are to be installed at MSP with two years. Use of the system will take substantially more time however since aircraft will equip with the associated avionics at a slower -- and very uncertain -- rate. Since the ICAO deadline for fully operational MLS is 1998, many observers do not foresee its broad application until that time. This view is reflected in Table 7.

Baseline Forecasts

According to the Office of Technology Assessment, estimates by the FAA indicate that the gains could range up to 10-15 percent at some airports under IFR conditions. No estimates specific to MSP are available and we have treated the 15 percent as an upper limit. The baseline forecast has been taken at one half that level with a five year learning curve after full MLS implementation (see Table 8).

Major Uncertainties

The chief motive for FAA in seeking to develop and deploy MLS is not the potential capacity benefits but rather operational advantages. These include more precise guidance, ease of installation, improved reliability, less susceptibility to electro-magnetic interference and greater number of transmission channels. The capacity benefits are secondary and highly dependent upon controller and pilot acceptance of radically new procedures. Since theoretical limits are rarely achieved even under current conditions, many believe that the capacity gains from MLS may be smaller than theoretical estimates suggest. The

ranges given in Table 8 thus suggest a greater likelihood of lower rather than higher results compared with the baseline forecast.

Further preliminary analysis of the prospective capacity impacts of MLS at MSP is presented in the appendix to this report.

Potential Flight Path Savings Using MLS at MSP

This section reviews the major elements that must be considered in estimating the possible gains from using MLS at Minneapolis. The estimate represent preliminary results only.

GENERAL

Radar Guidance

Aircraft are provided standard instrument arrivals into the Minneapolis airport by the en route controllers. Radar vectors are issued to the pilot by the approach controller to bring the aircraft to the best point for initiating the approach. This point is optimized for each approach. That is, for an ILS approach it will be the best point for commencing the ILS navigation; for an MLS approach it will be a different point, optimize for best use of MLS navigation.

Arrival Direction

Arrival directions are divided into three main categories. Arrivals from a direction leading straight in to the runway can be vectored for a "straight-in" approach using either ILS or MLS. For this analysis, arrivals from within plus or minus 30 degrees of the runway heading are considered straight-in. Arrivals from the opposite direction are referred to as "opposite direction" arrivals. The remaining arrivals will range in direction from just outside the straight-in cone through 90 degrees to the runway heading to just outside the opposite direction cone.

The estimates for MSP assume that arrivals are distributed as follows: 10 percent are straight-in, 10 percent are opposite direction and 80 percent are 90-degree arrivals.

Ground Speed

Aircraft ground speed varies considerably according to aircraft type, with the greatest variation in the earlier portions of an approach. Estimates of average ground speed used here are 200 knots on the downwind leg, reducing in stages to 140 knots on final approach. These figures are biased somewhat toward the higher speeds and thus would be representative of

larger air carrier aircraft for which most of the benefits would be gained.

Minneapolis Terminal Environment

ILS Procedures

Straight-In

Aircraft arriving from within the straight-in cone will be vectored directly onto final approach with little or no maneuvering.

90- Degree Arrival

Arrivals in this zone will normally be radar vectored to final by a series of maneuvers whose dimensions are critical to an analysis of MLS. For consistency, a radar vectoring aim point 5 n.m. laterally from the approach center line will be assumed for both ILS and MLS. Analysis commences at the threshold and works backward to establish the longitudinal location of the radar vectoring point, the length of the flight path and the time required to cover that distance.

The total time for a radar/ILS 90-degree procedure is estimated to require 6.3 minutes.

Aircraft being vectored to the ILS from the forward quadrant, meaning those arriving from between 30 degrees and 90 degrees from approach heading, would not necessarily all be vectored through the same aim point. Rather, they would be vectored to join the routing at the most convenient point in each case.

Opposite Direction

Opposite direction traffic was analyzed from a point opposite the runway threshold to arrival over the threshold, maintaining a distance of 5 n.m. laterally from the approach center line. The procedure follows a pattern similar to the 90-degree pattern on the final portions of the 90-degree arrival.

Total time for a radar/ILS opposite direction procedure is estimated to require 9.7 minutes.

MLS Procedures

Straight-In

Radar vectors will bring the aircraft straight in on an MLS approach exactly as in the ILS approach. Flight paths and time will be the same.

90-degree Arrival

As in the ILS case, radar vectors will guide the aircraft to

the optimum position from which it can commence the MLS procedure. In this case, the procedure is assumed to follow a curved path from an arrival vector at 90 degrees to the final, 5 n.m. laterally from the approach path and at the optimum longitudinal distance from threshold.

Total time for the radar/MLS 90-degree procedure is estimated at 3.7 minutes.

Opposite Direction

Opposite direction arrivals on MLS will normally carry out a 180-degree curved approach. Glide path will be intercepted before commencing the curved leg, so the entire curved and final portions will be flown at final approach speed.

Total time for the radar/MLS opposite direction procedure is estimated at 5.2 minutes.

Flight Path Time Savings

Straight-In

Flight paths will be identical for ILS and MLS. Time savings will be zero.

90-degree Arrival

Time saving will be: 6.3 - 3.7 = 2.6 minutes

Opposite Direction

Time saving will be: 9.7 - 5.2 = 4.5 minutes

Total

Weighting these estimates according to traffic direction, total time savings would be:

Straight-In	0.00
90 degree	2.6 x .80 = 2.08
Opposite Direction	4.5 x .10 = 0.45
Total, weighted, is:	2.53 minutes

Conclusions

The theoretical hourly instrument rate for Minneapolis airport is stated as 85 per hour. If we assume that half, or 42.5, of these are arriving aircraft, then an aircraft will be arriving on dependent parallel runways every 2.8 minutes, or every 7.3 miles in trail on runway 11 and 29. Based on the above analysis, 42.5 times 2.53, or 107.5 minutes of flying time are saved. If arrival spacing is maintained at 7 miles in trail and 50 per cent of the flying time saved is available for arrivals

then 19.1 arrivals can be added with the implementation of MLS.

This amounts to a 45 per cent increase in arrivals with the addition of MLS and a total increase of 22 percent.

Some analysts argue that an instrument rate of 85 per hour may be optimistic for Minneapolis and that a more realistic rate may be as low as 60 an hour, with about 35 being arrivals. Under these conditions, aircraft will be arriving every 3.4 minutes or every 9 miles in trail on runway 11 and 29. Using these numbers the savings would represent 91 minutes of flying time. If arrival spacing is maintained at 9 miles in trail and 50 per cent of the flying time saved is usable for arrivals then 13.4 arrivals can be added with the implementation of MLS. This amounts to a 38 per cent increase in arrivals with the addition of MLS.

The exact amount of increase will be determined by the ability of the flight crews and the air traffic controllers to make effective use of the flying time saved by using MLS. Since most estimates of MLS productivity indicate a maximum increase of 15 per cent then it seems unreasonable to expect Minneapolis to achieve the 38 per cent increase. On balance, it is likely that Minneapolis airport arrival capacity could be increased by 10 arrivals per hour when both runways have MLS and are available for landing.

APPENDIX D: DEMAND MANAGEMENT TECHNIQUES

The two sets of options discussed so far focus on improving the physical capacity of MSP either through greater runway capacity or relaxed air traffic control procedures. A third approach -- called demand management -- requires no physical modification to the existing airside configuration. Rather, they 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 capacity. All three approaches have the same end goal, however, to reduce the expected gap between capacity and peak-period demand.

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.

LIMIT GENERAL AVIATION ACTIVITY AT MSP

Description

Typically, the term general aviation (GA) applies to small private planes and includes a wide variety of aircraft from corporate multi-engine jet aircraft to single-engine piston aircraft built by amateurs. Technically, GA includes all civil aircraft except air carrier aircraft certified in accordance with FAR Parts 121, 123, 127, and 135.

How the Variable Affects Capacity

General aviation aircraft currently represent more than 18 percent of all operations at MSP. Due to the required separations for landings and takeoffs, the variety of GA planes places operational constraints on the use of terminal airspace and airport facilities. Restricting the availability of MSP facilities to the relatively large and faster air carrier and regional carrier aircraft would have the immediate benefit of increasing the number of commercial service passenger aircraft without requiring any additions to existing facilities.

In the short term, eliminating all GA operations at MSP could allow other aircraft operations to increase by as much as

25 percent. Because of the much higher number of passengers in commercial aircraft, the number of travelers able to use MSP would increase by much more than the number of operations. This improvement in capacity would probably not be concentrated at peak times of day.

Baseline Assumptions

Operations by GA at MSP aircraft are expected to drop precipitously over the period through 2008, from 18.1 percent of total operations in 1986 to 3.8 percent in 2008. This is substantially below the lowest levels found at major U.S. airports today. The annual number of GA operations would decline from 71,000 today to 22,000 by 2008. Remaining general aviation operations at MSP are projected to be almost exclusively corporate business jets.

The data sheet assumes takes 70 percent of GA traffic as a target for shifting to other airports or to off-peak times of day at MSP. The distribution is strongly skewed toward lower numbers based on the difficult history that such efforts have had in the past.

Major Uncertainties

Key questions concern whether or not this dramatic decline in GA traffic will actually occur. What role can regulations and/or landing fees have in speeding up this trend or ensuring that it takes place?

Historical data indicate that small aircraft use of major airports declines as capacity becomes constrained (as delays increase) and as the number of larger, heavier aircraft increase. These two forces provide a "natural" incentive to use less-crowded reliever facilities and other general aviation airports. The current low end of this trend is about 10 percent of operations at major congested airports such as La Guardia.

The HNTB forecast for MSP surpasses this trend in predicting a considerable decline in the number of GA operations at MSP. FAA forecasts, in contrast, suggest a very slow increase nationwide. This implies a dramatic shifting of GA demand at MSP to outlying airports. Is this shift realistic without other incentives?

In restricting GA aircraft from access -- whether this occurs "naturally" or due to regulations -- considerable attention should be paid to the needs of so called corporate

jets. Otherwise there may be an unintended affect of reducing the attractiveness of the Twin Cities region to business. (The National Business Aircraft Association adamantly opposes these restrictions).

Reliever airports may require additional facilities to accommodate higher levels of general aviation activity. In addition to airport improvements, land access to regional business centers must usually be improved. Further, the environmental impacts associated with such actions may be unacceptable to area residents.

The timing of any restrictions could be critical, since it will not be for some time that such restriction would be necessary.

RESTRAINTS ON REGIONAL CARRIER ACTIVITY

Description

Regional carriers is a broad term that includes air taxis, commuter carriers as well as local airlines that operate larger aircraft -- sometimes up to 100 seats. They provide the feeder service to the major airlines from smaller, less trafficked airports. They are by far the fastest growing class of aircraft at MSP and could account for more than 40 percent of total operations by the year 2008. Even though their aircraft are smaller, regionals can place demands similar to those of air carrier aircraft on an airport. Because they provide feeder service, there is considerable interest in coordinating the schedule of reliever carriers with those of the hub airline.

One option would be to designate a reliever airport--perhaps the new reliever that will be located to the Northwest of Minneapolis -- for the exclusive use of regional traffic. Such a facility would require greatly improved ground access both to the major business centers in the Twin Cities area and to MSP for connections to longer distance flights.

How the Variable Affects Capacity

Regional carrier operations currently comprise nearly 20 percent of all aircraft operations at MSP. Encouraging regionals to land at one of the area's reliever airports could, therefore, increase the capacity of MSP for air carrier aircraft operations by up to 20 percent today and even more in the future. Much as it is for GA aircraft, the required separations for landings and

takeoffs can place nearly the same requirements on the terminal airspace and airport facilities. Encouraging the use of reliever facilities by these aircraft could, therefore, free up capacity for aircraft with higher passenger capacities.

Baseline Assumptions

Due to the increased use of "code-sharing" agreements, or contractual agreements between regionals and major air carriers, the number of regional carrier flights is expected to increase rapidly. Regional carrier operations as a percent of all operations at MSP are, therefore, forecast to rise from its current level of 19.5 percent to 41.5 percent in 2008. This tremendous growth could, by itself, determine the capacity additions needed at MSP and perhaps even the question of whether or not a new airport is needed.

The estimates shown in the attached table take slightly less than one half of all regional carrier operations as a target for shifting to off-peak periods at MSP. As with general aviation, this distribution is strongly skewed toward lower levels, reflecting some skepticism about the ability to implement such a plan.

Major Uncertainties

Some considerations are as follows:

- The ability to reduce regional airline service would be determined in part by the availability of alternative transportation to MSP to make connecting flights and, if available, the time requirements of transfers.

Not all regional airline service to MSP involves passengers transferring to connecting flights -- many are starting or ending their travel in the Twin Cities. Shifting only these passengers to a new site would cause much less inconvenience. However, is the volume of this origin and destination traffic enough to justify non-connecting flights that could provide service to and from one of the relievers. At present, the market does not appear to be large enough to justify creating such dedicated flights. If, however, regional traffic grows to beyond 4 million passengers a year as shown in the most recent MAC forecast, traffic volumes may be large enough to justify such exclusive service between certain city pairs.

Forcing all regional service away from MSP would effectively reduce the accessibility to and from communities served solely by

regional carriers. The negative economic effects on these communities could be significant.

VARIABLE LANDING FEES

Description

A commonly considered alternative for reducing aircraft activity levels, particularly during peak travel times, is a variable landing fee. Higher landing fees typically affect smaller aircraft such as general aviation aircraft and air taxis most directly. If these higher fees are focused on peak periods hours, the net effect is to encourage smaller aircraft to use other airports or shift operations to off-peak periods. Some form of peak period fees are in use at the three New York airports, Miami and Boston as well as European airports. Boston's Logan Airport has a controversial proposal to greatly expand its fee structure.

Fees need not be very large for an impact to be seen. Differential landing fees of under $50 had a significant effect at the three New York airports in the late 1960s and still serve to keep almost all GA traffic except for corporate jets away.

How the Variable Affects Capacity

While the degree to which variable landing fees will affect capacity varies depending on the nature of demand, and how the fees are imposed. Some estimate of the potential benefit can be estimated by comparison to a similar situation at Boston's Logan Airport. As proposed by the Massachusetts Port Authority, variable landing fees are expected to reduce aircraft operations by 5 percent. Because Logan is already capacity-constrained, the estimated benefit is considerable, reducing delays by 80 percent for most of Logan's passengers. Similar effects were found at La Guardia in the late 1960s.

No such peak period fees are in use at MSP.

The capacity gains could be substantial, in the extreme, even approaching the effects of the two previous options. The numbers shown in the attached table represent a rough average of the gains from the two previous options.

Major Uncertainties

Variable landing fees have traditionally met with considerable opposition on the part of small aircraft owners. Consequently, Logan's plan for increased fees -- in addition to the existing peak-period landing fee -- was released two months late in order to "perfect its legal position."

As with the previous two demand management options, a key question is whether or not the benefits from reduced peak-period delays are seen as offsetting the reduced service that smaller communities and users of general aviation are likely to receive

These fees, however, can be quit flexible, with adjustments made according to shifts in demand and the level of net capacity that exists at any time. For example, fees might be reduced after a new runway addition or major change to air traffic control rules. Fees can also be used as a source of revenues in order to help add new capacity. Proposals have been made to use peak-period fees as "cross-subsidies" to reduce costs for airport users who shift to off-peak periods. Thus, the same fee schedule could provide a "double" incentive, allowing air taxi operator's, for example, to offer reduced fares as one means of offsetting the greater inconvenience.

Variable fees, if structured properly, are also one way to assign scarce peak-period capacity to those travelers who receive the greatest benefit from travelling at that time.

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Reuse Potential of MSP

Alternative Land Use Panel

Report

May 19, 1988

Metropolitan Council of the Twin Cities Area
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DATE: May 19, 1988

TO: MSP Adequacy Study Task Force

FROM: John Kari

SUBJECT: Report of Alternative Land Use Panel

Introduction

On April 15, 1988 at the Scanticon Executive Conference Center a thirty-member panel was convened to generate ideas and provide advice on the reuse potential of MSP International Airport. The panel members came from varied professional backgrounds: suburban and urban real-estate development, market research, architecture, urban design, aviation and land transportation, land use law, community development, land use planning, technology/communications and development finance. The panelists also had a broad range of experiences in the development/redevelopment of the Twin Cities Metropolitan Area.

The results of this one-day panel discussion need to be viewed as a first step, an initial broad brush examination of the reuse potential of MSP. More detailed study will certainly be required, but the advice of panel will be very valuable in setting study parameters, guidelines, and assumptions.

The alternative land use panel was jointly sponsored by the Metropolitan Council and the Minnesota Society-American Institute of Architects.

MSP Adequacy Study

The Metropolitan Council is involved in a major study concerning the long-term adequacy of Minneapolis-St. Paul International (MSP) Airport. The study is designed to answer two broad questions. First, what is going to be the demand for air transportation service over the next 30 years. And second, what airport capacity will be required to meet that demand. The study is also designed to help the Metropolitan Council, the Legislature and the citizens of the Region make judgements, decisions and tradeoffs concerning the long term adequacy of MSP.

The adequacy study will examine four options to improve airport and terminal airspace capacity. These range from revised operational procedures to major capital investments including a possible new replacement airport. In some cases, these options are limited by FAA regulations or concerns for safety as with the ability to handle simultaneous aircraft operations on the parallel runways. Other choices, such as adding new runways and taxiways may be constrained by concerns for noise impacts or by the limited size of the current airport site. The possibility of a major new airport depends on the level of demand, how much demand the region wants to meet, the ease with which that large undertaking could be financed, and on the availability of a new site reasonably close to existing business centers.

At present, the study is focusing on four airport development options:

- o Base Case - current programmed improvement
- o Enhanced Existing - ten-year perspective
- o Ultimate Development - Maximum site development within the highway ringroad.
- o New Replacement Airport - A paper airport embodying state-of-the-art airport design, a non-site specific development option.

Each alternative includes a range of possible assumptions regarding demand management techniques and options for reliever airport development.

The Alternative Land Use Panel Assignment

The potential reuse of MSP is an integral part of the financial and cost implications of either enhancing airport capacity at MSP or the development of a replacement airport. Either general option presents costs and benefits for the Twin Cities Metropolitan Area and for the immediately adjacent residential communities and the commercial-industrial developments along the I-494 freeway corridor. The alternative land use scenarios developed as a part of the panel's work will help delineate specific costs and benefits of different actions.

The panel had the following objectives:

(1) To identify development opportunities, constraints and incentives which may influence the reuse of the 3,000-acre site.

(2) To identify the market potential of the site and to suggest phasing strategies for the redevelopment/reuse.

(3) To identify governance issues and a preferred governance structure.

(4) To develop several alternative land use scenarios which would generate revenue to be used to assist in the financing of a new airport and mitigate to the extent possible adverse economic impacts on adjacent.

The panel was also given the following land use assumptions:

(1) The site will not be available for reuse until after the year 2000.

(2) Potential locations for a replacement airport have not been identified; therefore, the reuse scenarios need to consider the potential impact if the replacement airport is south or north of the current site.

(3) Evidence to date shows that the region can only support one major airport therefore, it must be assumed the replacement airport will perform that function. The aviation use of MSP, if there is any at all, will be limited to corporate and general aviation similar to downtown St. Paul.

(4) The governing structure is an open question; there are a range of possibilities from incorporation with the adjacent municipalities to the establishment of an independent development district. There are a number of existing land owners and legal stipulations on certain parcels. -The resolution of these intergovernmental and ownership issues should be facilitated by a plan and regional consensus on the comprehensive reuse of the site.

Panel Advice

The panel's advice on the reuse of MSP is contained in the following seven sections. Each section is a distillation of the discussion and ideas generated in the brainstorming and scenario developing sessions.

Section 1:	Overview: National Perspective "Urban Development in the 21st Century" Dr. Royce Hanson, Dean School of Social Sciences The University of Texas at Dallas
Section 2:	Reuse Principles and Guidelines
Section 3:	Constraints
Section 4:	Governance
Section 5:	Market Potential/Development Opportunities
Section 6:	Reuse Scenario 1 "Central Airport Passenger Terminal"
Section 7:	Reuse Scenario 2 "Regional Development District"

The appendix contains background materials used by the panel.

Section 1: OVERVIEW: NATIONAL PERSPECTIVES

The potential reuse of MSP needs to be examined in light of national and international urban development trends. Where will the Twin Cities fall in the hierarchy of urban places? What are the characteristics of the urban places of the future? What are the major factors to watch?

Urban development of the future -- City of the 21st Century

Dr. Royce Hanson, Dean, School of Social Sciences
The University of Texas at Dallas

- Envisioning the future is difficult, it is extraordinarily hard to revise "images of the city". Learning about cities and urban development is really quite easy but changing our ideas about them is impossible. It is hard to think about things that we know such as MSP International Airport not being there or being there in a different way.

- The physical city lags behind the functional city, form really does follow function. In looking at the reuse of MSP what are the functions that need to be accommodated or encouraged in the reuse of MSP?

- The internal linkages and the external linkages are both extremely important. How will the site relate to the rest of the Region and the world for that matter and how should the internal circulation be designed? Look at both up front in the design process.

- The future of the urban area (the city) and the urban economy cannot be separated. What do you want the economy to be will tell you what you really want your development to be like.

- We are in a period of transformation of our cities, a process as significant as the beginning of the Auto Age.

- Half-life of physical development is less and less, the pace of change is faster and development becomes obsolete before it is worn out. Physical stuff is hard to get rid of. Adaptive reuse or flexible design should be considered in the beginning.

- A new international urban system is evolving--command and control centers. It is unlikely that there will be more than 10 in the United States and most likely only six. New York, Los Angeles, San Francisco and Chicago are definite candidates. Strong potential, depending on how active they are in promoting and enhancing their economies and infrastructure, exists for the Twin Cities, Boston, Seattle, Denver, Atlanta and Dallas.

- These command and control centers will be "smart cities," knowledge is an important resource. Telecommunication and airports are the ports of the future. Telecommunications and airports are helping to decentralize activity as well as to centralize things. Airports are important facilities for the future of cities in the 21st Century. The labor force will have to be well educated from top to bottom. Research and development will be major industries.

Characteristics of these "Smart Cities" of the 21st Century

Autonomy - they will be the most adept at adjusting to change because they will be headquarter locations, they will have strong independent banking and financial institutions.

Local Media Industry - they will have strong independent local media that will provide civic education and help articulate the visions of the future as well as be critics of the present.

Institutionally competent - they will be able to deliver services -- urban services, cultural, education; they will be high service amenity areas.

Governance - they will have a mix of public/private structures and intelligence systems for making choices and determining future visions; the governance (public, private and civic) will be accountable and responsible. Strategic planning will be a way of life for public agencies as well as for private businesses.

Infrastructure - they will invest in their future, no city wanting greatness can wait to answer its problems, there is a greater risk in not doing something and having extra facilities than trying to catch up. It is too easy to do little. Also for cities to maintain their status they cannot stand still. They will have to continually invest in infrastructure.

Section 2: REUSE PRINCIPLES AND GUIDELINES

Principles

No Tie To New Airport Finance	The issue of new replacement airport finance must be separated from the reuse of MSP; the maximization of economic return should not drive reuse.
Unique Development	Development of the site should be primarily limited to new, unique uses and users and not a transfer of uses and users from other parts of the Metropolitan Area.
Metropolitan Development Framework	Development of the site should support the Region's guided growth concept.
New Governing Structure	A new special purpose public entity chartered to develop the site ought to be created. The development entity ought to be completely separate from the airport authority and adjacent municipalities.

Guidelines

Advanced Planning	o	Stewardship of this resource and protecting the integrity of the long-term development concept must be protected.
Staging	o	A phasing strategy for 20 years should be adopted to allow for flexibility in meeting changing market conditions and to assure high quality development.
	o	Staging over 20 years would also minimize dislocations and ease the transition of users off the site as well as onto the site.
Landbanking	o	A financial strategy needs to be implemented that would not tax vacant land too highly and prevent pressure for premature development.
Clear Site	o	The site should be cleared of existing uses and all land within the ringroad (except national cemetery) should be purchased and made a part of the site.
Commercial Retail	o	The scale of commercial retail development should be limited to meeting the needs of the residential population and daytime users.
Development Concept	o	The site should be developed as a unique metropolitan resource; the region would be best served by having something new added to the urban fabric than by having existing/users/activities be shifted around and relocated.
Single Control	o	The site should be governed by a single entity dedicated to the implementation of the reuse concept.
Light Rail Transit	o	If the region gets an LRT system it should serve the site and the land uses should be integrated into it.
Existing Interests	o	All existing governmental bodies should be bought out.
Ownership	o	Reuse should be done through ground lease arrangements not fee title.

Section 3: CONSTRAINTS

The Site	o	Is the 3,000-acre site that unique? It is an ideal area for an airport -- flat with limited topographical relief and virtually no vegetation or natural environmental features. This presents design problems.
	o	The adjacent land uses (beyond the highway ringroad surrounding the site) reflect both the positive and negative influences of the operation of the airport and are of mixed quality. In total they do not provide much in the way of pluses for the reuse of the site.

The Freeways	o	The freeways surrounding MSP effectively cut off the site from the major natural amenities - the river bluffs, the Minnesota and Mississippi Rivers and Fort Snelling.
	o	Highway capacity serving the site has definite limits and may effectively reduce the amount of redevelopment possible.
Existing Infra-structure	o	By the time the site would be available for reuse (sometime after the Infra-year 2000), the infrastructure will be either worn out or functionally obsolete for any reuse; and because of its location on-site, it's much more of a constraint to rational reuse than an aid. It will be necessary to remove much of the infrastructure.
New Infra-structure	o	Basically one needs to view the site as vacant unserviced land requiring all new infrastructure (roads, utilities, etc.)
Ownership	o	The ownership pattern and ownership rights pose major problems. All land within the ringroad with the exception of the national cemetery should be placed under single ownership and control to avoid inconsistent and piecemeal development.
Transition Period	o	The transition period between full airport use to total reuse will be long and, therefore, difficult to keep the reuse on track. The dislocation of existing users -- military, airlines, air cargo, etc. -- will present logistical as well as financial tradeoff issues.
Long Range Plan	o	Total Master Plan developed today does not make sense, a flexible plan and concept will be required.
Aviation Use	o	The continued use of MSP for any aviation use (requiring the use of runways) whether transitional or permanent (general aviation/military) limits the reuse potential and, in fact, is a negative factor in the reuse of any land at MSP. No airfield related aviation use would be best (that is no runways, taxiways, hangers, gates).
National Cemetery	o	The national cemetery would be a constraint if its expansion beyond its current boundaries is allowed.
Regional Competition	o	The site with 3000 acres is larger than either downtown Minneapolis or St. Paul and it is centrally located. It could be an attractive relocation site for businesses/activity or compete more effectively for new development limiting other places.
Single Reuse	o	While desirable, no single reuse option or single reuser can be identified today. Therefore a mixed use development is foreseen. However, before the reuse plan is finalized, the alternative of a single use option ought to be re-examined.

Section 4: GOVERNANCE

Independent Entity	o	There needs to be a separate legal entity, a "municipal-type" creation with own charter, free from outside interference. A special purpose metropolitan development district could be established to pursue areawide development objectives.
Development Controls	o	It is essential that the governing entity have the ability to zone and guide/stage development.
	o	The plans and controls should be flexible in order to meet changing market conditions while maintaining the integrity of the development concept.
	o	The process to reconcile differences needs to be established.
Public/ Private	o	The governing entity should function like an urban development corporation in that it will need to form several development partnerships over time to redevelop all the land.
	o	The land should remain in the ownership of the public entity with long-term ground leases.
Existing Public Interests	o	All the interests of existing governmental bodies need to be bought out outright as a part of a comprehensive solution to relocating the airport.
Finance	o	The governing body needs to have independent financing capability and taxing power.

Section 5: MARKET POTENTIAL/DEVELOPMENT OPPORTUNITIES

ASSETS

The Land	o	The 3000 acres is a state/regional resource. It is also a national/international development opportunity.
The Location	o	The site is centrally located, highly visible and highly accessible.
	o	If the new replacement airport is located to the south or southeast, the site becomes an intervening opportunity between the airport and Downtown Minneapolis, Downtown St. Paul and I-494 Strip.
The Highway System	o	The site is afforded Metropolitan highway access equaled by few other locations.
Fort Snelling	o	The historic Fort Snelling Park offers "theme" potential

The Rivers o While not currently tied to the site, the Minnesota and Mississippi Rivers are the major natural amenity available.

The Opportunity -o The availability of such a large site offers the opportunity to do something unique and to attract something that is not already in the Metropolitan Area.

Government Offices o The federal government office building and VA Hospital could be the core of a federal office center for the region and state.

OPPORTUNITIES

Hierarchy of Options

o (1) National and international campaign to attract unique development proposals for the reuse of the entire 3000 acre site under the control of an inde-pendent development entity.

o (2) The division of the site into separate 300- to 500-acre development districts; staging the reuse under a development entity, responsible for coordination and overall integration of development.

o (3) A mixed use development district where reuse is controlled and evolutionary; incremental staging over 20 years.

Mixed Residential

o The site is an important regional asset and should be kept affordable by all income groups and could

be used as an example of how to provide housing for special population groups and low and moderate income households.

Corporate Office Park

o Part of the site could be designed to attract the corporate headquarters of businesses in medical technology, high technology or research/development.

Open Space

o The site could have significant amounts of land (approximately 1000 acres) dedicated to open space in terms of trails, parkways and active outdoor recreation facilities. The trails/parkways should be connected into the Minneapolis and Richfield trail/parkway systems and into the Minnesota River Valley National Park.

o Open space development is essential to creating an amenity needed by the site.

Light Rail Transit	o	If an LRT system is developed, the site could be used to demonstrate how LRT and urban development can be integrated.
Integrated Project	o	The site could be developed as an integrated whole and broken down into discrete development districts with their own unique focus.
Educational Center	o	Part of the site could be used by the Industrial Technology School at the University of Minnesota as a joint education/training center bridging the gap between education and applied practice. This site could be traded with the U of M for its Rosemount Research area.
	o	A "new age" industrial park of tomorrow could be built including a training center of new technology and new industrial processes.
	o	A think-tank of applied technology could be established.
	o	The education center could be set up as a consortium of Minnesota and foreign schools (e.g. University of Tokyo) for advanced training and research.
Marketing Center	o	Part of the site could be dedicated to the location of industrial/research plants to showcase what is available in Minnesota, it would be developed as actual working, productive operations not as a trade mart demonstrating technology.
Water Resource Management	o	A major asset of this part of the United States is water and since the site is adjacent to the confluence of the Mississippi and Minnesota Rivers it would be an ideal location of a major institute dedicated to water resource management.
International Business Center	o	A part of the site could be marketed and developed as a major foreign trade zone, or for the U.S. location of major foreign companies.
Aviation	o	The major benefit of the airport to adjacent communities is the passengers and the economic activity they generate and the major problem is the adverse environmental impact of the aircraft. The passenger terminal could be kept as the only passenger terminal and the runways and aircraft moved to a new site, thereby addressing both the positive and negative impacts of the airport. The site could be developed as the region's major intermodal transport hub (air, transit, taxi, highway).

Section 6: REUSE SCENARIO I "Central Airport Passenger Terminal Concept"

CONCEPT

- o Remove all airfield aviation functions (runways, taxiways, hangers, gates) except the passenger terminal to a new site to the south of the existing airport.

- o Develop remaining land around the site's major regional transportation hub status -- Airport, LRT and Highway.

This remote terminal concept would require:

(1) The no passenger access to the airlines at the new site.
(2) A dedicated high-speed transport between the passenger terminal and the new site for passengers, baggage and package/air freight.

The advantages:

(1) Air accessibility remains in the middle of the Metro Area.
(2) Maintains the economic advantages/benefits to businesses along I-494 and keeps the airport passenger terminal "centrally" located; minimizes disruption.
(3) Removes the largest negative attribute of the airport -- noise and the aircraft.
(4) Opens up land on the existing airport site for higher, better and more intense use. Enhances economic impact on surrounding communities.
(5) Removes land-intensive airport uses -- runways, taxiways, hangers, gates.

LAND USE PROPOSAL CONCEPT

A.	Central Airport Passenger Terminal	50 acres
B.	Recreational Open Space o Trails, Parkways, Active Outdoor Recreational Activities	1000 acres
C.	Research/Corporate Business Park	600 acres
D.	Residential o Average Density 20 units per acre 15,000 dwelling units	750 acres
E.	Retail/Neighborhood Commercial	100 acres
F.	Special Development District	500 acres
		3000 acres

Section 7: REUSE SCENARIO II "Regional Development District Concept"

CONCEPT

- o No aviation use remains on the site and all existing uses and infrastructure are removed.
- o The site is divided into development districts connected through a system of internal parkways and trails. Areas adjacent to major amenities (Fort Snelling and Minnesota River) are developed compatibly
- o Light Rail Transit is used as an internal movement system as well as connection to rest of the region.
- o Commercial/retail is limited to serving the residential population and the daytime users.

LAND USE PROPOSAL CONCEPT

A.	Recreational Open Space	800 - 1200 acres
B.	Special Development Districts	
	o University Research/Technology Park	400 - 600 acres
	o Corporate Headquarters Park	300 - 400 acres
	o New Technology Production & Training Center and Industrial Park	300 - 400 acres
C.	Residential Average density 20 units per acre 8,000 to 12,000 dwelling units	400 - 600 acres
D.	Retail/Neighborhood Commercial Residential/Daytime Users	100 acres
		3000 acres

A P P E N D I X

Alternatiave Land Use Panel Report

1. Alternative Land Use Panel Roster

2. Alternative Land Use Panel Assignment

3. Transportation Background Materials

4. Background Materials
   Regional Population and Economic Development Perspective

5. Existing Conditions
   MSP International Airport
   Summary of Draft Report
   Prepared for MAC February 1988

6. National Long-Range Urban Development Perspective

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Metropolitan Council of the Twin Cities Area
300 Metro Square Building, 7th and Robert Streets
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

DATE: April 3, 1988

TO: Alternative Land Use Panel

FROM: John Kar[illegible]

SUBJECT: Alternative Land Use Panel Assignment

Introduction

The Metropolitan Council is involved in a major study concerning the long-term adequacy of Minneapolis-St. Paul International (MSP) Airport. The study is designed to answer two broad questions. First, what is going to be the demand for air transportation service over the next 30 years. And second, what airport capacity will be required to meet that demand. The study is also designed to help the Metropolitan Council, the Legislature and the citizens of the Region make judgements, decisions and tradeoffs concerning the long term adequacy of MSP.

The adequacy study will examine four options to improve airport and terminal airspace capacity. These range from revised operational procedures to major capital investments including a possible new replacement airport. In some cases, these options are limited by FAA regulations or concerns for safety as with the ability to handle simultaneous aircraft operations on the parallel runways. Other choices, such as adding new runways and taxiways may be constrained by concerns for noise impacts or by the limited size of the current airport site. The possibility of a major new airport depends on the level of demand, how much demand the region wants to meet, the ease with which that large undertaking could be financed, and on the availability of a new site reasonably close to existing business centers.

At present, the study is focusing on four airport development options:

- **Base Case** - current programmed improvement
- **Enhanced Existing** - ten-year perspective
- **Ultimate Development** - Maximum site development within the highway ringroad.
- **New Replacement Airport** - A paper airport embodying state-of-the-art airport design, a non-site specific development option.

Each alternative includes a range of possible assumptions regarding demand management techniques and options for reliever airport development.

Any decision regarding long-term changes at MSP or the development of a replacement airport and the timing of those changes requires five types of evaluation measures:

- o system performance: how well will air transportation services be provided given expected growth in passengers and operations;
- o economic concerns including demand for air transport, its link to regional economic growth, and the local opportunity cost of capital invested in aviation;
- o social concerns such as community and environmental impacts; and
- o financial concerns which assess the capital and operating costs of various alternatives and possible sources of funds.
- o benefit cost: whether the economic value of new airport development - measured as the avoidance of delay and lost traffic - is likely to exceeed the costs of land acquisition and construction, minus the disposal value of airport assets and reuse potential.

The Alternative Land Use Panel

The reuse of MSP is an integral part of the discussion of the financial and cost implications of either enhancing airport service at MSP or the development of a replacement airport. Either option presents costs and benefits for the adjacent residential communities, commercial and industrial development along the I-494 freeway corridor, and the region as a whole. The alternative land use scenarios developed as a part of the expert panel will help delineate specifics and parameters on those costs and benefits.

The alternative land use panel will be composed of individuals with backgrounds and expertise in real estate development, large scale mixed use projects, architecture, urban design, transportation, aviation, redevelopment/adaptive reuse, land use law, development finance, and market analysis. The panelists were specifically chosen to provide an interdisciplinary perspective on the redevelopemnt possibilities of MSP.

Panel Assignment

The alternative land use panel has the following objectives:

(1) To identify development opportunities, constraints and incentives which may influence the reuse of the 3000 acre site.

(2) To identify the market potential of the site and to suggest phasing strategies for the redevelopment/reuse.

(3) To identify governance issues and a perferred governance structure.

(4) To develop several alternative land use scenarios which would generate revenue to be used to assist in the financing of a new airport and mitigate to the extent possible adverse economic impacts on adjacent areas.

- o Reuse Scenario(s)
- o Subregional Development Scenario(s)
- o Regional Development Scenario(s)

The panel will be divided into three subpanels each with specific reuse focus:

Focus 1: Reuse Scenario Maximize reuse of existing facilities and infrastructure:
May or may not include retention of some aviation uses such as an "intermediate airport" (similar to downtown St. Paul) whose primary users would be corporations and businesses but not regularly scheduled commercial air passenger carriers.

Focus 2: Subregional Compatibility Scenario Redevelopment as non-aviation land uses with primary focus on compatability with adjacent communities and existing land uses.

Focus 3: Regional/State Development Scenario Redevelopment as non-aviation landuses with primary focus on highest and best use for the site given its intrinsic value and potential regional function.

Panel Results

The results will be used by the MSP Adequacy Study team of Council staff and consultants to develop a range of reuse scenarios and to estimate the gross revenues that could be generated from those alternative uses. The result is not intended to be a detailed redevelopment plan but a concept plan, to show the range of feasible, market sensitive development alternatives.

The scenarios developed will be presented to the MSP Adequacy Task Force in May and will be incorporated into the task force's report to the Council.

Alternative Land Use Assumptions

1. The site will not be available for reuse until after the year 2000.

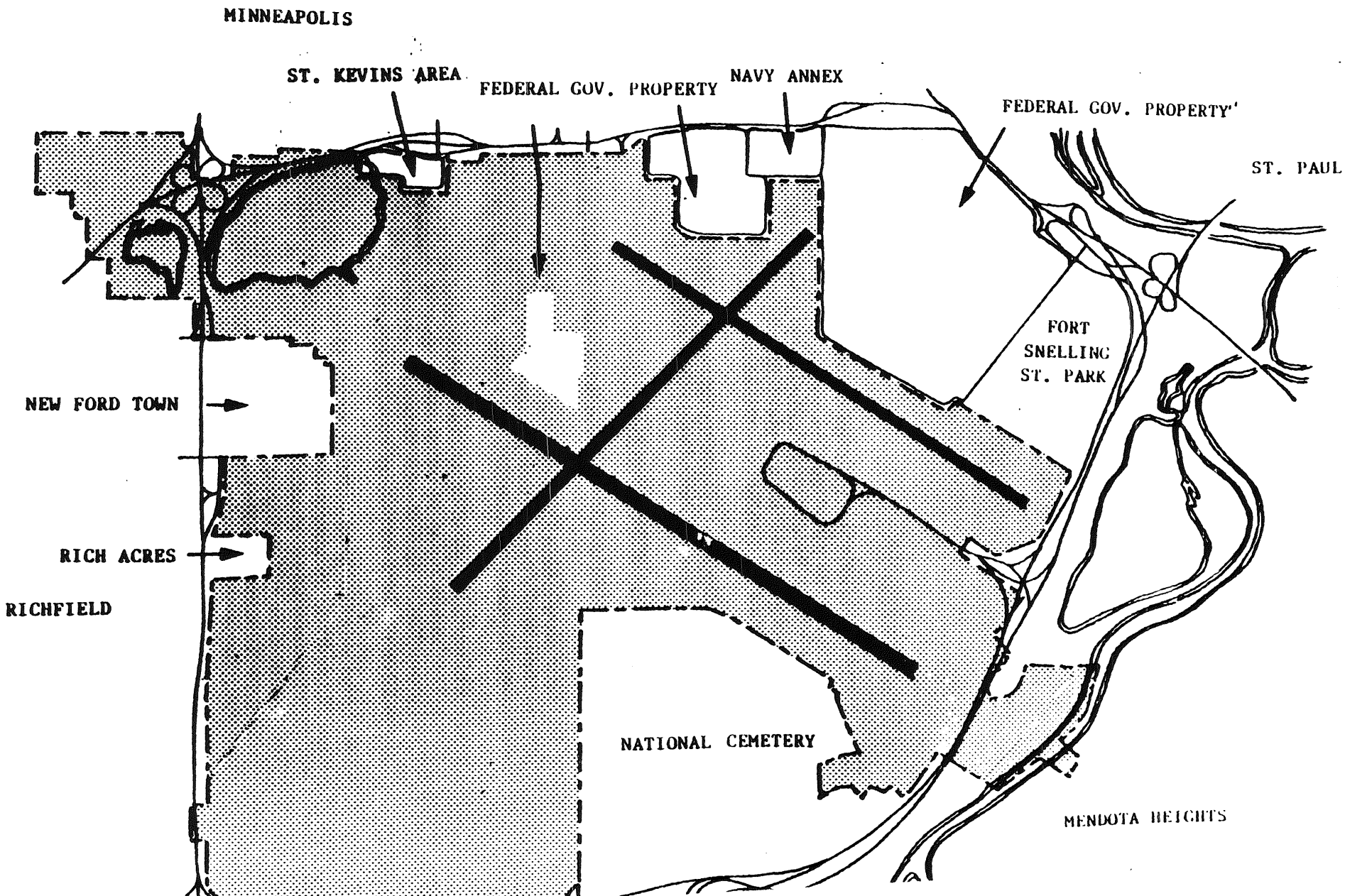
2. Potential locations for a replacement airport have not been identified; therefore, the reuse scenarios need to consider the potential impact if the replacement airport is south or north of the current site.

3. Evidence to date shows that the region can only support one major airport therefore, it must be assumed the replacement airport will perform that function. The aviation use of MSP, if there is any at all, will be limited to corporate and general aviation similar to Downtown St. Paul.

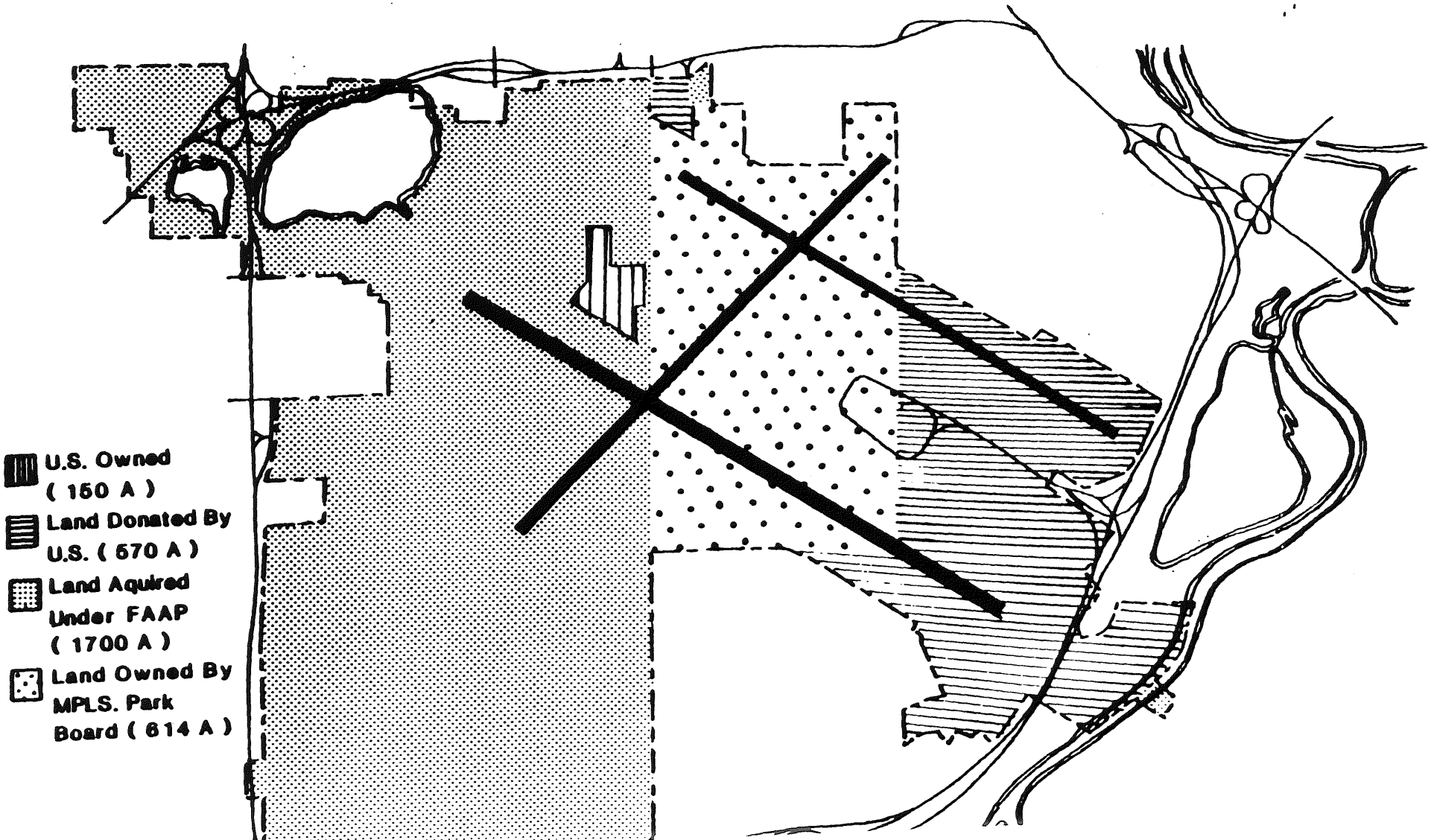
4. The governing structure is an open question; there are a range of possibilities from incorportion with adjacent municipalities to the establishment of an independent development district. There are a number of existing land owners and legal stipulations on certain parcels. The resolution of these intergovernmental and ownership issues should be facilitated by a plan and regional concensus on the comprehensive reuse of the site.

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MSP GENERAL AREA MAP



MSP PROPERTY HOLDINGS



Metropolitan Council of the Twin Cities Area
300 Metro Square Building, 7th and Robert Streets
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

DATE: April 6, 1988

TO: Alternative Land Use Panel

FROM: John Kari

SUBJECT: Transportation Background Materials

Highway Related Information

Transportation Analysis Area Map

Airport Area Highway Use 1986 and 2010 Map

Airport Area Highways Functional Classification Map

General Distribution of Traffic for Airport South Study

Typical Trip Generation Rates

Transit Use

Light Rail Transit

GH012H

HIGHWAY-RELATED INFORMATION

I-494 CORRIDOR PLAN

LAND DEVELOPMENT
- Coordinate new development with staging of transportation improvements
- Minimize the impact of new developments on peak period traffic

TRANSIT SERVICES
- Crosstown service parallel to I-494
- New express service focused on I-494 employment concentrations
- Coordinate transfer with I-35W routes

TRAVEL DEMAND MANAGEMENT
- Ridesharing
- Variable work hours
- Parking Management
- Land Use Mix and Site Design
- Preferential Access and Ramp Metering
- HOV Lane
- Private Sector Transportation Management Organization

ROADWAY CAPACITY IMPROVEMENTS
- Add one lane in each direction (two between CSAH 18 and TH 100) and upgrade to meet current design standards. Continue to study making this lane an HOV lane
- Reserve ROW in median for additional lane, if needed
- Reconstruct interchanges with other metro system highways (77, 35W, 100 18, Crosstown) and adjacent arterial streets. Design to be consistent with forecasted traffic
- Construct a full movement interchange at Portland Avenue and remove ramps at 12th and Nicollet
- Improve arterials parallel to I-494 to serve short trips and to replace adjacent frontage roads
- Add a lane in each direction to CSAH 62 and CSAH 18

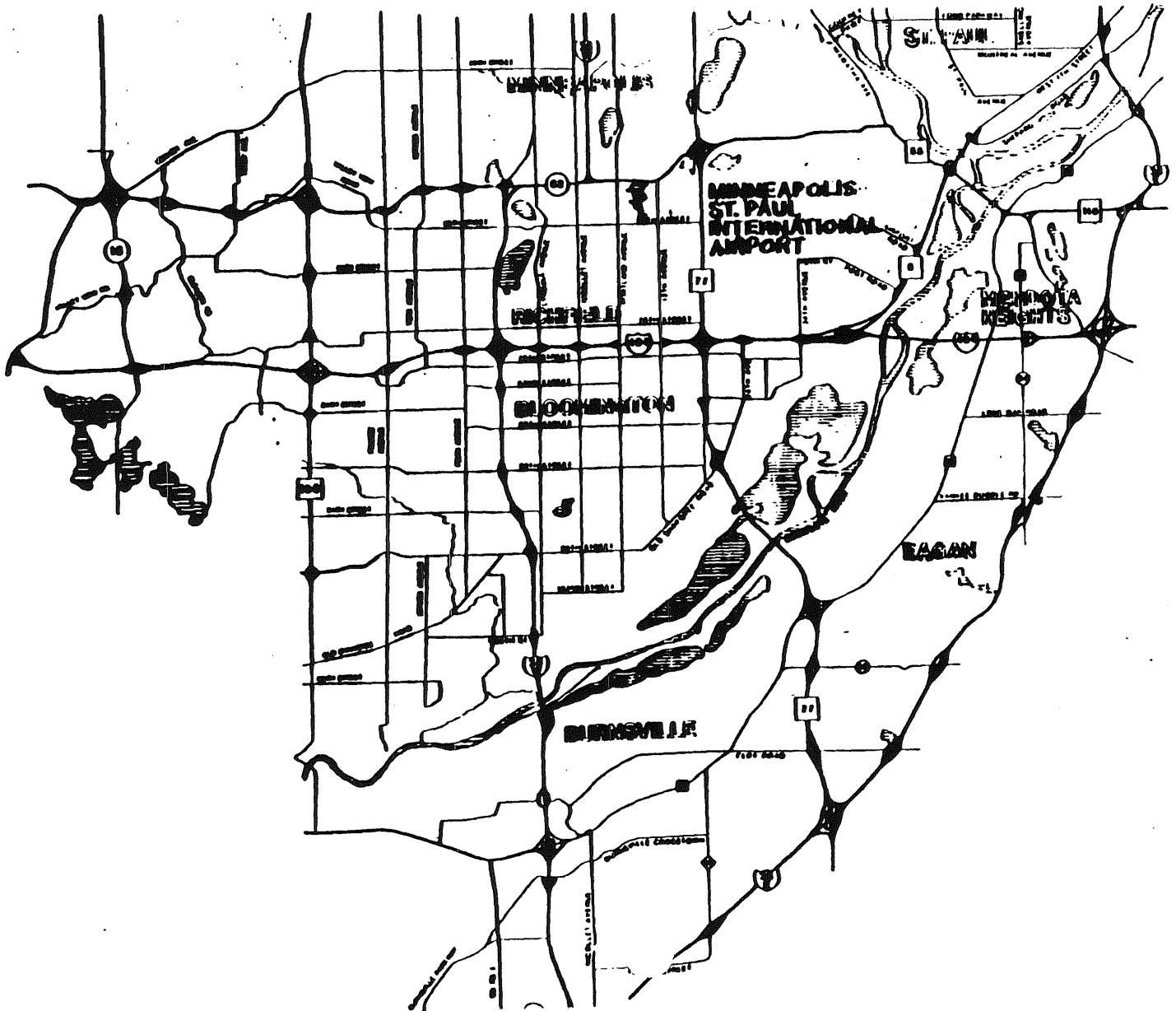
FUNDING RESOURCES
- Traditional and alternative funding

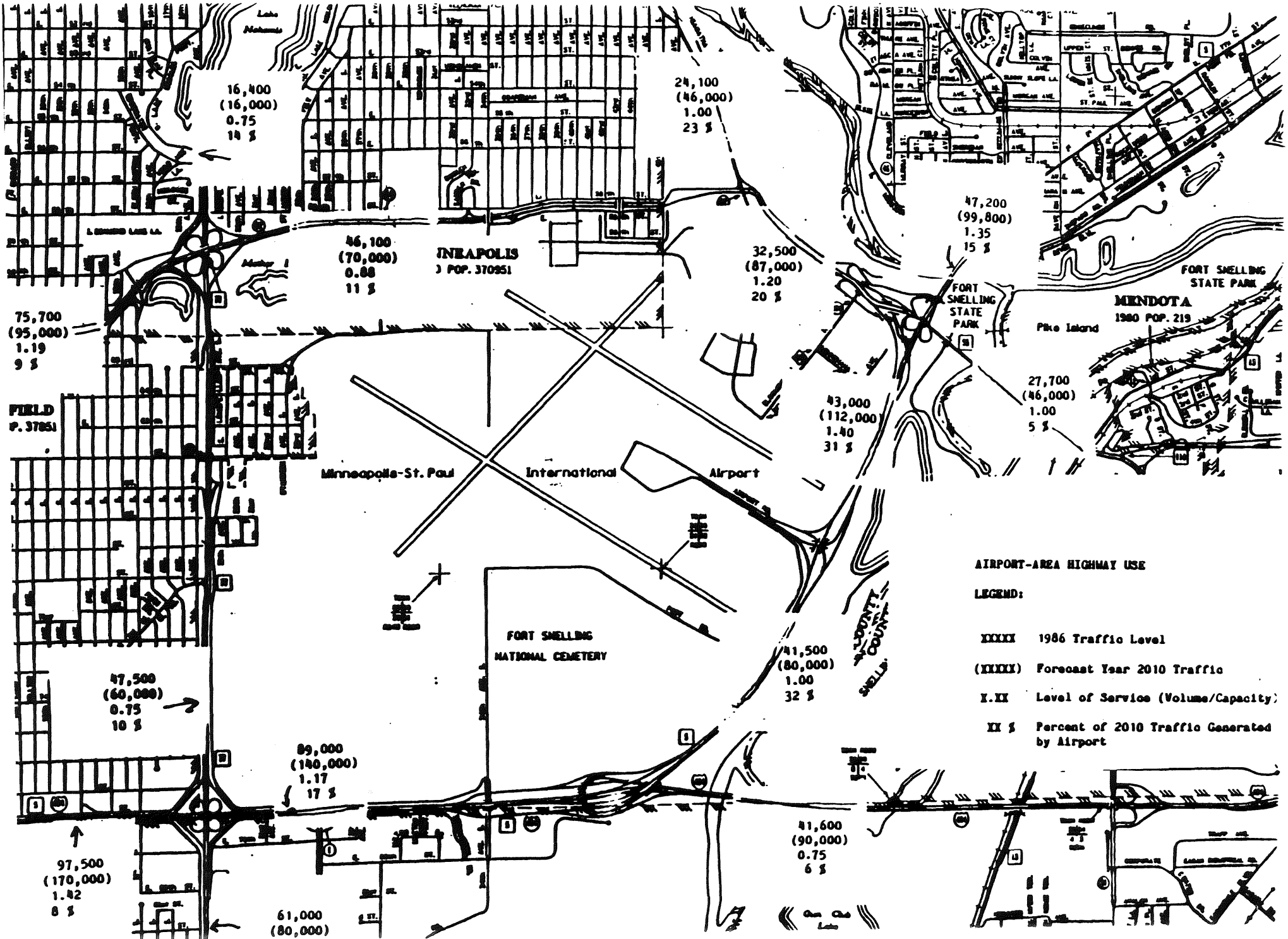
IMPLEMENTATION PROGRAM
- Continue interagency team to implement
- Program of short (1-5 year), medium (5-10) and long (10-20) range steps

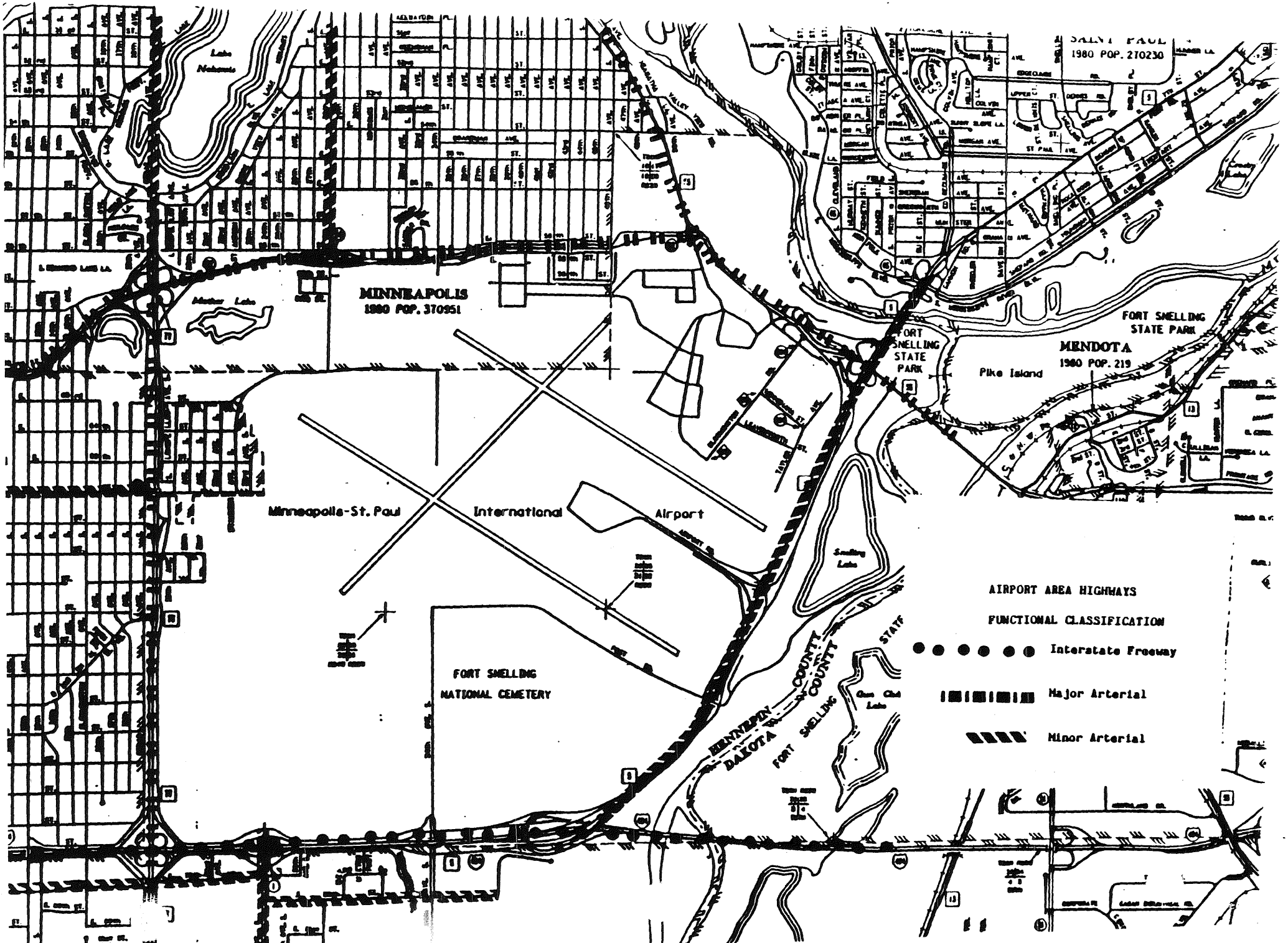
OTHER RELATED PLANS

- Pending Improvements to Hiawatha Avenue: Improved access to Downtown
- Cedar Avenue Study between I-494 and TH 62: Potential reconfiguration of access to airport site and increased Cedar Av. capacity
- Mall-of America Proposal: Substantial demands on 24th Av., 34th Av. interchange capacity

TRANSPORTATION ANALYSIS AREA




16,400
(16,000)
0.75
14 %
24,100
(46,000)
1.00
23 %
46,100
(70,000)
0.88
11 %
32,500
(87,000)
1.20
20 %
47,200
(99,800)
1.35
15 %
75,700
(95,000)
1.19
9 %
43,000
(112,000)
1.40
31 %
27,700
(46,000)
1.00
5 %
41,500
(80,000)
1.00
32 %
47,500
(60,000)
0.75
10 %
89,000
(140,000)
1.17
17 %
41,600
(90,000)
0.75
6 %
97,500
(170,000)
1.42
8 %
61,000
(80,000)
FORT SNELLING
STATE PARK
MENDOTA
1980 POP. 219
Pike Island
Minneapolis-St. Paul
International
Airport
FORT SNELLING
NATIONAL CEMETERY
AIRPORT-AREA HIGHWAY USE
LEGEND:
XXXX 1986 Traffic Level
(XXXX) Forecast Year 2010 Traffic
X.XX Level of Service (Volume/Capacity)
XX % Percent of 2010 Traffic Generated by Airport


Lake Nokomis
MINNEAPOLIS
1980 POP. 370951
Minneapolis-St. Paul
International
Airport
FORT SNELLING
NATIONAL CEMETERY
FORT SNELLING
STATE PARK
MENDOTA
1980 POP. 219
Pike Island
FORT SNELLING STATE PARK
1980 POP. 270230
AIRPORT AREA HIGHWAYS
FUNCTIONAL CLASSIFICATION
Interstate Freeway
Major Arterial
Minor Arterial

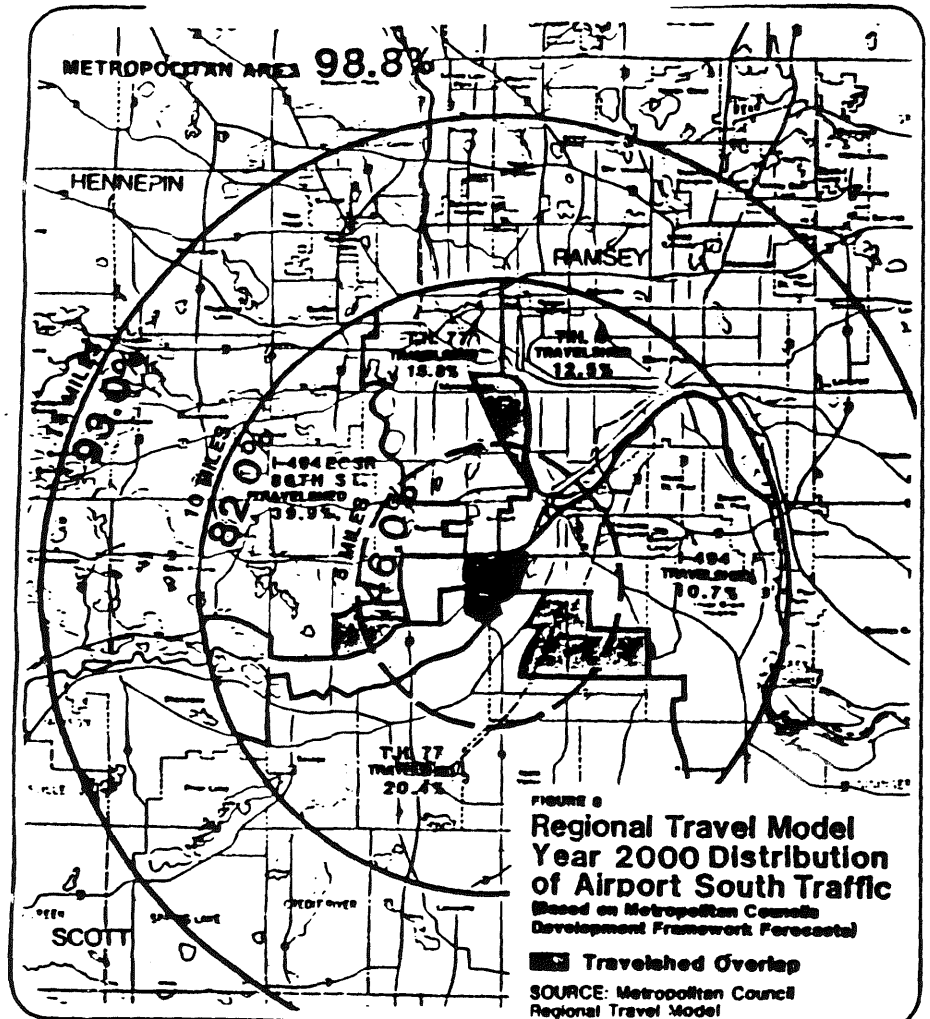


FIGURE 8

Regional Travel Model Year 2000 Distribution of Airport South Traffic

Based on Metropolitan Councils Development Framework Forecasts)

Travelshed Overlap

SOURCE: Metropolitan Council Regional Travel Model

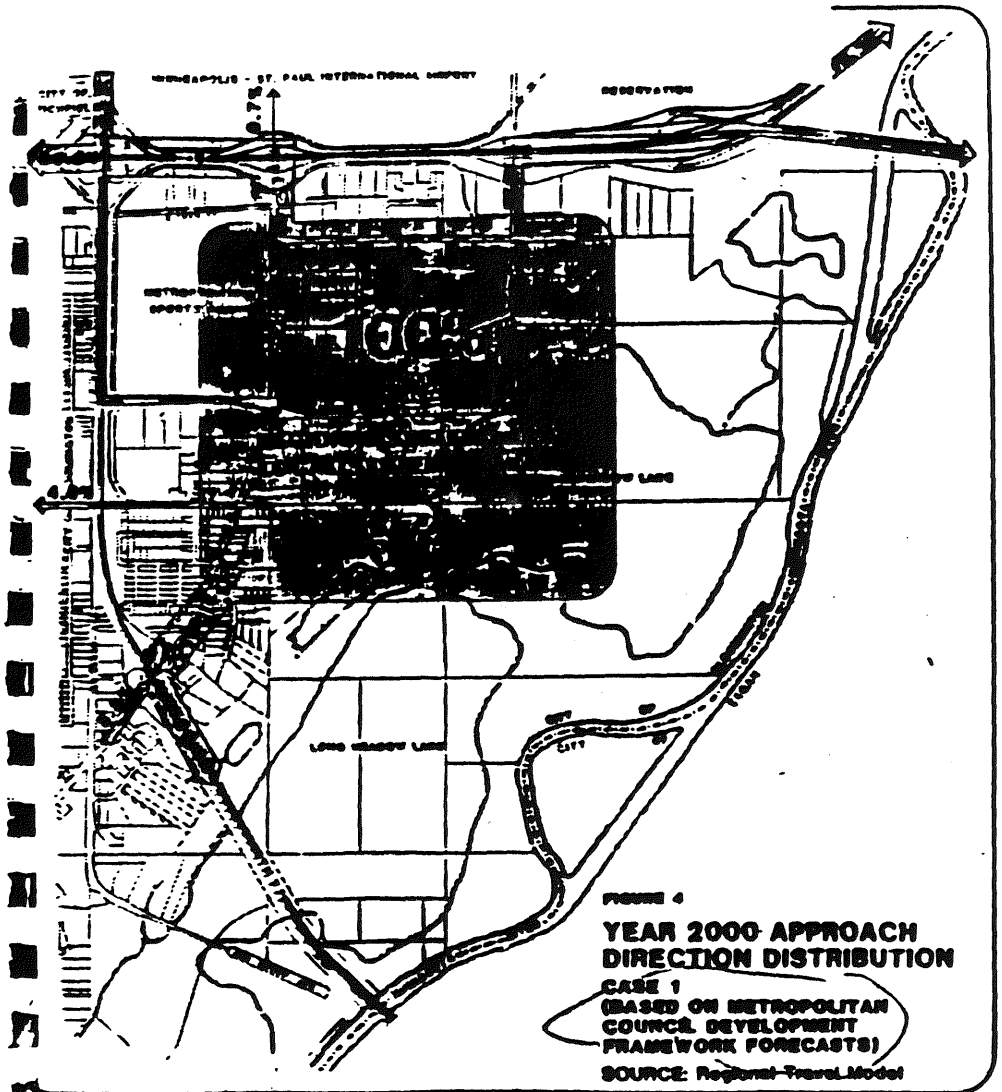


FIGURE 4

YEAR 2000 APPROACH DIRECTION DISTRIBUTION

CASE 1
(BASED ON METROPOLITAN COUNCIL DEVELOPMENT FRAMEWORK FORECASTS)

SOURCE: Regional Travel Model

Airport South TRANSPORTATION AND ENVIRONMENTAL MANAGEMENT STUDY

KKW

Airport South TRANSPORTATION AND ENVIRONMENTAL MANAGEMENT STUDY

KKW

TYPICAL TRIP GENERATION RATES
(Source: Institute of Traffic Engineers
Trip Generation, 3rd Edition, 1983)

	Weekday Average Vehicle Trip Ends
Residential (per unit)	
Single Family Detached	10.0
Apartment, General	6.1
Low-Rise Apartment	6.6
High-Rise Apartment	4.0
Planned Unit Development	7.8
Retirement Community	3.3
Lodging (per room)	
Hotel	10.5
Motel	12.8
Recreational	
City Park (per acre)	6.0
Office (per 1000 gross square feet)	
General Office Building	12.3
Office Park	20.7
Research Center	5.3
Retail (1000 gross sq. ft. of leasable area)	
Specialty Retail Center	40.7
Discount Store	70.1
Shopping Center	
Under 50,000 square ft.	117.9
50 - 100,000 square ft.	82.0
100,000 - 500,000 square ft.	50.0 (approx.)
500,000 and over	35.0 (approx.)
Supermarket	125.5
24 Hour Convenience Market	625.2
Wholesale	6.7
Typical Suburban Mixed Use (per 1000 square feet)	11.0
Industrial (1000 gross square feet)	
General	5.4
Light Industrial	5.5
Heavy Industrial	1.5
Industrial Park	7.0
Warehousing	4.9

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TRANSIT USE

o PRESENT CONDITIONS IN AIRPORT AREA

Residential Uses

- 9 percent work trips via transit
- 3 percent non-work trips via transit
- Primary service focus to downtown Minneapolis

Non-Residential Uses

- Virtually all transit is carpooling or vanpooling, not bus service

o FUTURE CONDITIONS

- Improved Service Along I-494 Corridor
- LRT to Downtown Minneapolis via Hiawatha Avenue
  (Could result in about 25 percent more transit riders)
- LRT would tunnel under airport runways, but could be built on surface if site use is other than airport

Light Rail Transit

Metropolitan Council of the Twin Cities Area
300 Metro Square Building, 7th and Robert Streets
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

DATE: April 7, 1988

TO: Alternative Reuse Panel

FROM: John Kari

SUBJECT: Background Materials
Regional Population and Economic Developoment Perspective

Twin Cities Regional Forecasts and History

- Population 1950 - 2010
- Households 1950 - 2000
- Employment 1970 - 2000

Regional Population By Age Group 1970 - 2020

Trends For Three Age Groups in the Twin Cities

Map of Employment Concentrations 1980

Twin Cities Employment Trends 1980 - 1987

Value of All Building Permits 1982 - 1987 in Twin Cities.

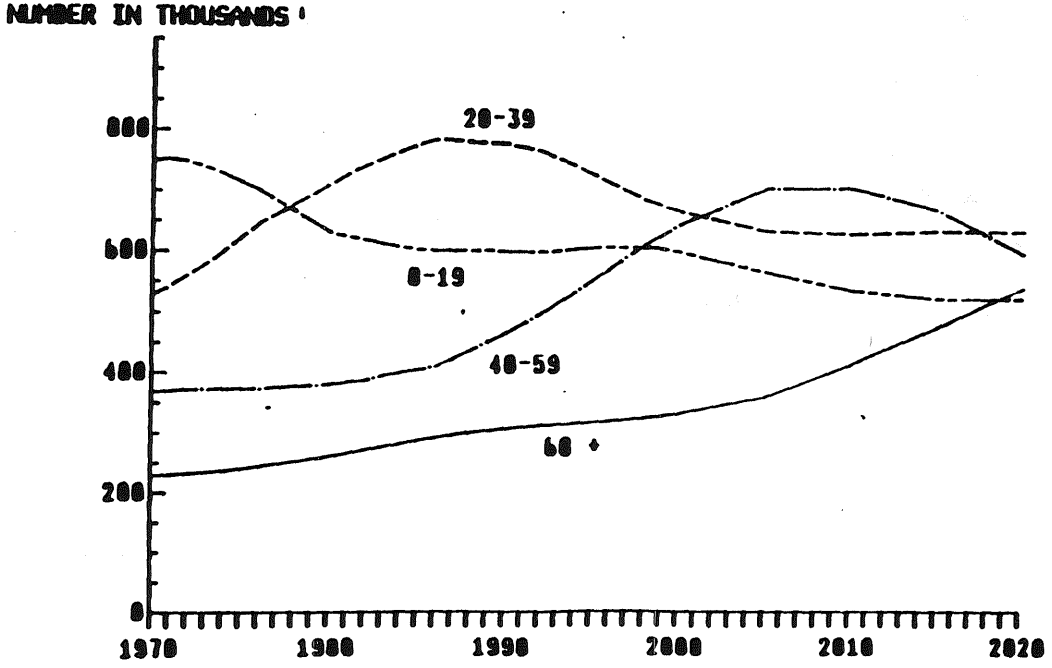
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TWIN CITIES REGIONAL FORECASTS

	Population		Households		Employment	
	Number	Percent Change	Number	Percent Change	Number	Percent Change
1950	1,185,694		346,563		NA	
1960	1,525,297	29%	452,276	31%	NA*	--%
1970	1,874,612	23	573,834	27	853,000	--
1980	1,985,873	6	721,444	26	1,075,000	26
1990	2,160,000	11	845,000	12	1,300,000	21
2000	2,260,000	5	910,000	8	1,400,000	8
2010	2,305,000	2	NA	--	NA	--

*Figures that are available are not directly comparable but would indicate total employment for 1960 to be about 650,000.

REGIONAL POPULATION BY AGE GROUP
1970 TO 2020



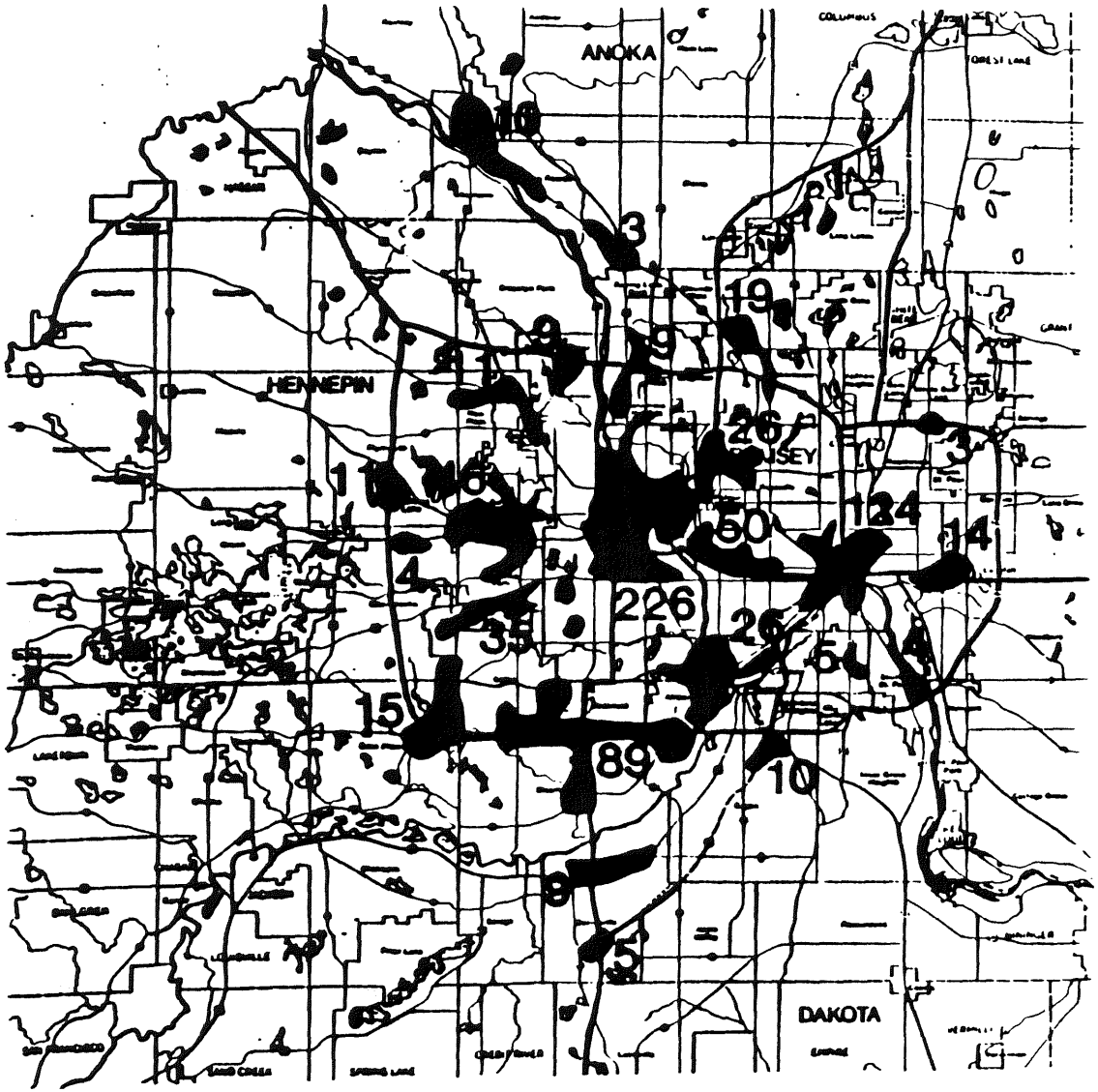
Source: Metropolitan Council

TRENDS FOR THREE AGE GROUPS IN THE TWIN CITIES
(in thousands)

Year	20 to 24	40 to 44	60 to 64
1960	99	92	61
1970	166	103	65
1980	205	104	73
1985	197	123	80
1990	168	164	82
2000	145	203	84
2010	165	168	134

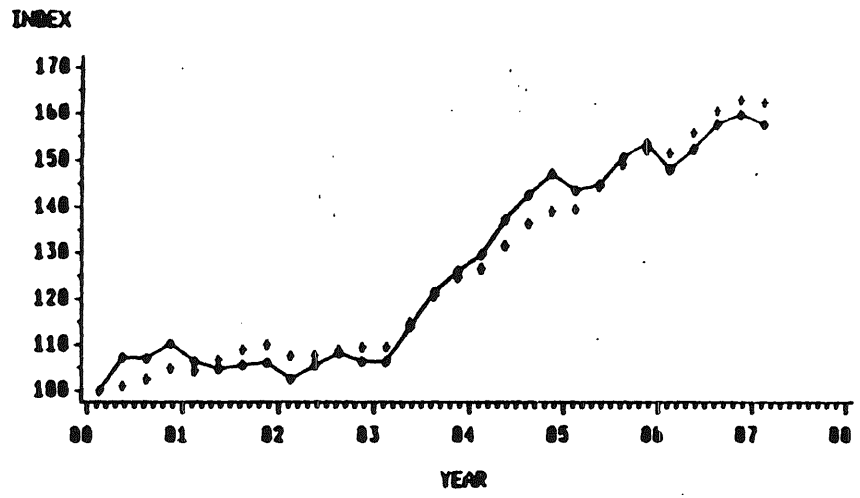
EMPLOYMENT CONCENTRATIONS 1980

(IN THOUSANDS)



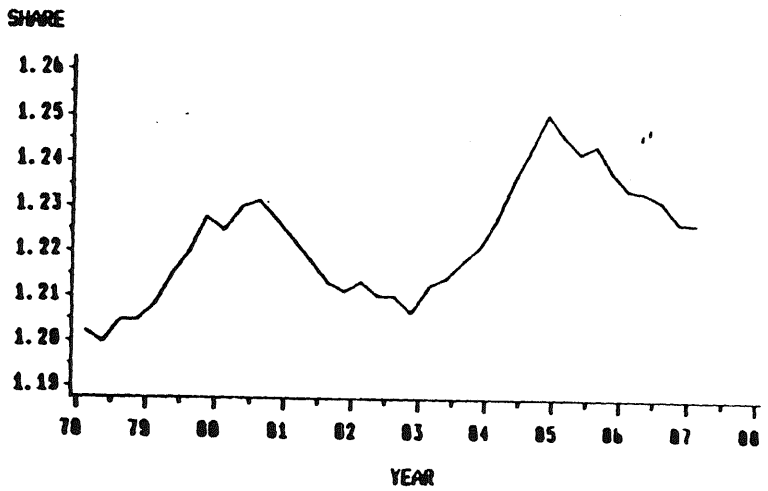
BUSINESS SERVICES, 1980-1987

(Twin Cities vs United States--1980=100)



TWIN CITIES SHARE OF U.S. EMPLOYMENT

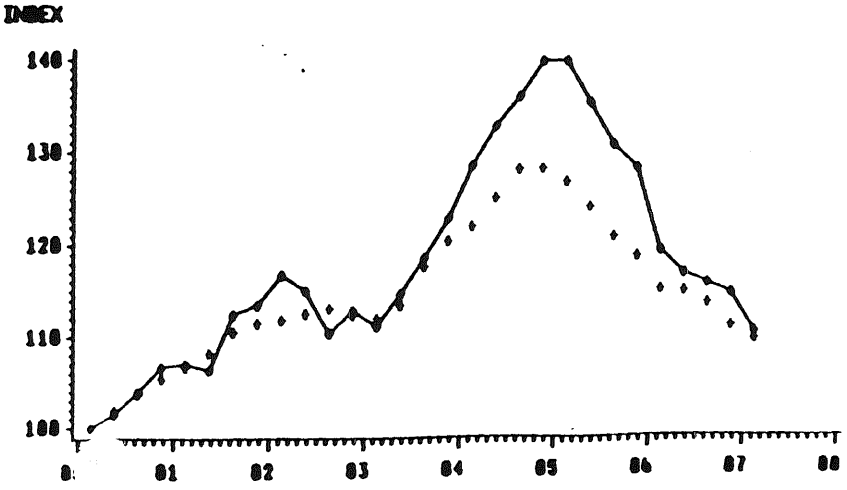
(seasonally adjusted)



LEGEND: United States=plus
Twin Cities=line

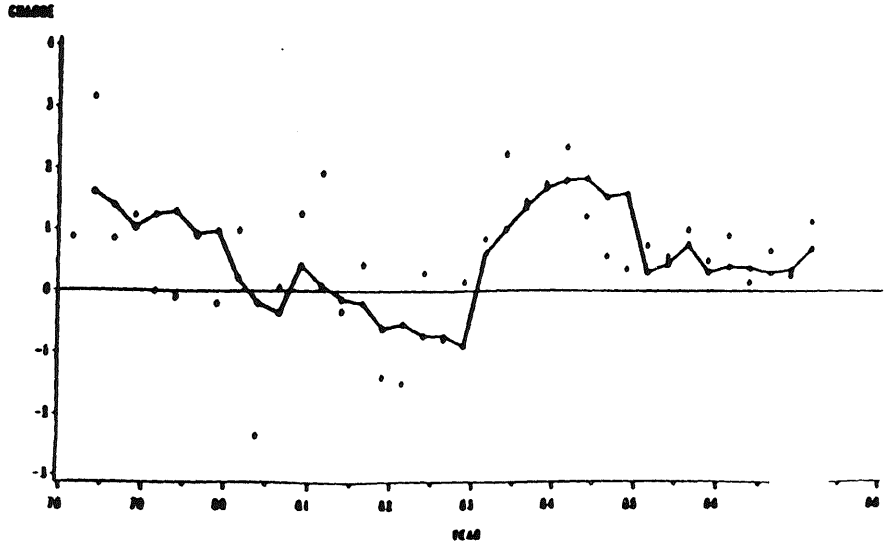
COMPUTER EMPLOYMENT, 1980-1987

(Twin Cities vs United States--1980=100)



REAL GNP VS TWIN CITIES EMPLOYMENT(seas adj)

(annual percentage change)



VALUE OF ALL BUILDING PERMITS
ISSUED IN THE TWIN CITIES METROPOLITAN AREA,
BY TYPE, JANUARY-JUNE 1982-1987
(in thousands of 1982 dollars)[1]

	1982	1983	1984	1985	1986	1987
All Housing	$260,404	$462,864	$502,369	$491,540	$730,871	$882,123
Single-Family[1]	183,024	347,080	374,703	383,737	554,110	688,350
Multifamily[2]	54,956	82,350	101,861	90,703	150,639	176,886
Other[3]	22,424	33,434	25,805	17,100	26,122	16,887
Residential Alterations & Additions	50,049	55,591	56,590	54,799	54,086	77,159
Commercial	133,374	150,358	146,636	202,123	221,308	256,107
Industrial	19,339	16,513	48,616	24,032	54,534	15,392
Miscellaneous[4]	28,973	48,233	36,015	36,373	64,909	42,057
Nonresidential Additions and Alterations	117,294	134,278	150,096	168,528	152,622	170,297
METROPOLITAN AREA TOTAL	$609,433	$867,837	$940,322	$977,395	$1,278,330	$1,443,135

[1]Derived from Department of Commerce Composite Index of Construction Costs, 1982 = 100.

[2]Buildings of five or more units.

[3]Includes two-, three- and four-unit buildings and mobile homes.

[4]Includes churches, residential garages, privately owned hospitals, institutions, utilities and schools, but does not include publicly owned buildings in these categories.

Source: Report of Building Permits Issued and Local Public Construction.

EXISTING CONDITIONS
MSP INTERNATIONAL AIRPORT
SUMMARY OF DRAFT REPORT
PREPARED FOR MAC FEBRUARY 1988

HISTORY OF THE AIRPORT

Minneapolis-St. Paul International Airport (Wold Chamberlain Field) has a long history of both civil and military service.

Wold Chamberlain Field flying activities date back to the formation of the Aero Club of Minneapolis in 1920. The club leased land at an old concrete race track on the present MSP site. The landing strip consisted of a sod area of approximately 2000 feet in length in the center of the existing race track. In 1926, airmail service under government contract was established between Chicago and the Twin Cities. Northwest Airways received the contract and occupied the hangar built for the Aero Club.

In 1928, the airport was taken over by the Minneapolis Park Board; the facility then comprised some 325 acres and 8 hangars with 7 small, single-engine planes based at the field. The new name of the airport was "Minneapolis Municipal Airport." In 1929, Northwest Airways began passenger service to Chicago with 12-passenger, Ford Trimotor Airplanes.

A new administration building was dedicated on September 19, 1930, and remains in use today for rental to airport tenants. In 1936, with the aid of WPA projects, Wold Chamberlain Field boasted 150,000 square yards of concrete comprising three 3,000-foot runways. The Weather Bureau began operation in 1937, and a Control Tower was activated in 1938.

In 1943, Wold Chamberlain truly became the regional air carrier airport. The Minnesota State Legislature in that year created the Minneapolis-Saint Paul Metropolitan Airports Commission to eliminate costly rivalry between the cities of Minneapolis and St. Pasul in the area of air transportation. At that time two airlines provided single plane service to 17 cities from Wold Chamberlain Field. The Commission took over the operation of the field on August 14, 1944.

Wold Chamberlain Field was designated Minneapolis-St. Paul International Airport - Wold Chamberlain Field on August 23, 1948.

Military activity has been present since 1921 when the Minnesota 109th Observation Squadron became the first National Guard Air Unit in the nation to receive Federal Recognition. A second military activity was the Naval Reserve. The Naval Reserve activity declined after World War II, but it still remains an active military unit on the airport.

The third Military activity was the U. S. Army corps, which later became the U. S. Air Force and continues today as the U. S. Sir Force Reserve.

GENERAL DESCRIPTION OF THE TERMINAL AREA

The present MSP International Airport opened January 20, 1962, replacing the original Wold Chamberlain Terminal which is located west of Runway 4-22, and

is now being used for FAA offices. Subsequent to rapid growth in air carrier activity, the Lindbergh Terminal received major expansion in 1980 and 1986. Existing terminal facilities, including the regional commuter terminal, presently comprise 1,521,000 square feet.

The Lindbergh Terminal is situated in the center of the airport between parallel Runways 11L-29R and 11R-29L, east of Runway 4-22. The front of the terminal faces east and is served by a two-level roadway connected to a single-level access road loop. The terminal consists of four levels: the basement level containing public valet parking, mechanical rooms, and storage space; the ground or lower level with facilities for baggage claim and make-up, police, ground transportation, and auto rental; the main or upper level for ticketing and waiting areas with related food/beverage services, shops and concessions; and a mezzanine level offering space for airport and airlines staff, office rental and mechanical equipment rooms.

Joined by bridges to the main passenger terminal are four passenger boarding piersd identified as the Gold, Red, Blue and Green Concourses. Contained on the upper level of these piers are the airline departure lounges for assembling passengers. Also on upper levels are airline offices, mechanical rooms, food/beverage, shop, and public service facilities. Located on lower levels are airline operations, maintenance, and some presently unoccupied space.

Parking is located directly east of the terminal. Short-term parking is situated adjacent to the main terminal. Short-term parking is situataed adjacent to the main terminal on the lowaer level of the two-level parking structure. Auto rental car pick-up and return is also located adjacent to the terminal on the lower level of the seven-level long-term parking structure. The access road infield contains rental car storage and surface long-term parking. Additional parking demand is accommodated by remote parking lots using shuttle buses to the terminal.

GOLD CONCOURSE: PIER "A"

The Gold Concourse is the longest concourse and is the most recent expansion by Northwest Airlines, completed in 1986. It is a two-level concourse designed as a series of gate lobby pods connected by circulation linkages. The pier extends eastward, 1,950 feet from the south end of the main terminal. Passengers are assisted in traversing this distance by four 350-foot long moving sidewalks.

The regional carrier, Mesaba Airlines is located at the apron level east end. Mesaba facilities are wood frame portable buildings accessed through stairs adjacent to Gate 15. The apron level contains NWA maintenance and operations including a cargo transfer and a central stores facility. Allied Fueling and Mesaba operations are located below Gate 15.

A twenty-foot wide connector bridge allows secure passenger circulation to the Red Concourse. NWA occupies all gates on this concourse.

RED CONCOURSE: PIER "B"

The Red Concourse is a seventeen gate, two-level, linear boarding pier, extending 861 feet westward from the south end of the main terminal. This concourse has undergone several remodelings and expansions since its origination.

A twenty-foot wide bridge connects this concourse to the main terminal; a second connector bridge allows secure passenger circulation to the Gold Concourse.

The lower level is used for maintenance and operations by NWA, TWA, and MAC. Also included is a Triage Center, however, its use is being phased out due to current methods of handling airline disasters.

Two penthouse structures are located on the roof level. One structure contains a public observation deck and the other structure contains the NWA gate control facility.

BLUE CONCOURSE: PIER "C"

The Blue Concourse is a thirteen gate, two-level, linear boarding pier, extending 641 feet westward from the north end of the main terminal, and it is the smallest concourse. This concourse has also undergone several expansion remodelings since its origination. A twenty-foot waide bridge allows secure passenger circulation to the Green Concourse. The lower level includes maintenance and operation areas for each of the airlines and Marriott-Host storage areas.

A penthouse structure located on the roof level contains a MAC communications and operations facility.

GREEN CONCOURSE: PIER "D"

This concourse has evolved through several expansions to its current configuration. Most significant of these is the two-level gate pod with six gates completed in 1986, which is connected to the north end of the main terminal.

The remaining concourse is an eleven-gate, two-level linear boarding pier extending eastward 1,443 feet. These gates are designed as three separate piers linked by two circulation bridges.

The lower level is used by NWA as a maintenance and operations area. There are also two temporary mobile trailers located east of the concourse on the apron level which are used by NWA and Express One for operations.

A penthouse structure is located on the roof level above the gate pod which is used as a line maintenance control area by NWA.

The main heating and cooling plant for the terminal complex is located adjacent to the concourse at the east end.

REGIONAL AIRLINE TERMINAL

The regional terminal is a single-level 20,200 square foot facility; the terminal was completed in 1984. This facility is connected to the Green Concourse by a temporary wood structure and extends eastward 250 feet.

HUMPHREY TERMINAL

The Humphrey Terminal is a single story building, constructed of steel frame, steel joists and steel deck structure with concrete block interior and precast

concrete or metal panel exterior. A 1987 expansion to the public areas increased the total building area from 65,500 square feet to 89,760 square fe.

The majority of the air cargo facilities are located in the southwest portion of the airport. Some are located in the old terminal area between Runways 11R and 11L.

SUMMARY OF AIR CARGO FACILITIES

Location	Building (Sq. Ft.)	Apron (Sq. Ft.)	Area of Facility (Acres)
S. of Humphrey Terminal (NWA)	77,608	77,437	8.45
S. of Humphrey Terminal (Delta/other)	34,500	N/A	2.5
W. of Humphrey Terminal (Standard)	34,323	N/A	2.29
Southwest Apron Area (Fed. Exp.)	32,144	N/A	8.52
Southwest Apron Area (Various)	110,760	N/A	8.77
Southwest Apron Area (Zantop)	8,650	60,000	1.93
Southwest Apron Area (Viking)	22,500	48,000	N.
Air Cargo Center (Burlington)	25,550	N/A	2.5
Air Cargo Center (Various)	283,122	-	24.43
Air Cargo Center (Sterling)	7,268	-	2.1
Navy/Page Avjet Apron (Orion/ Evergreen)	N/A	180,000	2.5
Van Dusen Apron (Mt. Air)	-	-	-
Page Avjet Apron (Flying Tiger)	-	17,000	-
Totals	636,425	382,437	63.99

GENERAL AVIATION FACILITIES

General Aviation and Fixed Base Operations (FBO) facilities are operated by Van Dusen and Page Avjet. The facilities are placed in various locations on the airport. They provide services and support for general aviation and corporate aircraft based at MSP, as well as for itinerant aircraft. In addition, they provide support for various air carrier, air freight, and charter operators. For example, general aviation pilots and passengers connecting to air carri services are transferred from the FBO to the terminal buildings by shuttle

SUMMARY OF FBO AND GENERAL AVIATION FACILITIES

Function	Van Dusen	Page Avjet	Total
Site	33.7 Acres	2.57 Acres	36.27 Acres
Apron	755,875 SF	60,800 SF	816,675 SF
Building Ground Cover	201,564 SF	34,656 SF	246,220 SF
Hangar Floor Space	166,046 SF	32,000 SF	198,046 SF
Office, shops, terminal etc.	45,721 SF	14,880 SF	60,601 SF
Total Building Floor Space	211,767 SF	48,276 SF	260,043 SF

AIR CARRIER MAINTENANCE

Air carrier maintenance facilities are located in several areas of the airport and typically include more than facilities for the maintenance and overhaul of aircraft. The larger facilities include a variety of support functions such as general office, computer operations, and material storage.

The various air carrier maintenance operations include the following:

- The Northwest Airlines Main Base is located on the south side of the airport entrance road. The hangar can accommodate ten narrow-body and two wide-body aircraft. The complex includes office space, shops, two engine testing cells, computer facilities and storage.

- The Northwest Airlines Flight Simulator and TRaining Buildilng is located on 34th Avenue South. The facility includes eight flight simulator rooms, a warehouse for stores, office, computer room, repair shop, and class rooms.

- A Northwest Airlines Hangar facility is located on 34th Avenue South, north of I-494. The hangar currently holds three narrow-body and one wide-bodyu aircraft, and is scheduled for expansion by two B-747-400 bays. The summary table includes the anticipated expansion.

- The Mesaba Airlines Hangar is located on 34th Avenue at the north end of the apron. The building includes hangar space for one F-28 type aircraft, shops, and office facilities shared with ACDO and GADO. THis hangar violates the building restriction line for Runway 11L.

- The Sun Country Airline hangar is located on 34th Avenue South at the south end of the southwest apraon. The building contains ofices, shops, and can accommodate one wide-body aircraft.

- The Viking Airlines hangar is located south of MAC Buildilng No. 16 in the old terminal area. The hangar contains 24,830 square feet of hangar and shop space on a site of 0.51 acres. The apron in front of the hangar is used to park an aircraft for freight handling, thus it is included in the air cargo setion.

SUMMARY
AIR CARRIER MAINTENANCE FACILITIES

	NW Main Base (Entrance Rd.)	NW Flight Simulator Training Building	NW Hangar Complex 34th Ave.	Mesaba Hangar	Sun Country Hangar	Viking Hangar	Total Space
Site	91.12 Ac.	13.78 Ac.	81.01 Ac.	2.15 Ac.	4.48 Ac.	0.51 Ac.	193.05 Ac.
Apron	1,001,413	None	568,894	30,000	60,000	None	1,660,307
Bldg. Ground Cover	1,109,944	99,797	721,354	33,000	56,300	22,400	2,042,795
Hangar	340,150	None	N/A	17,500	N/A	N/A	N/A
Shops	748,005	-	N/A	10,425	N/A	N/A	N/A
Office	264,000	-	N/A	6,200	N/A	N/A	N/A
Other	-	217,609	N/A	-	N/A	N/A	N/A
Total Floor Space	1,352,755	217,609	N/A	34,125	46,000	24,830	N/A

One additional hangar is located on 34th Avenue on the south end of the old terminal area apron. The facility is used primarily for aircraft maintenance in combination with air freight handling support.

FUEL STORAGE AND DISTRIBUTION

Air carrier fueling facilities are located in three areas of the airport, the Williams Pipe Line Terminal, the WAold Chamberlain Field Fueling Facility Corporation area, and the MAC constructed fuel farm.

CRASH, FIRE, AND RESCUE FACILITIES

MAC operates a Crash, Fire, and Rescue (CFR) facility located between the FAA Office/Weather Bureau building and the Control Tower. The single-story building contains 13,415 square feet on a site of approximately 0.66 acres.

ADMINISTRATION (MAC) FACILITIES

The Metropolitan Airports Commission (MAC) occupies several facilities on 28th Street, south of the Crosstown Highway, to provide offices for MAC staff and to provide maintenance of facilities and equipment owned and operated by the airport owner/operator. The facilities included here are the MAC Office Building, the Snow Removal Equipment and Storage Building, the Carpenter, Paint and Electrical Shops, and Building No. 16 on 34th Avenue South.

FEDERAL AREAS

Federal areas and facilities at MSP include Federal Aviation kAdministration (FAA), the U. S. Weather Bureau, and the U. S. Postal Service.

The FAA operates an Air Traffic Control Tower, VORTAC, and various other navigational aids such as instrument landing systems (ILS) and radar equipment. They also occupy several office areas providing service to the aviation community.

SUMMARY - MAC FACILITIES

Operation	Location	Site (Area)	Building Space
Office Building	West side of 28th Ave.	2.31 Ac.	43,024 SF
Snow Removal Equipment and Maintenance Materials Building	East Side of 28th Avenue	7.7 Ac.	Equipment storage 45,173 SF Material Storage 10,690 SF Pole Barn 5,600 SF
Boiler Plant - Serves FAA office bldg. Weather Bureau, CFR bldg. and Control Tower	Old Terminal Area	0.08 Ac.	1,500 SF
Storage Bldg. No. 16 - serves FAA (FSS), Viking, MAC storage and equipment overflow	Old Terminal Area	1.0 Ac.	22,600 SF
Paint Spray Bldg.	Old Terminal Area	0.06 Ac.	1,248 SF
Paint, Carpenter & Electrical Shop	Old Terminal Area	1.73 Ac.	1,600 SF
West Terminal Area Admin. Off. serves as maintenance and security office	Old Terminal Area	N/A	396 SF
Regulator and Emergency Generator Building	Old Terminal Area	N/A	480 SF

The Control Tower is located at 6311 34th Avenue. The building footprint is 0.09 acres and contains a total of 19,090 square feet. The VORTAC is centered in a circular site of 1,000 foot diameter having 4.5 acres of land. The building is a cone shaped facility providing very high frequency omni-directional radio equipment and tactical long distance navigational aid.

FAA office space is assigned as follows:

- ACDO (Air Carrier District Office) in Hangar No. 1 (6201 34th Avenue S., Second Floor) - 7,384 square feet.

- GADO (General Aviation District Office) near ACDO has 7,277 square feet, also on the second floor.

- FAA office building 6301 34th Avenue S.

District Office (ADO)	5,999 SF
Security Office	1,255 SF
Facilities and Equipment Installation Group	840 SF
Flight Service Station (FSS)	9,300 SF
Minneapolis Airway Facility Section	3,450 SF
TOTAL	20,844 SF

- Air Facilities Sector located on the second floor of Building 16, 8,810 square feet.

The U. S. Weather Bureau (National Oceanic and Atmospheric Administration) is located at 6301 34th Avenue South, Third Floor - 4,045 square feet, and Second Floor - 3,926 square feet.

The U. S. Postal Service is located on "D" Street off the main terminal entrance road. The building contains 52,310 square feet of space on a site of 3.69 acres and has direct access to the terminal apron on the north side.

FLIGHT KITCHEN

There is currently one flight kitchen located at MSP. The site is 3.6 acres and the building contains 78,189 square feet of total space (41,406 square feet on the first floor and 36,783 square feet on the second floor). The facility is located off 34th Avenue South, behind the Northwest Air Cargo Building.

COMMERCIAL/PUBLIC OPERATIONS

Commercial functions are variously located around the airport. Included are the Vocation Aviation Mechanics Training School; Northwestern Bell Telephone Company; dKavouras, Inc.; Univac Division of Sperry Rand Corporation; Metropolitan Transit Commission (MTC); Airport Medical Center; the Northern States Power (NSP) substation; and the Foreign Trade Zone.

MILITARY AREAS

Military activities occur at two areas of the airport. The first area is an island of land within the MSP boundary leased to the U. S. Navy. The site is located west of the old terminal area along 34th Avenue South between Runways 11R and 11L. It contains 21.4 acres of land on which eight buildings are located. The second area is on the north side of the airport and is leased to the U. S. Air Force. The area contains approximately 21 acres.

SUMMARY
COMMERCIAL/PUBLIC AREAS

Operation	Location	Site (Acres)	Function
Vocational Aviation Mechanics Training School	34th Ave. S. and Crosstown Highway	1.1 Ac.	Ground Training
Northwestern Bell Telephone Company	North of MAC office-28th Ave.	0.7 Ac.	Telephone System Eq.
Kavouras	In public parking area awest of Control Tower	0.16 Ac.	Storage & testing of satellite receiver stations & mobile meteorological stations
Univac	Weather Bureau Building	None (Floor space only)	--
MTC	Frontage Rd. at Cedar Ave. & I-494	12.6 Ac.	Bus Garage
NSP	East of NWA Main Base and old term. parking lot	0.9 Ac.	Electrical Power
Foreign Trade Zone	East of MTC Bldg.	5.42 Ac.	Pending

GH012E

Metropolitan Council of the Twin Cities Area
300 Metro Square Building, 7th and Robert Streets
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

DATE: April 6, 1988

TO: Alternative Land Use Panel

FROM: John Karl

SUBJECT: National Long Range Development Perspective

The assignment that you have agreed to take on requires looking into the future -- what type of reuse development could be carried out on a vacated MSP Airport site sometime after the Year 2000. First, to help you with your task, Dr. Royce Hanson, Dean, School of Social Sciences, University of Texas at Dallas will be our luncheon speaker. Hanson will observe the brainstorming sessions in the morning and will tie some of the ideas generated into his talk about urban development in the 21st Century. Dr. Hanson edited "Rethinking Urban Policy: Urban Development in an Advanced Economy" which was prepared under the auspices of the National Research Council and the Committee on National Urban Policy. He was project director for that multiyear, interdisciplinary study. Dr. Hanson was formerly associate director of the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota. A short summary of the book is attached for your information.

The second attachment on national development trends summarizes several articles in the Land Use Digest published by the Urban Land Institute.

GH012G

URBAN DEVELOPMENT IN AN ADVANCED ECONOMY
Royce Hanson
1987

- The transformation in the structure of the natural and international economies is remaking urban economies and revising the ways in which urban areas relate to each other.

- A new urban system has emerged characterized by polarization between relatively few large diversified "command and control centers" and the larger number of remaining "subordinate centers". Twin Cities of Minneapolis - St. Paul are one of the 19 Regional Diversified Command and Control Centers. As such it has a source of autonomy and power in dealing with its economic future.

- The size and diversity of the Twin Cities' industries and occupations have been built up over time and give the Region a relatively adaptable trained work force needed to attract promising industries.

- The Twin Cities is well positioned for the future foreseen in the study of urban areas. The study observes that a new generation of computer, energy, communications, bioengineering and other technologies complemented by the internationalization of business institutions and markets and by substantial demographic shifts and cultural developments is transforming cities to meet the needs of an advanced economy.

- While people and businesses have and will probably continue to decentralize, headquarters functions of the economy have been concentrating in the largest urban areas such as the Twin Cities. These "producer services" include highly specialized services in banking, law, accounting, advertising, and economic analysis. These services generate wealth by exporting knowledge and services to regional and international markets. They also have a multiplier effect on the rest of the economy.

- Urban development is the product of a guided market, an amalgam of private market choices and public policies. Because of its dependence on infrastructure, urban development is highly sensitive to policy decisions.

- Deregulation of airline travel has generally benefited command and control centers that have high-volume international airports and has caused some economic harm to subordinate centers which are harder to serve without the cross subsidy from bigger markets.

- As the knowledge requirements for both manufacturing and services grow, the quality of the labor force is of paramount importance.

- The development of a labor force prepared for work in an advanced economy would be the wisest investment in attracting growing sectors. In a knowledge-based economy, cheap labor is not as important as good labor.

- In an advanced economy, interlocal competition within a metropolitan area makes even less sense than it made in an industrial city setting.

- o Most command and control centers need good access to an international airport from a variety of activity centers containing headquarters and related services.

- o The command and control centers also need to be structured to facilitate access by advanced telecommunication systems including fiber optics and satellites. That structuring can occur by chance or be planned at the metropolitan scale and brought into being faster through coordinated development.

GH005Y

National Development Trends
Land Use Digest
The Urban Land Institute

Trends That Will Affect Industrial and Office Real Estate in the 21st Century

- Technology. Increased use of computers and improvements in communications may mean that more people will work at home, rather than in offices. The World Future Society predicts that by the year 2000, one-third of the workforce in industrialized countries will be "telecommuting," which will reduce the demand for office space significantly. Growth in biotechnical firms will create a need for office and industrial space especially suited for research, administration, and production.

- Economics. A continued shift from a manufacturing- to an information-based economy is predicted; 71 percent of the labor force is expected to be working in information-related jobs by 2000 (compared with 50 to 55 percent today). By then, only 11 percent of all jobs will be in manufacturing compared to 28 percent today.

- Urban development and land use. An important trend will be the redevelopment of offices in the fringe areas of central business districts, as well as the continued development of offices and mixed-use projects in suburban growth corridors. Rural areas will look more attractive to developers; public/private partnerships will become stronger; and approval processes will become increasingly complex and therefore costly, barring small developers and projects from participating.

- Taxation. Tax benefits of real estate investment will likely continue to decrease, while tax abatement to encourage development will probably increase. Assessments will probably be made more frequently.

- Financing Pension funds will increase their investments in real estate and in public real estate companies; limited partnerships will continue to grow.

- Building design. Technology for the communications age, including robotics, as well as flexibility for industrial space, will need to be taken into account.

- Markets and investment analysis. Due to the increased demand for properties and to greater efficiency, a potential exists for a national trading center, which will make it more difficult to find undervalued property. (The Appraisal Journal, January 1987; American Institute of Real Estate Appraisers, 430 North Michigan Avenue, Chicago, Illinois.)

Top High-Tech Growth Centers: 1980-1986

Metro Area	1986 Employment (000s)	Total Job Change: 1980-1986 (000s)	Average Annual Change: 1980-1986 (In Percentages)
San Jose, CA	234	49.8	4.5%
Boston, MA	175	36.9	4.4
Los Angeles, CA	297	25.6	1.6
Dallas, TX	96	22.5	5.1
Phoenix, AZ	69	17.7	5.8
Anaheim, CA	114	17.3	3.0
Seattle, WA	101	16.7	3.3
Washington, DC	34	14.0	11.6
Atlanta, GA	35	9.8	6.5
Nassau/Suffolk, NY	85	9.6	2.1
San Diego, CA	64	9.4	2.8
Philadelphia, PA	66	8.9	2.6
Tampa, FL	23	8.4	9.3
Minneapolis, MN	58	8.3	2.8
Ventura/Santa Barbara, CA	30	7.8	5.9
National	3,731	457.0	2.3

Source: Grubb & Ellis Research Services; Department of Commerce, Bureau of Labor Statistics

Strategies For Success in Urban Environmental Design

The decline in state and federal funding for urban development and the pressure from taxpayers to reduce local spending have caused cuts in planning staffs and increased cooperation between the public and private sectors. These changes present a different atmosphere for urban environmental design, yet the following strategies have remained constant for ensuring success:

- Prepare an agenda that identifies issues and establishes priorities; distinguish between long-short-term projects.
- Cultivate administrative and financial resources; nurture nonprofit organizations; tap private sector support; assemble a political coalition. For example, Pittsburgh's Action-Housing, Inc. a nonprofit group, originally administered the city's housing rehabilitation program.
- Find leaders who can envision "new realities" and maintain public support for a lengthy period, leaders who have credibility in the community.
- Identify the qualities that make a city unique-such as its history, commercial/industrial enterprises, geographical setting, or cultural makeup. For example, Baltimore's Inner Harbor area was once the center of the city's fishing and shipping industries.
- Integrate urban design with solutions to functional problems, such as mass transit or flood control. The "Riverwalk Canal" in San Antonio was built in conjunction with a flood control project.
- Be knowledgeable about successful environmental design programs in

- o Involve the community from the beginning, including the poor, elderly, and racial and ethnic minorities.
- o Be prepared for the project's implementation to take longer than expected; provide for "continuity" of effort.
- o Create a market (tourists, households, businesses) for the newly developed area.
- o Learn from past mistakes. For example, Boston's Copley Plaza was in part a result of the failure of the Park Plaza Project.

Minneapolis, Baltimore, Boston, Cincinnati, Dallas, Pittsburgh, San Antonio, San Diego, and Seattle are examples of "extraordinarily successful urban design programs." (The Journal of Architectural and Planning Research, September 1987; Locke Science Publishing Co., P.O. Box 146413, Chicago, Illinois 60614. The redevelopment stories of Boston and Pittsburgh, as well as St. Louis and Louisville, are told in ULI's book, Cities Reborn, published in 1987.)

Commercial Development and Major Airports

COMMERCIAL DEVELOPMENT NEAR AIRPORTS may have less to do with the airports themselves than with proximity to highways and rails, says Chuck Babb, of the Denver office of Bennett & Kahnweiler, a Chicago-based developer. Air shipping rates are less competitive than surface rates, and time is less of a factor when, as one corporate director of transportation says, Federal Express is available; "cheap land and a good employee base" are more important. On the other hand, developments near airports may be influenced by the character of the airport; congested airports may attract development to avoid problems of getting downtown (and back). Building near airports poses few problems, although height limitations and vibrations must be taken into account. Noise can be overcome by building parallel to the runways, says Victor Trapasso, president of GT Realty & Investment. Moreover, office and industrial parks at airports can benefit from the built-in surface transportation and the high visibility of a project. (Development Magazine, December 1987; National Association of Office and Industrial Parks, 1215 Jefferson Davis Highway, Arlington, Virginia 22201.)

Biotechnology and Real Estate Development

THE BIOTECHNOLOGY INDUSTRY COULD STRONGLY AFFECT REAL ESTATE DEVELOPMENT over the next five to 10 years. Grubb & Ellis recently analyzed the possibilities for growth and the future real estate needs of the biotechnology industry. Personnel in the field are expected to increase 25 to 30 percent annually. Two to 3 million square feet of new R&D space will be needed each year for the next five years, exclusive of support firms (that provide specialized instuments and equipment) and space for marketing and administrative operations.

Centers are typically located near large research universities (for example, in the Boston and San Francisco areas) or near drug firms and medical centers (in areas like New York, Connecticut, New Jersey, and Chicago). Emerging centers for the industry are notably Seattle/Bellevue, Washington; Austin/San Antonio, Texas; Minneapolis, Minnesota; Research Triangle, North Carolina; Atlanta, Georgia; and Denver/Boulder, Colorado. A survey of tenants revealed locational criteria important to biotechnological firms (see accompanying chart). (Market Trends, January 1986; Grubb & Ellis Company, One Montgomery Street, Crocker Center, West Tower, San Francisco, California 94104.)

Locational Criteria[1] for Biotechnology Industries

Large Companies

- o Proximity to government research labs, other well-established health care companies, and teaching or large community hospital.
- o Ample supply of qualified scientific, technical, managerial, skilled, and semiskilled workers.
- o Reputation of good labor relations.
- o Quality-of-life factors, including affordable housing, low real estate raxes, and wide range of cultural, recreational, and educational opportunities.
- o Pro business environment including favorable tax structures, tax incentives, progressive elected officials.
- o Sophisticated and efficient transportation network that provides easy access to protential site.
- o Relatively low local expense levels-wages, land, energy, and construction costs.
- o Master-planned land plan and environment.
- o Proximity to company's headquarters or abilaity to consolidate operations.
- o Established networking system with nearby universities.

Small Companies

- o Familiarity with area by partners or founders.
- o Accessibility to investors or venture capital groups.
- o Ability to expand
- o Proximity to qaulity university that can offer faculty, student, and equipment support.
- o Easy access to major highways and airport.
- o Availability of shared support service.
- o Favorable tax levels and availability of tax incentives.
- o Low-cost, strong potential workforce in region with minimal labor problems
- o Image area or address.
- o Affordable land, rent, and building costs.
- o Supportive community that encourages entrepreneurship.
- o Proximity to supplier and customer markets.

[1]Listed in order of significance.

Source: Grubb & Ellis Company Research Services Department.

Top 20 Apartment Growth Markets: 1980-1986

Market Area (PMSA)	Annual Average Absorption (Thousands of Units)	Annual Growth Percent
1. Dallas	19.4	7.7%
2. Los Angeles	19.4	2.0
3. Phoenix	18.6	11.9
4. San Diego	12.3	5.8
5. Atlanta	10.1	4.7
6. Houston	9.9	2.8
7. Fort Worth	9.8	11.1
8. Tampa	9.5	6.1
9. Riverside-San Bernardino	7.9	8.3
10. Seattle	7.4	4.5
11. Miami	7.1	2.6
12. Fort Lauderdale	6.4	3.2
13. Anaheim-Orange County	6.0	3.2
14. Denver	5.7	3.3
15. Oakland	5.2	3.2
16. Minneapolis	5.0	2.5
17. San Antonio	5.0	6.5
18. Boston	4.5	1.8
19. Washington D. C.	4.2	1.0
20. Sacramento	4.0	4.7

Source: Grubb & Ellis Research Services

Retail Sales Forecast

Total per Capita Retail Sales by Metro Area: 1991 Force
(In Thousands of Dollars)

Anaheim	10.7	Philadelphia	8.1
Boston	10.4	New York	7.8
Miami	10.2	Los Angeles	7.6
Minneapolis	10.1	Nassau/Suffolk, N. Y.	7.6
Washington D. C.	9.9	San Diego	7.6
Chicago	9.2	Pittsburgh	7.4
San Francisco	9.1	Houston	6.7
Atlanta	9.1	Kansas City	6.6
Cleveland	8.7	St. Louis	6.3
Dallas/Ft. Worth	8.4	Milwaukee	6.1
Detroit	8.4		
Newark	8.3		
Baltimore	8.2		

"Metropolitan Retail Forecast 1987-1991," published by Economic Perspectives, Inc. (EPI), of Delaware, Ohio. (Value Retail News, April 1987; 8800 49th Street, N., Pinellas Park, Florida

GH011N

Metropolitan Council of the Twin Cities Area
Mears Park Centre, 230 East Fifth Street
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

MSP Area Property Holdings

May 1988

Metropolitan Council of the Twin Cities Area
Mears Park Centre, 230 East Fifth Street
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

The attached map indicates the major property holdings for Minneapolis-St. Paul International Airport and other areas within the highway ringroad. Based upon the airport development alternatives being considered in the MSP Adequacy Study, it is apparent that airport area land use will play an important part in the decision process. For airport enhancement alternatives at the current MSP site, significant private and public land properties plus additional off-site parcels, will need to be acquired. For the landbanking and new major airport alternatives, the potential reuse of MSP and property ownership reversion issues become important.

The following listing indicates the ownership of alnd parcels and known instances of ownership reversion clauses when, under the property transfer agreements, the property is no longer used for aviation purposes:

1. Deed transferred from General Services Administration to MAC June 1974 (appropixmately 28 acres), and Jan. 1980 (approximately 9 acres)

   With the folowing agreement excerpt: Para. 6 NOW THEREFORE, by the acceptance of this Deed or any rights hereunder, the Grantee, for itself, its successors and assigns, agrees that the transfer of all the property transferred by this instrument, is accepted subject to the following restrictions set forth in subparagraph (a) and (b) of this paragraph, which shall run with the land:

   (a) that, except as provided in subparagraph (A) of numbered paragraph 7, the property transferred by this instrument shall be used for public airport purposes for the use and benefit of the public,...

   Paragraph 7.A that no property transferred by this instrument shall be used, leased, sold, salvaged, or disposed of by the Grantee for others than (sic) the airport purposes without the written consent of the Administrator of the FAA. The term "property" as used herein is deemed to include revenues or proceeds derived therefrom.

2. Deed transferred from U.S. Air Force to MAC December 1950 (approximately 26 acres)

   The property interest herein conveyed shall automatically revert to the United States pursuant to Section 16 of the Federal Airport Act, supra, in the event that the lands herein described are not developed, or cease to be used for airport purposes; and the party of the second part for itself and assigns, agrees by the acceptance of this deed, or the rights granted herein, that a determination by the Administrator of Civil Aeronautics, U.S. Dept. of Commerce, or his successor in function, that the lands have not been developed, or cease to be used, for airport purposes shall be conclusive of such fact.

3. Deed transferred from Veterans Administration to MAC June 1950 (approximately 421 acres) and December 1966 (apprxoimately 78 acres)

   The property interest herein conveyed shall automatically revert to the United States pursuant to Section 16 of the Federal Airport Act, supra, in the event that the lands herein described are not developed, or cease to be used, for public airport purposes; and a determination by the Administration of Civil Aeronautics, U. S. Dept. of Commerce, or his successor in function, that the lands have not been developed, or have ceased to be used for public airport purposes shall be conclusive of such fact.

4. Transferred from V.A. to the Navy (approximately 2.3 acres)

5. City of Minneapolis residential area Navy Annex (approximately 18 acres)

6. Transferred from V.A. to Army Reserve (approximately 61 acres)

7. General Services Administration (approximately 35 acres)

8. U. S. Air Force owned (approximately 233 acres)

9. V.A. to Mn/DOT (approximately 10 acres)

10. U.S. Air Force to Army (approximately 2.5 acres)

11. Transferred from V.A. to Navy (approximately 9.5 acres)

12. Veterans Administration (approximately 16 acres)

13. U. S. Bureau of Mines (approximately 5.5 acres)

14. V.A. to Minnesota State Park (approximately 141 acres)

15. Veterans Administration - Fort Snelling National Cemetary

16. City of Richfield residential area (Rich Acres) (approximately 14 acres)

17. City of Richfield residential area (New Ford Town) (approximately 90 acres)

18. City of Minneapolis residential area (St. Kevins) (approximately 15 acres)

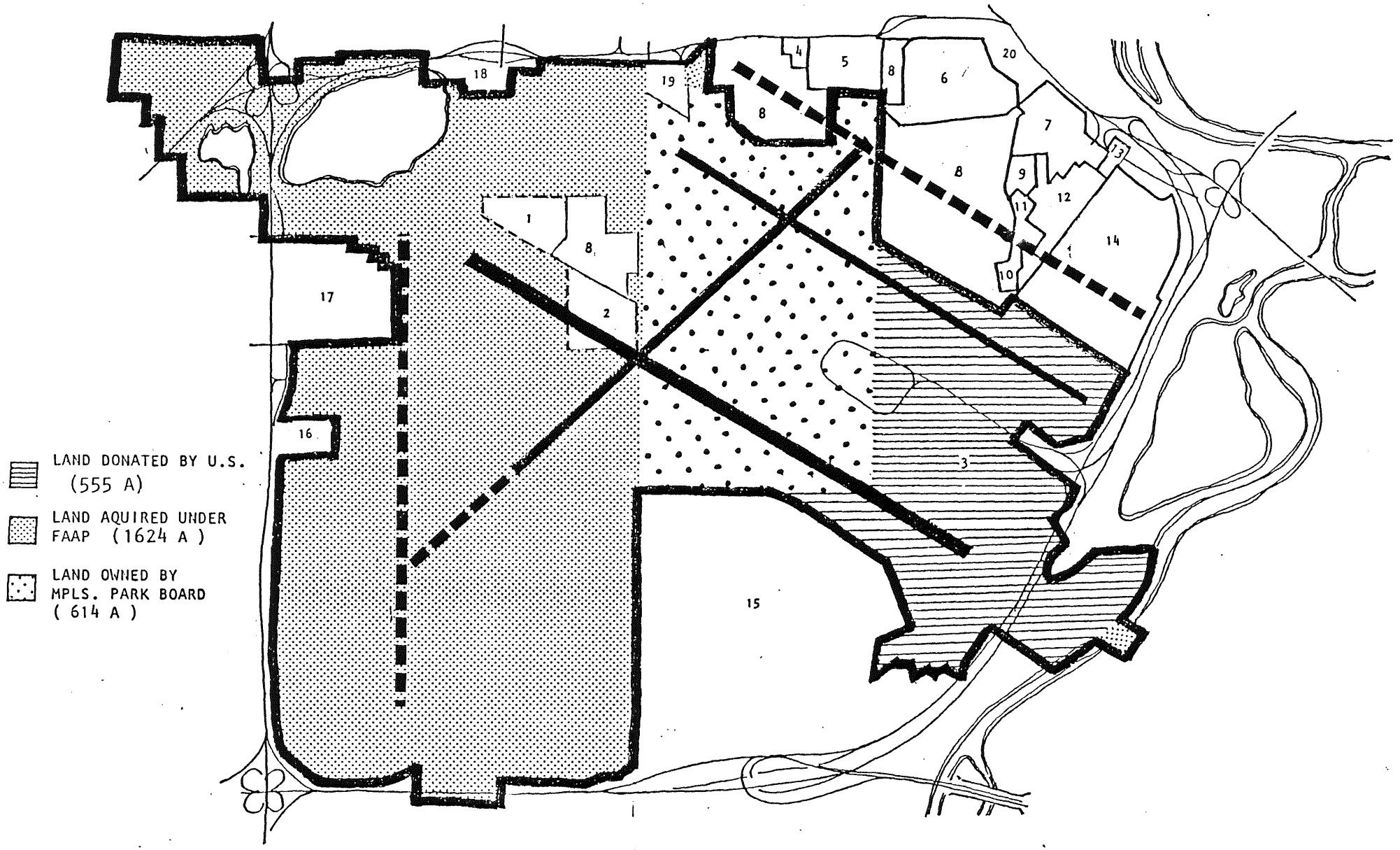
19. Navy to MAC (approximately 15 acres)

20. V.A. to Mn/DOT (right-of-way acreage not included in estimates)

NOTE: Under Minn. Statute 473.631 "the western boundary of any major airport located within Hennepin County shall not be extended by said corporation into the city of Richfield beyond Cedar Avenue as laid out as of the date of enactment of laws 1953, Chapter 715; provided that nothing herein shall be or constitutes a limitation upon the power of such corporation now or hereafter given, to zone said airport and lands adjacent thereto by the enactment of an ordinance or otherwise."

JM3065.PHTRN1@5

MSP AREA PROPERTY HOLDINGS



Metropolitan Council of the Twin Cities Area
Mears Park Centre, 230 East Fifth Street
St. Paul, Minnesota 55101 Tel. 612 291-6359/TDD 291-0904

Estimates of Potential MSP Development Costs Relating to Runway Clear Zones and Land Use Safety Zones

May 1988

Estimates of potential MSP development costs relating to runway clear zones and land use safety zones were developed according to existing land use impacts and whether the safety zones were to be applied to both new and existing runways; the cost of such policy approach has been shown previously in tables A and B.

The following diagrams show the general runway orientations and approximations of the various runway approach zones.

Diagram #1 shows the relationship of the runway to the FAA clear zones and Mn/DOT land use safety zones.

Diagram #2 depicts the existing runway layout of MSP with only the clear zones.

Diagram #3 shows the Enhanced A runway development scheme with clear zones and land use safety zones if applied to all runways.

Diagram #4 shows Enhanced B layout with safety zones depicted only for the new runways.

Diagram #5 shows Ultimate A development and safety zones only for the new runways.

JM3069.PHTRN1@5

Airport Zoning is Simplified to A, B, C in Minnesota

State Aeronautics Department develops formula that can be applied to any airport, any length runway

When the Minnesota Legislature passed a statute that required some evidence of an effort at zoning by local authorities in order to qualify for state airport aid funds, a number of questions immediately surfaced: How much land should be zoned for a given airport? How do you define the area to be zoned? How stringent should the zoning for any particular area be?

Out of the situation came a staff effort by the State's Department of Aeronautics, headed by Commissioner Lawrence E. ("Larry") McCabe. Principal developers of the solution, according to Commissioner McCabe, were staff men Dave Nybakken and Steve Gatlin. Their effort resulted in, first, a simplified formula for specifying the area to be zoned; and then a complete "package" to aid a local community in implementing the zoning requirement including draft resolutions and ordinances.

A, B, C Zoning

Larry McCabe explained the simplified formula as simply "three times the maximum contemplated length of the runway." This is the overall area to be zoned. This area is then subdivided into three zones — defined as A, B, and C.

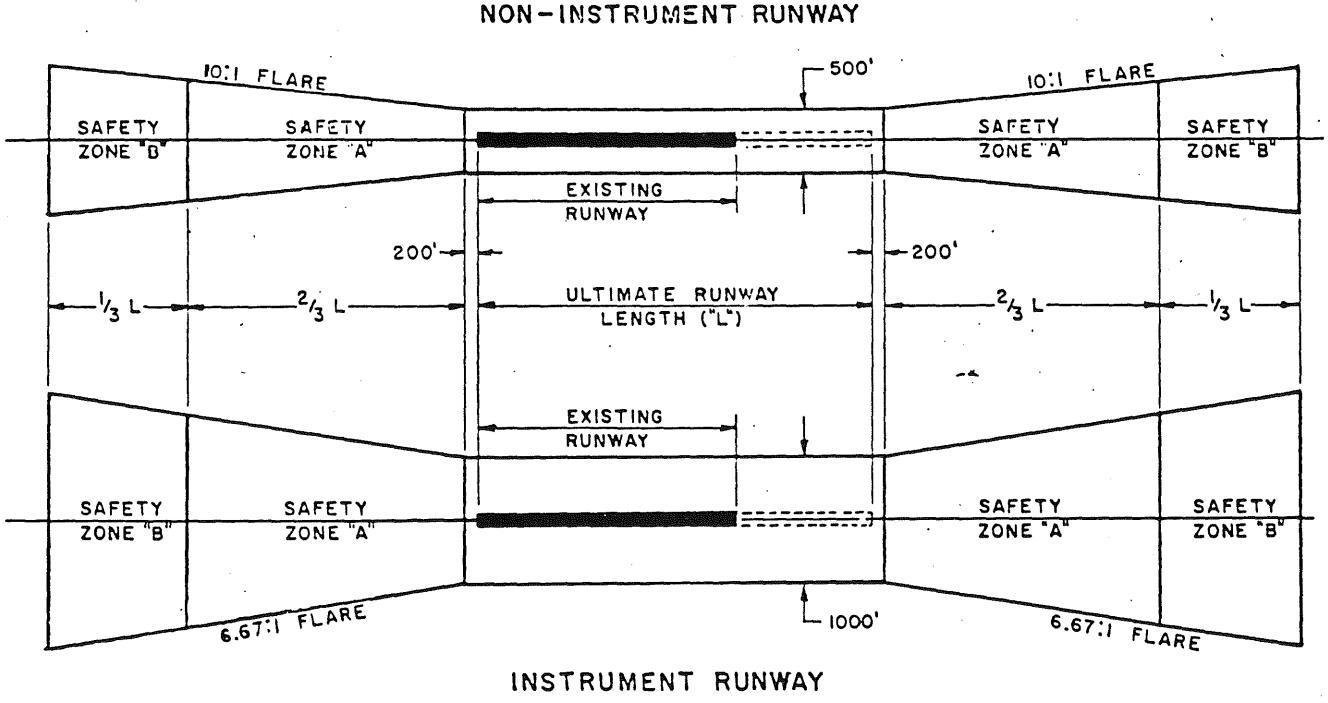
Both height of structures and types of land uses allowable are covered in all three zone categories.

Zone A is defined as "All land in that portion of the approach zones of a runway...which extends outward from the end of primary surface a distance equal to *two-thirds* of the planned length of the runway..." An area designated as Zone A should not have any buildings or structures, and the land use "shall be restricted to those uses which will not create, attract, or bring together an assembly of persons thereon. Permitted uses may include agriculture, light outdoor recreation (nonspectator), cemeteries, and auto parking," according to the suggested zoning ordinance.

Zone B begins at the end of A, and includes "All land in that portion of the approach zones of a runway...which extends outward from Safety Zone A a distance equal to *one-third* of the planned length of the runway..." Areas designated in Zone B may have structures on them, but each site must be at least three acres; only one building plot per site may be developed; and specific ratios are given for various size plots as to the building area and maximum site population. The idea, as Larry McCabe explained it, is "If a guy has an engine quit on takeoff, he's got plenty of room to miss buildings in a forced landing."

Specifically prohibited in Zone B are churches, hospitals, schools, theaters, stadiums, hotels and motels, trailer courts, camp grounds and other places of public and semipublic assembly. Also, nothing should be permitted that will bring together a site population that would exceed 15 times the site acreage.

Zone C restrictions are somewhat more flexible: it includes land enclosed within the perimeter of the horizontal zone of the airport, defined in a separate subsection, and which is not included in A or B. There are some height restrictions as noted below, but the land use restrictions are generalized as: "No use shall be made of any land in any of the safety zones...which creates or causes inter-



Dimensions of Land Use Safety Zones A and B are shown, without scale, on this drawing. Zone C encompasses both A and B zones for all runways on the airport.

ference with the operations of radio or electronic facilities on the airport or with radio or electronic communications between the airport and the aircraft, makes it difficult for pilots to distinguish between airport lights and other lights, results in glare in the eyes of pilots using the airport, impairs visibility in the vicinity of the airport, or otherwise endangers the landing, taking off, or maneuvering of aircraft."

The simplifying key to the application of the three-zone system is, of course, that it adapts to any airport and any runway configuration. The only real decision is what the ultimate contemplated length of a runway will be or could be.

Height restrictions

A separate subsection of the suggested ordinance provides an above-ground "ceiling" profile for allowable ground structures. This is based again on the three zone layout of the safety areas — going up as the distance from the runway increases. The proposed wording says that "no structure or tree shall be constructed, altered, maintained, or allowed to grow in any airspace zone...so as to project above any of the imaginary airspace surfaces described..."

Provisions are made in the suggested ordinance for granting variances, but based on experience in Minnesota, Larry McCabe cautions: "Watch out for granting variances. When you grant one you immediately open yourself up for pressure to grant others. Precedent can blow the whole idea."

It should also be noted that the idea of the "ceiling profile" is not to create a TCA over the airport. It does not regulate the airspace above — it protects it from incursions from the ground below.

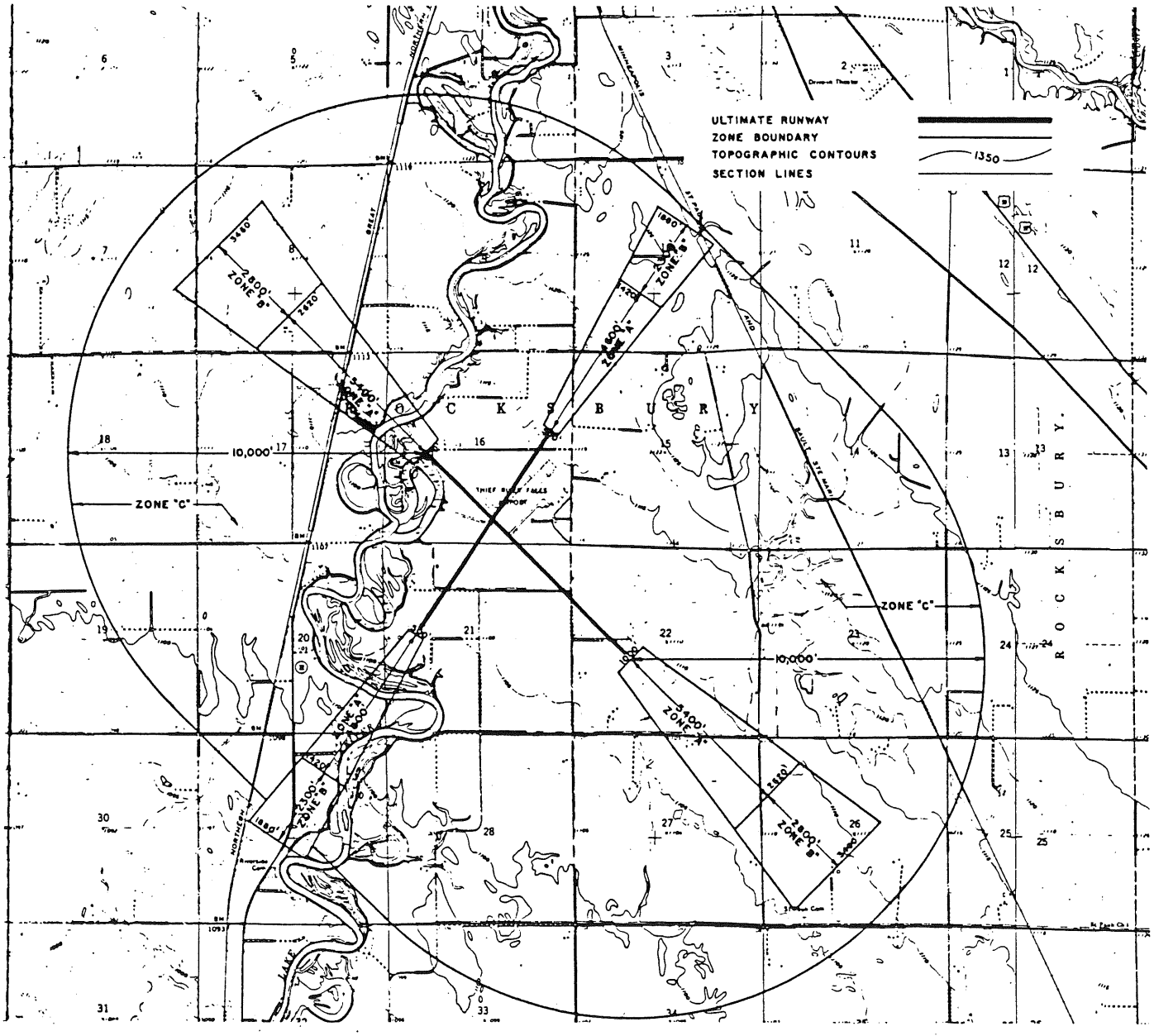
Applying the Zone Concept

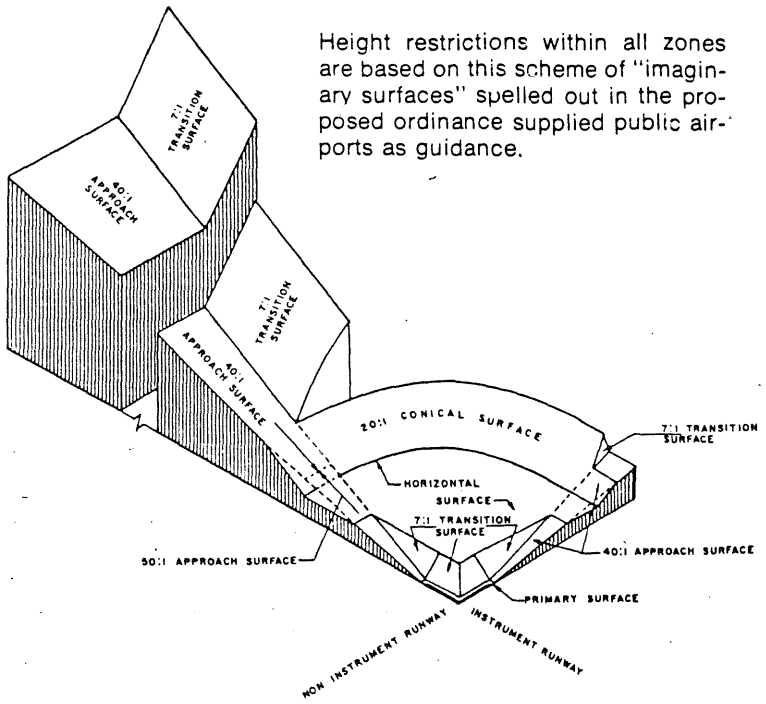
The three-zone concept does work to protect airport airspace. Applying the concept, however, is not always easy. Larry McCabe suggests the following:

"The best way to protect the airport," he says, "is to own the property. If you can't own it all, then at least try to own Zone A. For Zone B, get easements to the ground. This allows you to grow crops on it, and it lets you control the height of anything else above it. For Zone C, it is probably enough to be able to zone for height and land use."

(A test case is in a County District Court on the right of the Mankato, Minn., airport to put an "A" zone into

Minnesota's "A,B,C" airport land use zoning scheme as applied to the airport at Thief River Falls, Minn. The large oval is the boundary of Zone C.





Height restrictions within all zones are based on this scheme of "imaginary surfaces" spelled out in the proposed ordinance supplied public airports as guidance.

force on existing farm property. The case is looked upon as a test, and all parties involved are reported to be amicable. The zoning board in question is on record as being in favor of paying the farmer damages for not allowing him to develop the 15-acre tract.)

Program Moves Slowly

Out of Minnesota's 140 public airports, 138 of them have demonstrated some interest in zoning since the 1973 Legislative requirement went into effect. "Over 91" zoning authorities have been established — the figure isn't definite because the State Aeronautics Department isn't sure that it knows of all of them.

So far, 60 proposed ordinances have been reviewed by the Department and, of these, 38 have been approved and sent back for local reviews. Of these, 25 have been completed and are in effect.

The fact that the program is not moving faster is simply the limitations of manpower in the Department of Aeronautics. "It takes a lot of meetings," says Larry McCabe, and his staff does not have the time available to promote the program.

The State's statute also has some glitches in it, and modifications have been requested of the current Legislature. These are considered to be primarily minor changes in wording, and no great difficulty is expected in getting them made. One example is that the way the law reads now, it is difficult to set up joint zoning boards where more than one local authority may have some jurisdiction over airport land zones.

But the Minnesota "A,B,C" system of zoning is being looked at by both other states and the FAA as providing a simple way to make order out of chaos on a tender subject: zoning the airport to protect its airspace.

Minnesota's Recommended Procedures for Establishing Airport Zoning:

1. Municipality requests county, in writing, to join in creating a joint airport zoning board per State statutes.
2. Municipality and county each pass a resolution creating the joint airport zoning board and appointing two representatives each *pro tem.*
3. Appointed members elect another member to serve as chairman.
4. Zoning board, working with an attorney and an engineer, creates a draft ordinance and map. (State supplies models of these.)
5. The draft ordinance is submitted to the Minnesota Department of Aeronautics for review and approval. Approval will be in the form of an order stating that the ordinance conforms to the minimum standards prescribed.
6. After receipt of State approval, the board passes a resolution declaring the ordinance to be their proposed ordinance, setting a date and place for public hearing and instructing the publication of the proposed ordinance.
7. A hearing is held, following which the board either passes a resolution that the ordinance has been adopted as the final airport zoning ordinance, or amending the proposed ordinance and declaring that to be the new proposed ordinance. (Another public hearing need not be held unless changes are very substantial.)
8. The adopted ordinance must be filed with the County register of deeds per Minnesota statute.
9. Documentation is then submitted to the Department of Aeronautics.

Socio-economic Impact of Airports Reported in Minnesota Study

The impacts of the airports serving three selected communities in Minnesota have been studied by David Braslau Associates, Inc., in cooperation with Howard, Needles, Tammen, and Bergendorff, for the Minnesota Department of Aeronautics.

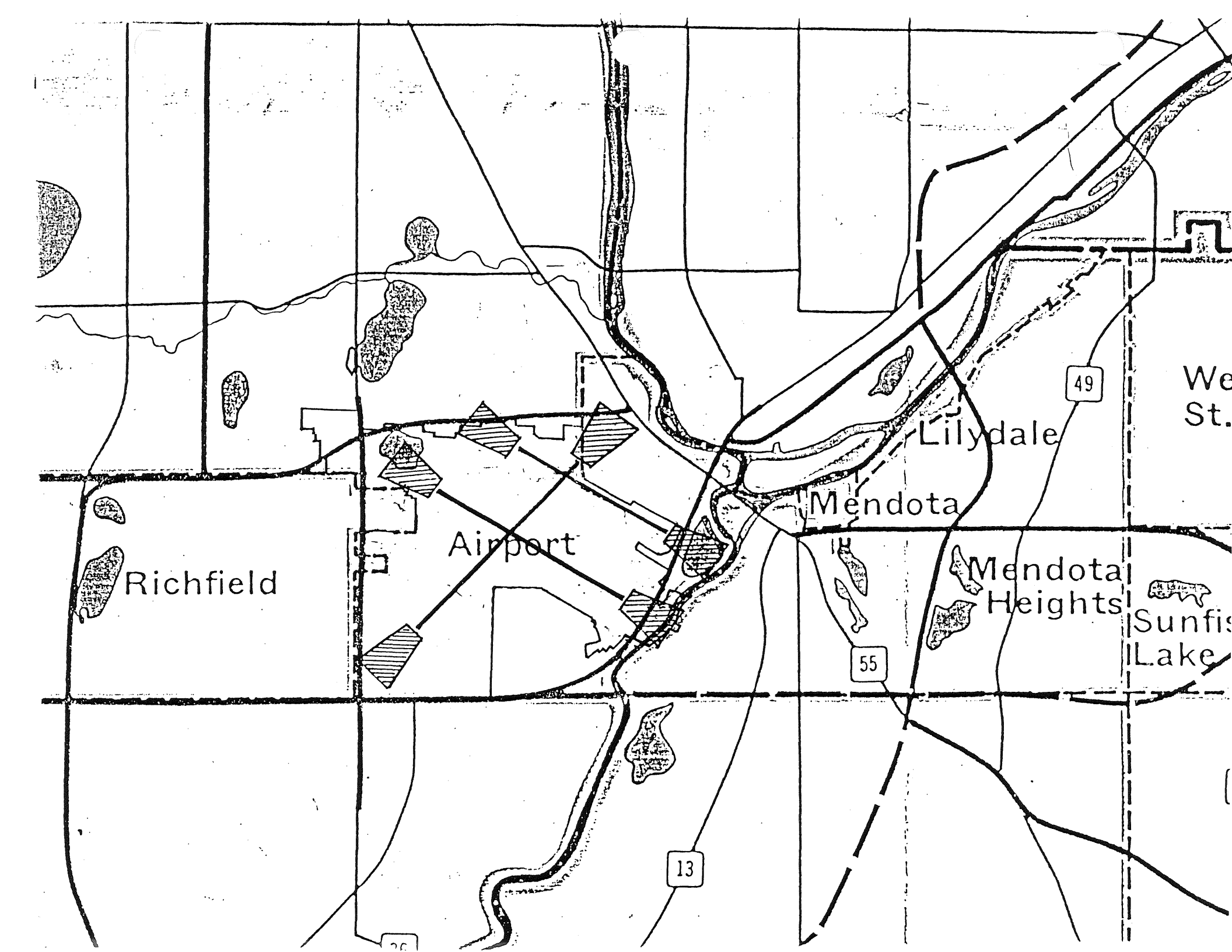
The three communities were selected to represent diverse economic regions of the state having typical airport facilities. Thief River Falls, in the Northwestern Region, and Duluth, in the Arrowhead Region, both have scheduled air service. They differ in that the former serves as a market center in a primarily agricultural region, while Duluth is in a Standard Metropolitan Statistical Area. Austin, in the Southeastern Region, is served only by general aviation.

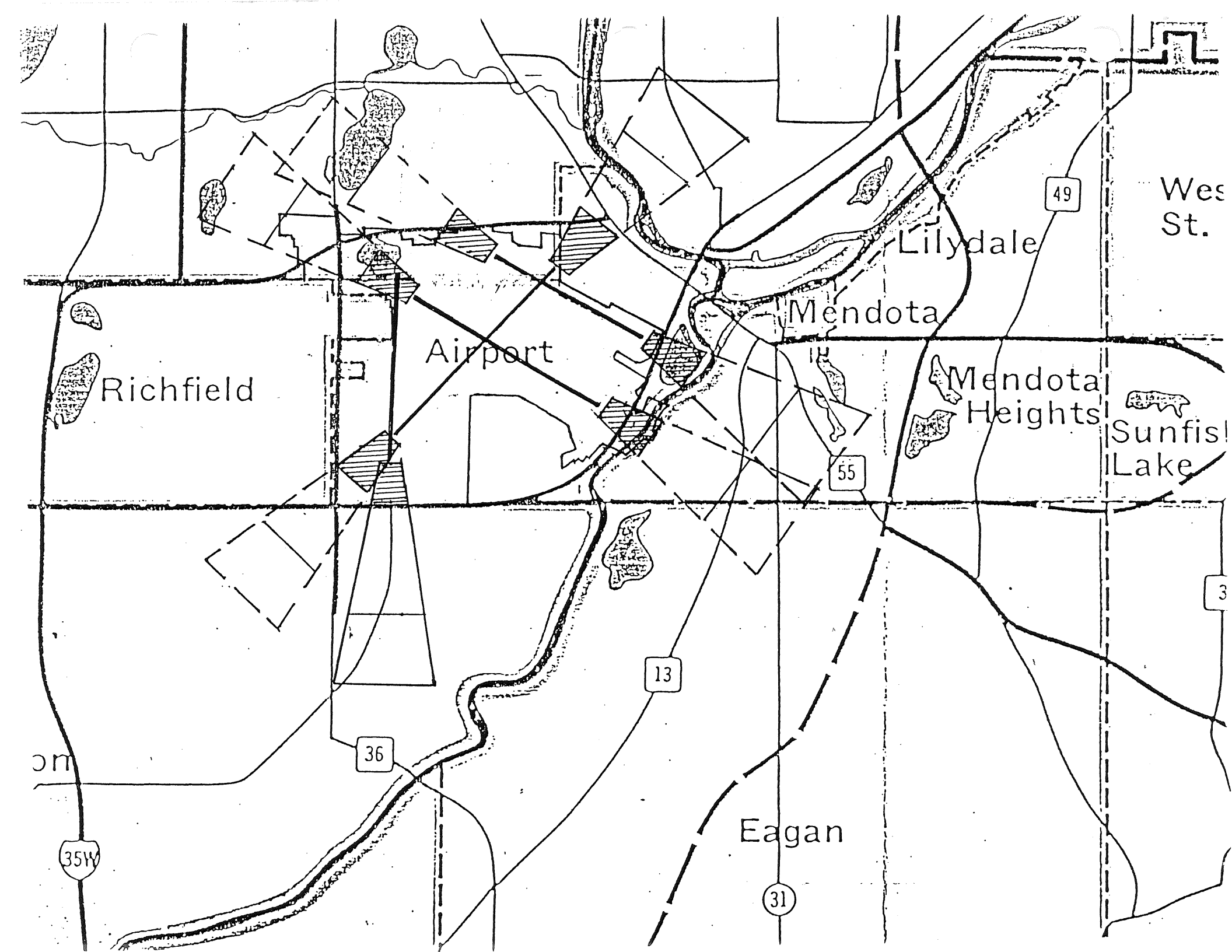
Air passenger surveys were distributed to boarding passengers for one and two-week periods. General aviation survey techniques varied for the three airports; a 55 percent response was achieved at Duluth. Major industrial and institutional users of aviation were also interviewed to define the role of this mode of transportation in company location and operations.

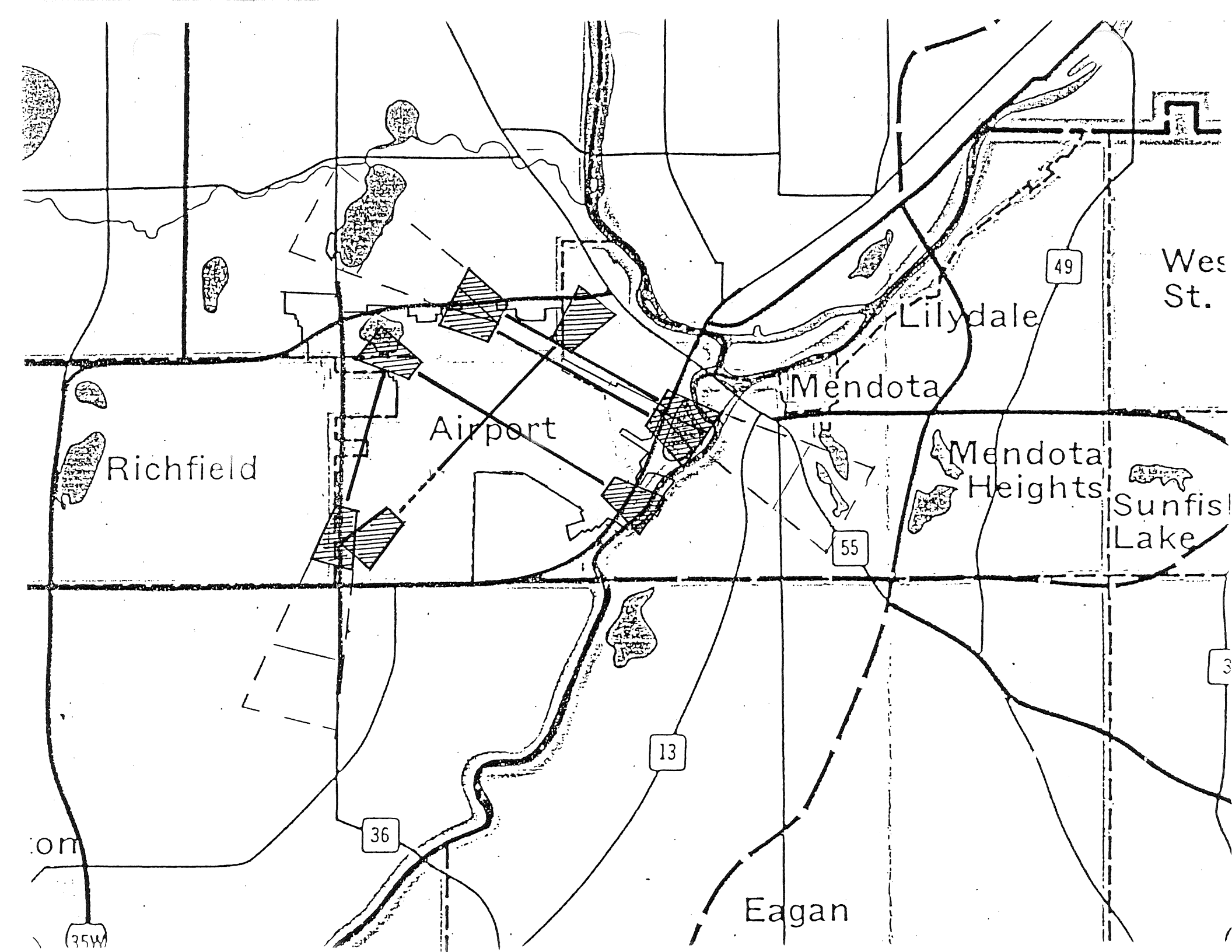
Economic results revealed direct impacts ranging from $500,000 at Austin to $6.5 million at Duluth, including both primary and secondary incomes, but not including airport-related military pay and procurement of $23 million in the Duluth area.

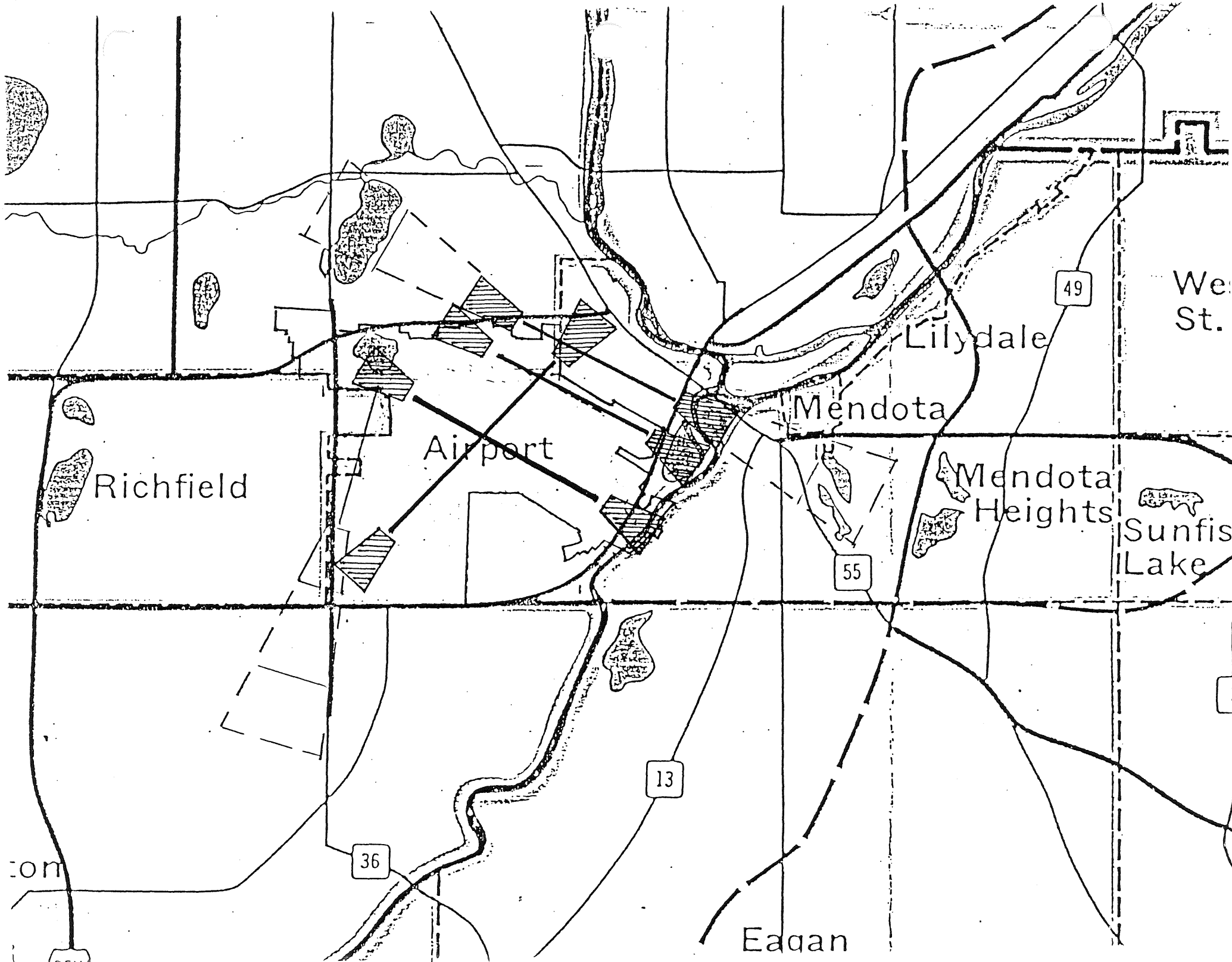
An Executive Summary of the study covers survey methods used with relevant conclusions regarding types of airport facilities needed to respond to community economic development desires.

Single copies of the Executive Summary of "A Study of the Socio-Economic Impact of Aviation on Selected Minnesota Communities" may be obtained by writing: Minnesota Department of Aeronautics, Administration Building, St. Paul Downtown Airport, St. Paul, Minn. 55107.


Richfield
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Mendota Heights
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Richfield
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Mendota
Airport
Richfield
Mendota
Heights
Sunfish
Lake
Eagan
49
55
13
36
35W


Richfield
Airport
Lilydale
Mendota
Mendota Heights
Sunfish Lake
Eagan
49
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36

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

A PRELIMINARY ANALYSIS OF NEW AIRPORT DESIGN CONCEPTS

JUNE 1988

Prepared By:



APOGEE RESEARCH

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CH2M HILL

Enviroscience

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INTRODUCTION

Previous working papers have established several options for expanding the capacity of the existing MSP Airport site. This paper places these options in the broader context of potential new sites. The paper draws on the deliberations of the New Airport Design Concepts Panel that convened May 18-19, 1988 at Metropolitan Council offices in St. Paul. Panelists are listed in Appendix A.

The paper proceeds in three sections. The first section reviews key considerations in evaluating new site options and defines four possible prototypes. The second section estimates the probable land requirements of prototypes. The third section presents some preliminary estimates of their cost.

PRINCIPAL CONSIDERATIONS

Three questions are central to the consideration of new site prototypes, the choice of planning horizon; capacity; and the general configuration of facilities.

Choice of Planning Horizon

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

As the planning horizon is extended toward 2020, the analysis indicates a high probability that the current site will be insufficient to meet demand. Even the Ultimate A option, the most extensive runway capacity available on the current site, provides only a 40% probability of sufficient capacity over the longer 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 with the existing site.

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[1]The ability of an option to meet capacity is a probability rather than a certainty because future air traffic and technological capabilities cannot be forecast with certainty. The calculated probabilities are based on past trends and expert opinion combined using a "Monte Carlo" procedure. For a full description of this methodology, see MSP Airport Adequacy Study: Forecast Methodology and Findings, May 1988.

TABLE 1:

PROBABILITY OF ADEQUACY IN
MEETING PEAK-LOAD CAPACITY REQUIREMENTS
(In percent)

OPTION	YEAR 1998	2008	2018
Base Case	2	1	4
Enhanced A	18	18	9
Enhanced B	73	64	25
Ultimate A	92	87	40

Choice of Capacity

Given the planning horizon outlined above, the design of prototype capacity options for a new site was governed by two principals:

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

Options were developed without reference to or expectation of a particular site location.

The expert panel concluded that;

- Parallel runways would be most the most effective operating configuration; and
- Capacity requirements would likely be met by either 3 independent runways or two pairs of dependent runways.

The panel's deliberations lead to the definition of five options (illustrated in Figure One):

- **Twin Dual Runways.** Two parallel pairs of dependent runways each 10,000 feet in length, and a 100 gate terminal complex;
- **Three Independent Runways.** Three parallel independent runways each 10,000 feet in length, and a 100 gate terminal complex;

- o **Three Dual Runways with Crosswind Runways.** Two parallel pair of dependent runways each 10,000 feet in length, with two crosswind runways each 6000 feet in length, and a 100 gate terminal complex; and

- o **Three Independent Runways with One Crosswind Runway.** Three parallel independent runways each 10,000 feet in length, a 100 gate terminal complex and a single 6000 feet crosswind runway.

- o **Remote Terminal.** Any of the above runway configurations with remote terminal facilities retained at the existing MSP site (and diminished terminal facilities at the new site). Rail service would connect the remote terminal facilities with the new site facilities.

  In discussing the options for a remote terminal facility, experts believed that some baggage handling, car rental and other services would be required at the new site as well. In particular, panelists believed that without on-site conveniences, MSP would lose its competitive edge and airlines and passengers would be drawn to other airports in the region.

The boundaries of the sites shown in Figure 1 represent the immediate area requirements for the runways, clear zones, and terminal. Since this land is only sufficient for air traffic projected to 2008, additional land for expansion was included in the cost of the options (see below).

The additional land was sufficient to accommodate two additional 10,000 foot runways, parallel to the planned runways at a separation of 3,000 feet.

LAND REQUIREMENTS

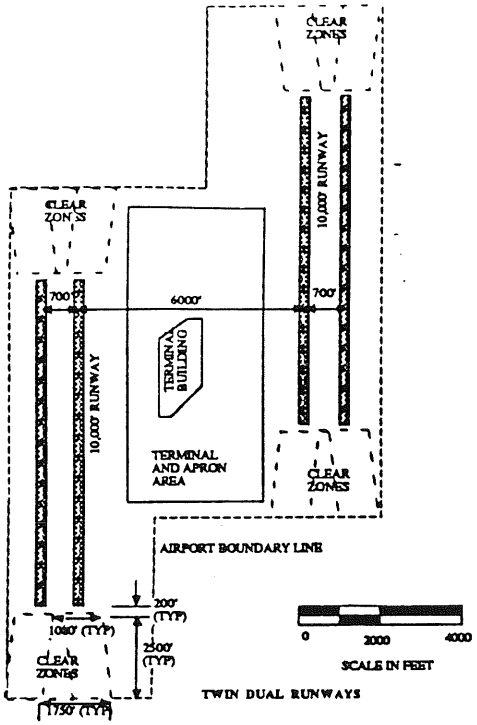
Table 2 shows the land requirements for each option. The first column shows the minimum requirement to build each option, as illustrated in Figure 1. The second column adds 2121 acres to accommodate future expansion. The 2121 acres is sufficient for two more 10,000 foot runways parallel to the initial runways with a separation of 3000 feet. These runways might be built at a later period to accommodate additional demand in the years after 2008.
The third column adds land requirements estimated to be necessary to contain the heaviest noise areas within the site boundaries. This is a separate possibility that might be considered. The land requirements were estimated to enclose the 65 Ldn (a noise measure) contour around the initial runway configurations depicted in Figure 1. The third column does not include sufficient land to enclose a 65 Ldn contour for the two additional runways accounted for in column 2. In total, the third column has land sufficient to enclose the initial runways, the 65 Ldn contour for initial runways, and land for future expansion.[2]

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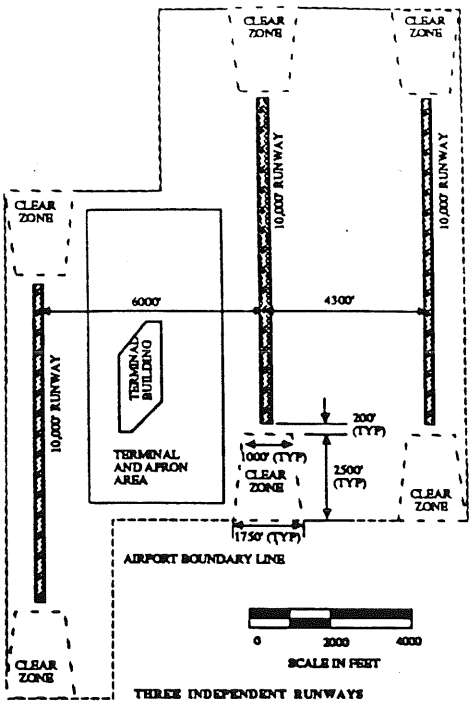
[2]The area required for the 65 Ldn contour was estimated by taking the size and shape of the contour for the current site, and applying these to the new designs. Information on MSP's current contour was taken from Environmental Assessment; Runway 4-22 Extension; Minneapolis St. Paul International Airport, Final Draft Report, Metropolitan Airports Commission.

FIGURE 1: OPTIONS FOR THE USE OF ALTERNATE SITES

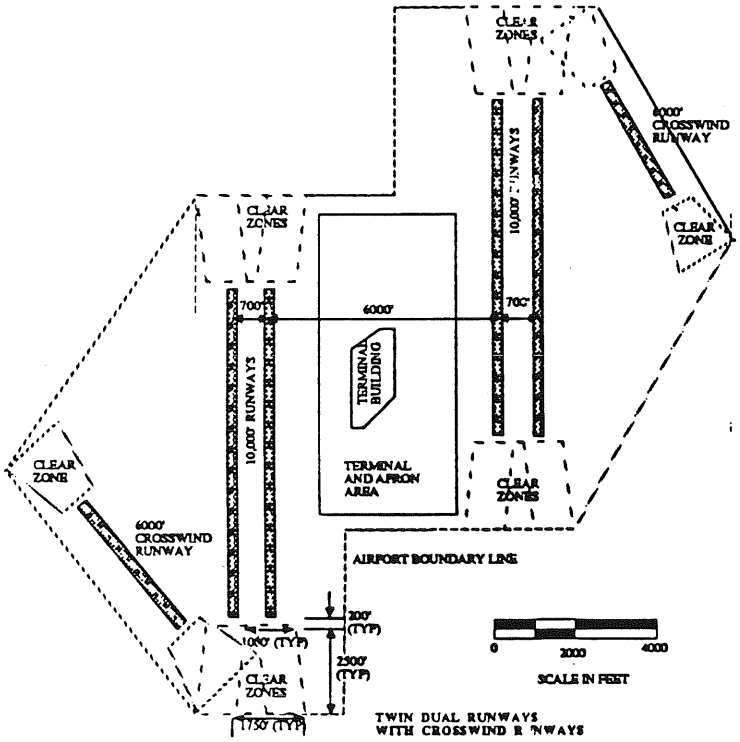
(PRELIMINARY)



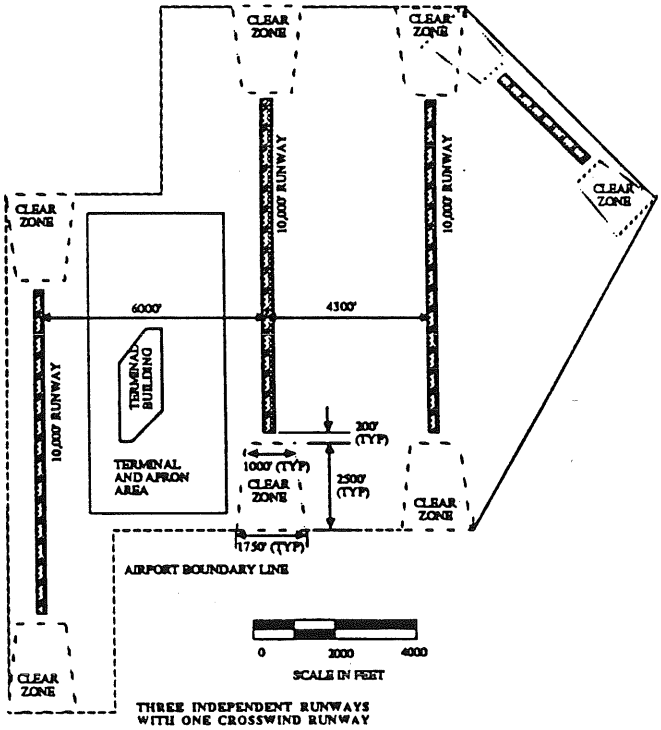
TWIN DUAL RUNWAYS



THREE INDEPENDENT RUNWAYS



TWIN DUAL RUNWAYS
WITH CROSSWIND RUNWAYS



THREE INDEPENDENT RUNWAYS
WITH ONE CROSSWIND RUNWAY

TABLE 3- ALTERNATIVE COST COMPARISON
(Millions of 1987 U.S. Dollars)
(PRELIMINARY)

COST CATEGORY	ALTERNATIVE SITE OPTIONS			
	TWIN DUALS	THREE INDEP.	T. DUALS & 2 CW	3 INDEP. & 1 CW
Property Acquisition; Immediate	21.2	28.7	38.9	38.4
Property Acquisition; 2018 Expansion	3.7	3.7	3.7	3.7
Site Preparation	205.5	277.8	376.3	371.7
Airfield Development	144.8	108.6	188.3	130.3
Ground Transportation	182.7	188.2	194.7	194.4
Terminal Facilities	320.0	320.0	320.0	320.0
General Aviation	0.4	0.4	3.5	3.5
Support Facilities	92.5	92.5	92.5	92.5
Federal Facilities	31.0	31.0	31.0	31.0
Microwave Landing System	N/A	N/A	N/A	N/A
TOTAL	**1001.8**	**1050.9**	**1248.9**	**1185.6**
Adjustment for Land Acquistion of Ldn 65 Contour--Obstructed Land**	5.1	9.0	7.2	10.5
TOTAL WITH CONTOUR--OBSTRUCTED LAND	**1006.9**	**1059.9**	**1256.2**	**1196.1**
Adjustment for Land Acquisition of Ldn 65 Contour **	-13.9	-18.2	-26.5	-29.1
TOTAL WITH CONTOUR--CLEAR LAND	**987.9**	**1032.7**	**1222.4**	**1160.1**
Add'l cost of Remote Terminal ***	+220.3	+220.3	+220.3	+220.3

** "Obstructed Land" shows the cost of additional land using the same cost per acre as in the primary case. "Clear Land" uses a cost of $1750 per acre and assumes no allowance for relocation or purchase building in surrounding areas. Under these restrictive assumptions, land cost is lower despite greater area. See text for elaboration.

***The additional cost of a Remote Terminal is calculated by reducing the cost of the new terminal ($320 Million) by one third, and adding $327 Million for a fixed rial shuttle link.. The net additional cost is 327-(320/3) or $220.3 Million.

Table 2

LAND REQUIREMENTS
(Preliminary)

Option	2008 Requirements (acres)	2018 Requirements* (acres)	2008 Requirements for Area within Ldn 65 Contour (acres)	2018 Requirements for Area within Ldn 65 Contour (acres)
Twin Dual Runways	3119	5240	6311	10603
Three Independent Runways	4215	6336	8139	12235
Twin Dual Runways with Crosswind Runways	5711	7832	9164	12567
Three Independent Runways with One Crosswind Runway	5640	7761	9695	13341

* An area of land 3000 feet either side of the 2008 site requirements was added to the immediate site requirements.

RELATIVE COST OF OPTIONS

Table 3 summarizes preliminary cost estimates for each of the options. There is one column for each of the potential runway configurations. Each runway option for a new site offers three totals based on alternative assumptions:

- **Total.** Assumes that only minimum land requirements are purchased. The cost per acre of land employed in this scenario includes an allowance for relocation and the elimination of some structures in surrounding areas.

- **Total With Contour -- Obstructed Land.** Assumes that land sufficient to contain the 65 Ldn noise contour is purchased. (Column 3 of Table 2). The same cost per acre of land is used as in the above case.

- **Total With Contour -- Clear Land.** Assumes that the land purchased is bought at a straightforward average market price of $1750 per acre. No allowance is

made for relocation or elimination of structures in surrounding areas. This option is highly dependant on the availability of land which is clear of residences and institutional structures.

In addition, the possibility of using a remote terminal was considered. This sub-option accounts for making use of the existing MSP terminal facility as a "land-side" facility. It would be connected to an "air-side" facility at the new site by a rail link assumed hypothetically to be 6 miles long (Actual length would vary depending upon site location). This option would be considered if planners wish to preserve the use of the infrastructure surrounding the existing MSP airport (roads, hotels, etc.).

Accuracy of Estimates

The costs developed here are preliminary. Details of the costing assumptions are given in Appendix A. For the most part, costs have been developed by scaling and adjusting the cost of an airport currently planned for Austin, Texas. The estimates incorporate a 10% contingency factor with all construction costs and an additional 19% to account for design and administration. No attempt was made to incorporate site-specific considerations, since an alternative site has not been selected.

The Appendix describes the cost categories used, the activities comprising each cost category and any factors which have a bearing on the accuracy of the estimate. The reader should examine the Appendix carefully in order to gain an appreciation for the limitations and applicability of the estimates.

APPENDIX A

COSTING METHODOLOGY

This appendix describes the methodology used in developing the cost estimates shown in Table 3.

Note that no attempt has been made to incorporate off-site costs. For example, the costs of creating highway links to the new site, the costs imposed on private owners of infrastructure dependent on the current airport location, and the effect of a new location on travellers' time have not been considered.

In addition, no allowance has been made for site-specific complications.

COSTING ALTERNATIVE SITE OPTIONS

Costs of the four alternative site options (Twin Dual Runways, Three Independent Runways, Twin Dual Runways with Crosswind Runways, and Three Independent Runways with One Crosswind Runway) fall into eight categories:

Property Acquisition;
Site Preparation;
Airfield Development;
Ground Transportation;
Terminal Facilities;
General Aviation;
Support Facilities; and
Federal Facilities.

Each category is described separately in terms of the activities which comprise it, the method of costing, and any perceived shortcomings of the estimate.

In addition there are adjustments to be made for the possibilities of

Acquisition of Land for 65 Ldn Contour
Use of Remote Terminal

These are also discussed below.

Property Acquisition

This activity includes the purchase of the necessary land, relocation of existing residents, and the acquisition of building improvements on all other property within the areas of proposed land-use compatibility control. All associated costs such as appraisal fees and title insurance are also included. The cost of this item is very sensitive to site location since property values vary depending upon location and the current use of the land. Fairly extensive relocation of residences was required for the Austin Airport. The cost of this activity for the MSP Airport was developed by using land cost estimates for the proposed area and adding an amount for relocation

and other acquisition costs by scaling the Austin Airport costs by site area. Land cost estimates for the MSP area are from $1000 to $2500 per acre. An average figure of $1750 was used.

The estimate is also uncertain in that it assumes the same number of private residences and businesses per acre must be relocated as is planned for Austin. For example, the Austin airport plans call for a total land area of 3460 acres (one half to one third the MSP land acquisition), and included the purchase of 75 residential properties.

Site Preparation

This activity includes the physical removal and relocation of existing facilities, earthwork, drainage and pump station, and utilities. These costs are scaled from the Austin Airport estimates by the ratio of site areas. The cost of the removal and relocation of facilities depends upon the number and type of facilities to be relocated. However, since this activity contributes only a small amount to the total category cost, inaccuracy is unlikely to introduce significant error in the bottom line. The earthwork component is sensitive to site location since it is affected by such things as soil quality and site flatness. Unfortunately, site specific inaccuracies are unavoidable.

Airfield Development

Airfield development costs include all costs associated with paving and lighting the runways, taxiways and aprons. This category cost was scaled from the Austin Airport estimates by the ratio of linear feet of runway.

Ground Transportation

This category includes costs associated with roadways and parking areas on the airport. Rental car facilities have also been included. Projected cost estimates for MSP were prepared by first breaking the Austin Airport costs into service road costs and parking costs. The parking cost component was scaled by the ratio of terminal gates. The service road cost component was first scaled by the square root of the ratio of site areas, to reflect a relationship with the linear dimensions of the site. Next, an arbitrary 50% was added to reflect the fact that the traffic carried by these service roads will increase in proportion to airport activity, which is a larger ratio than the square root of the ratio of site areas.

Terminal Facilities

This category involves the construction of the terminal facilities and includes airline space, concession space, public space, administration/operation, utilities and cargo facilities. The cost of this category was scaled from the Austin Airport by the ratio of the numbers of terminal gates. Austin is planned for 40 gates, while the MSP alternative site options are planned for 100.

General Aviation

The probable cost of providing general aviation facilities was scaled from the Austin Airport estimates using the ratio of projected general aviation operations in the year 2006. This scaled cost was applied to the two options involving crosswind runways. Options without cross-wind runways were assumed to incur only 10% of the cost of GA facilities attributed to options with crosswind runways.

Support Facilities

This cost category includes the following airport support facilities:

airport administration/maintenance;
airfield operations;
central plant; and
crash, fire and rescue facilities.

The cost of this category was scaled from the Austin Airport estimates using the ratio of the number of terminal gates.

Federal Facilities

This category includes a U.S. Weather Bureau Office, National Guard facilities and various FAA facilities. The same cost used in the Austin Airport estimates was used for the MSP projections.

The Remote Terminal Option

Two cost adjustments are necessary to account for the remote terminal option. The first is the reduction in the size of the terminal to account for the space requirements satisfied by the current terminal. An arbitrary 1/3 reduction in cost of the terminal was allowed. The second adjustment is to add the cost of a fixed rail link between the old and the new terminals.

A cost estimate for 6 miles of fixed rail shuttle link and associated cars has been prepared. This estimate is based upon a similar but lower capacity rail link currently under construction at Orlando International Airport. The Orlando rail link is a Westinghouse "People-Mover" 2000 feet in length, with a one way trip time of about 90 seconds.

There are significant uncertainties concerning the cost of this item. The cost of extending Orlando's system to 6 miles would be less than proportional to the length, since a substantial portion of the cost must be fixed. However, the duration of a 6 mile trip would be about 24 minutes at the design speed. Clearly, an MSP rail link would require a faster system with higher capacity. In addition, there is the question of acquiring the necessary right of way and any site preparation for track laying. In view of these uncertainties, a cost projection for the MSP rail link was

developed simply by scaling the Orlando rail link cost by the ratio of linear feet of track.

Orlando Cost	Track Length Ratio	Projected MSP Cost
23.5 million x	15.84	= 372 million

Adjustment for Land Acquisition of Ldn 65 Contour

Two possible scenarios were considered. The obstructed land scenario assumes a similar cost per acre for relocation and purchase of noise rights as was present in Austin. In this case, the cost per acre was the same as established in the principle case above.

The second scenario assumed the availability of a clear area of land where allowance for relocation and surrounding structures would not be necessary. This case assumes that land within the Ldn 65 Contour is acquired at a cost of $1750/acre. Since this is a much lower cost per acre than in the previous cases, there is a net reduction in the land acquisition cost despite the larger acreage.

Other

Some costs specific to the MSP region and not common to the Austin region may have been omitted. For example, no allowance has been made for housing and storage of snow removal equipment.

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

AIRPORT FINANCE: A PRELIMINARY REVIEW OF THE ISSUES FOR MINNEAPOLIS-ST. PAUL

JULY 1988

Prepared By:

THOMPSON-HICKLING
APOGEE RESEARCH

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I. INTRODUCTION

Early results from the current assessment of the long-term adequacy of Minneapolis-St. Paul International Airport (MSP) indicate that the airport faces a high risk with regard to its ability to handle increases in air traffic without imposing substantial aircraft delays. Figure 1 indicates that by the year 2008, the airport faces a 95 percent probability of inadequate capacity. The addition of a new runway ("Enhanced Option A") would leave the airport with only about a 20 percent chance of meeting the expected volume of traffic and even the addition of two new runways (Enhanced B and Ultimate A) still foreshadow a decreasing level of service in the longer term. Within 30 years, even the most ambitious development plan for MSP (called Ultimate A) shows less than a 50 percent chance of meeting expected demand (Figure 2).[1] This in turn has given rise to the consideration of a possible new airport for the region.

Of course, there is no requirement that all the expected demand must be served. If inadequate capacity exists, as is the case for many airports today, airlines will shift traffic to other airports, re-schedule traffic to off-peak times (imposing longer travel times), and delays will increase. These costs can be avoided only with the expenditure of substantial sums on capacity expansion, the extent of which must be determined by the benefits of various expansion options versus their associated costs.

The comparative costs and benefits of capacity options is under review in another part of this study. This discussion paper highlights the broad issues associated with financing whatever approach is ultimately selected.

Plan of the Paper

Section II of the paper provides a brief primer on airport finance and provides associated background regarding the Minneapolis-St. Paul International Airport. The primer draws on the results of a seminar on airport finance sponsored by the University of Minnesota and the Metropolitan Council of the Twin Cities in June 1988.

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[1]The Metropolitan Council of the Twin Cities, **Capacity Estimates and Preliminary Findings**, (May 1988).

Drawing once again on the University of Minnesota seminar, Section III outlines a preliminary strategic framework for considering financing options for airport development in the MSP region. Section IV concludes with a summary of key issues.

FIGURE 1

Net Capacity Probabilities at MSP International (2008)

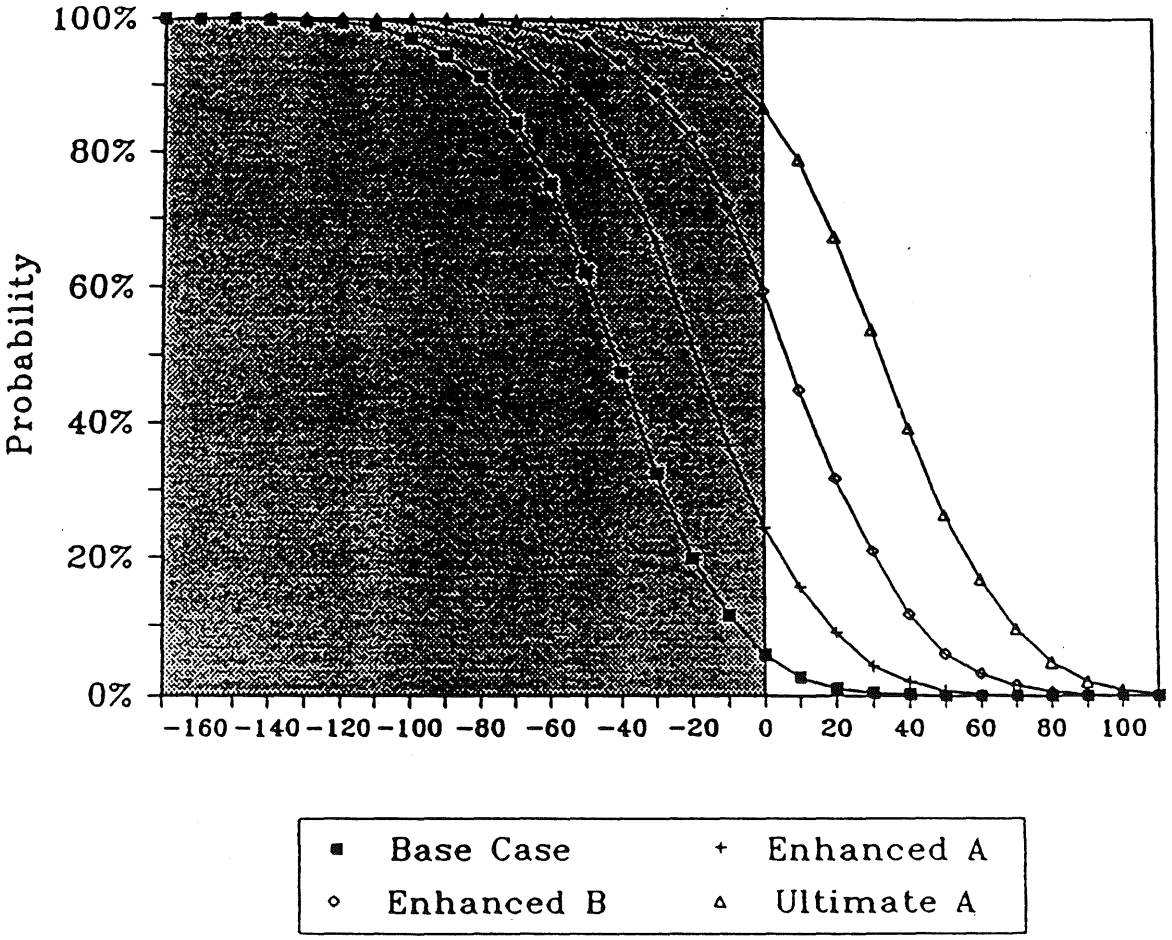
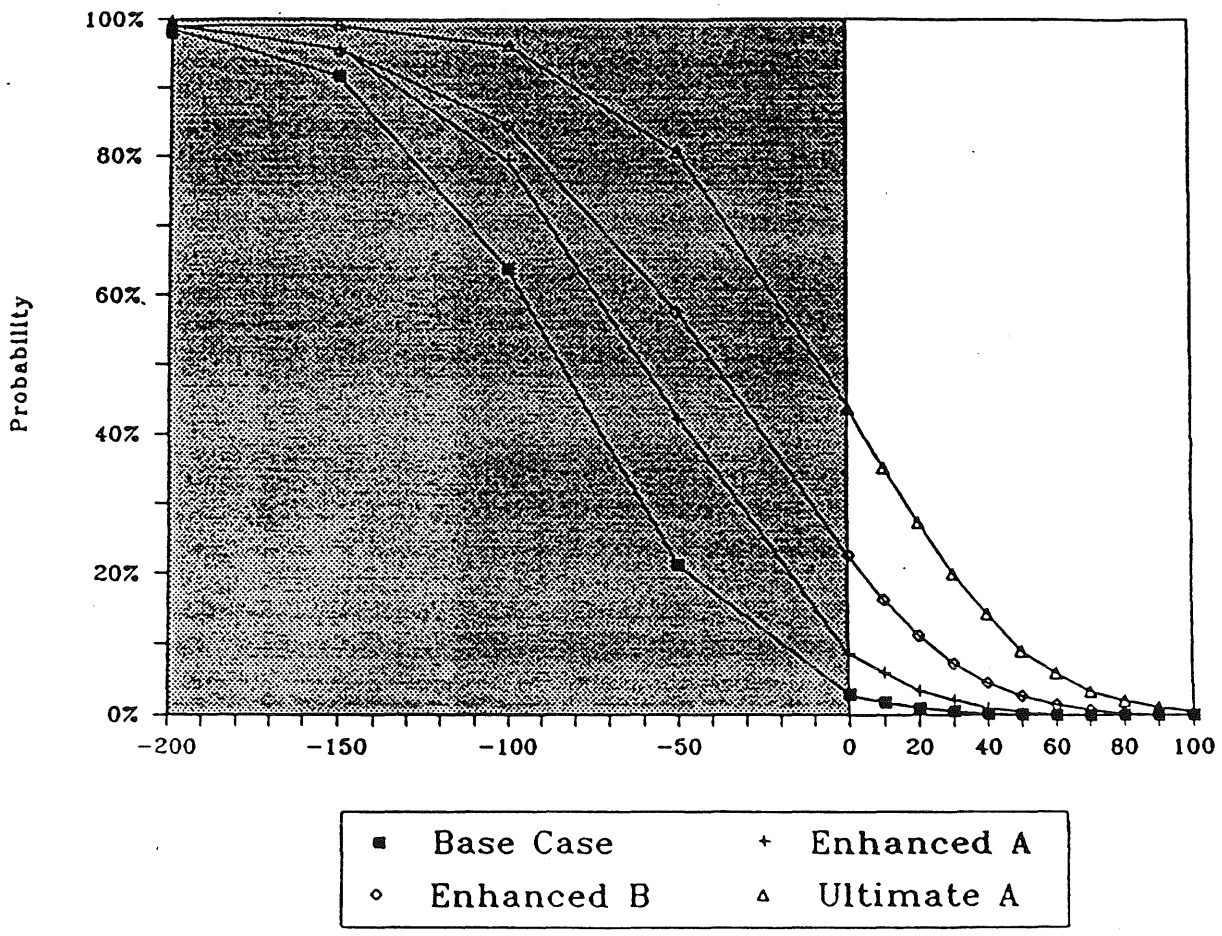


FIGURE 2

Net Capacity Probabilities at MSP International (2018)



II. A BRIEF PRIMER ON AIRPORT FINANCE

Unlike other countries' airports, many of which are owned and run by national governments, commercial U.S. airports are typically owned and managed by local governments or other nonfederal public authorities. Although the management of U.S. airports varies according to several factors, including size and type and nature of market served, major U.S. commercial airports function as mature business enterprises, applying up-to-date techniques of financial management and administration. These publicly owned and managed facilities are operated in conjunction with private industry -- the commercial airlines, which are the airports' link to their patrons. The success of this partnership depends, in turn, on the effectiveness with which the federal government operates the air traffic control system. This peculiar public/private character distinguishes the financial operation of commercial airports from that of wholly public or private enterprises, distinctively shaping an airport's management practices, the pricing of its facilities and services, and its investment planning process.

Six key factors shape an airport's financial position:

- Form of ownership and operation;
- Approach to financial management;
- Financial condition and performance;
- Position in the bond market;
- Extent of private ownership and "privatization"; and
- Availability of federal and state aid;

The following paragraphs outline the significance of each factor and examine how they relate to Minneapolis-St. Paul International Airport.

OWNERSHIP AND OPERATION

Public airports in the United States are owned and operated under a variety of organizational and jurisdictional arrangements. In many cases, ownership and operation coincide: commercial airports may be owned and run by a city, county, or state, or by several jurisdictions at once (for example, a city and a county) or a multi-county region. In some instances, however, a commercial airport is owned by one or more of these governmental entities but operated by a separate public body, such as an airport authority, created specifically for the purpose of managing the airport.

Regardless of a commercial airport's ownership, its public operator can be any one of four governmental entities or other public bodies with legal responsibility for day-to-day administration:

- o A municipal or county government (52 percent of all large an medium-sized airports)[2];
- o A multipurpose authority (15 percent);
- o An airport authority (24 percent); or
- o A state government (9 percent);

Publicly owned general aviation airports may be owned and operated by a municipality, county, or state, or they may be the property of one or more of these jurisdictions but run by a separate public body (as part of a multi-airport system) or by a private operator, which charges for its managerial services. A small fraction of general aviation airports are privately owned.

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2. Data are drawn from, **Financing U.S. Airports in the 1980's**, Congressional Budget Office, April 1984. No significant shifts have occurred since publication of the CBO book on airport finance.

Responsibility for operating the Minneapolis-St. Paul International Airport rests with the Metropolitan Airports Commission (MAC). Established in 1943, MAC is an independent, special-purpose agency with broad powers to acquire, develop, and operate airports within an area roughly equivalent to the seven-county Twin Cities Metropolitan Area. The MAC operates seven of the region's twelve public-use airport facilities including Minneapolis-St. Paul International Airport. South St. Paul Airport is a municipally owned facility, and several other airfields in the system are privately owned, but open to public use.

Minnesota Statutes 473.601-473.679, the "Metropolitan Airports Commission Act,"mandates "...that the development of the metropolitan airports system by the MAC be consistent with the airport chapter of the Metropolitan Council's development guide and promote the public safety and welfare of the state and that the development extension, maintenance, and operation of the system in such a manner as to assure the residents of the metropolitan area of the minimum environmental impact from air navigation and transportation with protective measures, is essential to the development of air navigation and the inclusion of this state in national and international systems of air transportation, benefits the people or the state as a whole, renders a general public service, and provides employment, and is of great public economic benefit."

MAC's plans and major capital expenditures are subject to Metropolitan Council review. All long-range plans must be consistent with Council plans and policies, as well as land use compatibility guidelines and airport noise standards that direct the MAC and local jurisdictions to alleviate environmental constraints through appropriate actions.

The responsibilities of the MAC and the Metropolitan Council are divided as follows:

	Planning	Implementation
MAC	Prepares a long-term comprehensive plan for each airport which includes: o Airport development o Airport and airspace safety o Airport and aircraft environmental capability o Compatibility with metro/local systems	Operates and maintains airport facilities and implements airport development projects;
		Protects runway approaches and airport area airspace from obstructions to navigable airspace and creates an airport zoning district and associated zoning ordinance;
	Prepares airport master plans including site identification for new airports required in the system; and	Prepares an airport operations plan to ensure safe and efficient use of airspace, determining need for navigational and landing aids, ground traffic control, and emergency services, as well as noise abatement information and monitoring and enforcement activities; and
	Prepares special studies.	Identifies land use strategies appropriate for land use compatibility in noise impact areas and develops noise abatement plans.

	Planning	Implementation
Metropolitan Council	Prepares and adopts transportation and aviation chapters of the Metropolitan Development Guide which serves as a long-range regional development guide upon which to base development decisions.	Reviews and approves proposed capital expenditures by the MAC in excess of $5 million at Minneapolis-St. Paul International Airport and $2 million at the reliever airports; Reviews and approves long-term comprehensive plans of the MAC for the operation and development of airports within the Metropolitan Area. If the Council finds the plan, or any part of it, inconsistent with the Metropolitan Development Guide, it may indefinitely suspend the operation of the plan, or any part of it; Reviews and approves the selection of a site by the MAC of a new major airport; Adopts criteria and guidelines for regulation of use and development of the airport development area; Reviews and approves amendments relating to land use and development control measures, or variances applicable to proposed airport development areas or to any property within five miles of a site; Establishes aircraft noise zones and acceptable levels of perceived noise decibels for each land use; Reviews applications of a metropolitan agency, independent commission, board or agency, local governmental unit or private party for funds, grants, loans or loan guarantees from the State of Minnesota and the

	Planning	Implementation
Metropolitan Council		United States of America for proposed matters of metropolitan significance or other agencies as required by state and federal law and regulation; Reviews and determines if a proposed matter is of "metropolitan significance" to be undertaken by any private organization, independent commission, board, agency, local government unit, or state or metropolitan agency in accordance with law and regulation. The Council may suspend action on such a proposed matter for up to 12 months; Reviews and comments on consistency of transportation plans and capital improvement programs of local governments with the Council's transportation guide chapter. The Council may require a local governmental unit to modify its comprehensive plan or capital improvement program if it substantially impacts on, or departs from, the transportation, sewer, regional recreation open space, and aviation chapters of the Metropolitan Development Guides.

Like other port or airport authorities, MAC has the power to issue its own debt to finance capital development and, like a few other airport authorities, MAC has the power to tax property in order to pay debt service on outstanding bonds.

APPROACH TO FINANCIAL MANAGEMENT

Although financial management practices differ greatly among commercial airports, the airport/airline relationship at the nation's major commercial airports typically is based on one of three very different approaches each with important implications for airport pricing and investment practices:

- **The residual cost approach,** under which the airlines collectively assume significant financial risk by agreeing to pay any costs of running the airport that are not allocated to other users or covered by non-airline sources of revenue;

- **The compensatory approach,** under which the airport operator assumes the major financial risk of running the airport and charges the airlines fees and rental rates set so as to recover the actual costs of the facilities and services that they use; and

- **Hybrid approaches,** under which airport management and the airport agree to a combination of the residual cost and compensatory philosophies.

In exchange for the guarantee of solvency, airlines that are signatories to residual cost use agreements often exercise a significant measure of control over airport investment decisions and related pricing policy. These powers are embodied in so-called majority-in-interest clauses, a much more common feature of airport use agreements at residual cost airports than at airports using a compensatory approach. Under the latter approach, since it is the airport operator that assumes the major financial risk of running the airport, the operator generally is freer to undertake capital development projects without consent of the airlines.

At most commercial airports, the financial and operational relationship between an airport and the airlines it serves is defined in legally binding agreements that specify how the risks and responsibilities of airport operation are to be shared between the two parties. MSP operates under a use agreement that establishes a residual cost approach in the airfield portion of the airport and a compensatory

system elsewhere. The existing use agreement expires in 1989 and the MAC is currently engaged in the process of negotiating a new agreement.

The airfield residual cost approach at MSP means that airlines guarantee to pay landing fees and charges that ensure coverage of all operating and capital costs of the runways, taxiways, aprons and other elements of the "airside" portion of the airport. In exchange for this guarantee, airlines that are signatories to the use agreement are credited with any surplus aeronautic revenues (hanger rentals and so on) earned from non-signatory airside users; this means that such surpluses are subtracted from airside costs before the "breakeven" level of landing fees is calculated and means of course that the airport cannot retain any surplus revenues in airfield operations. As well, a majority-in-interest clause in the airport use agreement gives the signatory airlines a major voice in proposed development projects. Through this clause, the majority-in-interest carrier -- Northwest Airlines -- can effectively block proposed new investments in the airfield area.

Since airlines do not share in the financial risks of running the terminal and other "groundside" facilities at MSP, there is no airline barrier to the retention of surplus revenue (profit) in the operation of concession contracts, parking lots and so on. Nor is there a majority-in-interest agreement for groundside investments. In other words, the airport absorbs the financial risk of groundside development and operation and in return retains the rights to all profits and final say over their disposition.

FINANCIAL CONDITION AND PERFORMANCE

As in any public enterprise, an airport's ability to finance capital investment hinges in part upon its financial strength -- the more financially sound the enterprise, the greater the likelihood that it can expand without public subsidy.

On the whole, the capital markets have judged large and medium-sized airports in the United States to be mature business enterprises whose securities are generally regarded as good investment opportunities. Purchasers of airport bonds look for assurances that an airport can generate net revenue (that is, gross revenues net of

operating and maintenance costs and debt service requirements) sufficient to pay interest over the term of the bonds and to repay the principal. Overall examination of these measures for large and medium-sized airports as a whole shows a continuing trend toward improved financial strength. Although the last comprehensive survey of airport financial performance was conducted in 1982 (see text box), more recent analysis confirms that airport operating cost exceed operating revenues by more than 50 percent and airports tend to outperform other public enterprises in key financial ratios.

The financial performance of Minneapolis St. Paul-International Airport is strong in relation to that of other similarly sized airports in the country. Over the years the operating ratio (operating costs as a percent of operating revenues) has consistently out-ranked that of airports generally and has displayed a trend of consistent improvement (falling from 85 percent in 1980 to 76 percent in 1987).

Minneapolis-St. Paul International also has a record of consistent profitability in groundside operations and uses parking surpluses to help support the operations of the region's general aviation airports.

FINANCIAL PERFORMANCE OF MAJOR PUBLIC ENTERPRISES

Operating Ratio and Net Take-Down Ratio. Major commercial airports typically use a smaller share of revenue to cover operating costs than either electric utilities or water supply and wastewater treatment authorities. They appear to operate with smaller operating margins than highway toll facilities, however.

Debt-to-Asset Ratio. Airports carry a high level of debt relative to their total assets compared with power and water.

Debt Service Safety Margin. Despite their relatively high debt ratios, airports appear able to service more new debt than both electric utilities and water authorities, largely because of their lower operating and maintenance costs. Also, they have a substantially greater cushion against unforeseen shortfalls in revenue.

MEDIAN RATIOS FOR SEVEN SERVICES IN 1982 (In percents)

Service	Operating Ratio	Net Take-Down Ratio	Debt-to-Asset Ratio	Debt Service Safety Margin
Airports	56.3	48.2	48.8	28.9
Electricity Generation and Transmission	76.8	26.0	56.5	15.9
Electricity Distribution	79.2	23.2	35.4	14.7
Water Supply	68.2	38.7	27.6	21.7
Wastewater Treatment	68.3	39.3	25.0	21.2
Bridges, Tunnels, Expressways	47.5	64.5	N/A	N/A
Turnpikes	38.8	62.0	N/A	N/A

SOURCE: Adapted by CBO with the permission of Moody's.

NOTE: This table reports medians because averages, as used in the body of this chapter, are not available for enterprises other than airports. Also, the airport data are drawn from a sample somewhat different from that used elsewhere in this report.

POSITION IN THE BOND MARKET

Although airports of all sizes and types participate in the bond market, larger airports do so to a greater extent than smaller ones. Among the large and medium-sized commercial airports -- together serving about nine-tenths of all passenger traffic, all have issued bonds at some time in the past.

In terms of total dollar volume of bond sales, large airports are far more prominent in the bond market than smaller ones. Of the total amount of municipal debt sold for airport purposes over the 1978-1982 period, 89.5 percent was for large and medium-sized airports, in contrast to only 9.2 percent for small commercial airports; general aviation airports accounted for little more than 1 percent of total airport bond sales. The role of bond finance in overall investment also varies greatly according to an airport's size and the type of air traffic it serves. Over the 1978-1982 period, airport investment dollars financed through the bond market exceeded federal grants to large airports by 340 percent (MSP is classified as large). In contrast, at small airports federal grants were more than double bond proceeds, (see Table 1). Not surprisingly, debt finance plays the smallest role at general aviation airports.

For most municipal bonds, including bonds for airport development, the bond issuer's pledge to pay interest and to repay principal is generally provided under one of two approaches:

- **General Obligation bonds** pledge the unlimited taxing power and the full faith and credit of the state, municipality, or other general-purpose government, while

- **Revenue bonds** pledge the user fee or lessee revenues generated by the actual facility to be developed.

General obligation bonds are usually issued only by states and other general-purpose governments; most states limit the amount of general obligation debt that a municipality may issue to a specified fraction of the taxable value of all property

TABLE 1 RELATIVE CONTRIBUTION OF FEDERAL GRANTS AND BOND ISSUES TO AIRPORT INVESTMENT, BY AIRPORT TYPE AND SIZE, 1978-1982 (In percents)

Airports by Size and Category	Federal Grants	Bond Issues	Total
	COMMERCIAL AIRPORTS		
Large	18.5	81.5	100
Medium-sized	27.1	73.0	100
Small	68.9	31.1	100
Subtotal	30.8	69.2	100
	GENERAL AVIATION AIRPORTS		
Reliever	80.1	19.9	100
Other	91.5	8.5	100
Subtotal	87.4	12.6	100
	ALL AIRPORTS		
Total	34.8	65.3	100

SOURCE: Congressional Budget Office.

NOTE: Details may not add to totals because of rounding.

within its jurisdiction. By contrast, the volume of debt issued through revenue bonds is not included in the amount of total indebtedness subject to state debt limits. Revenue bonds generally have higher interest costs than general obligation bonds, because they are not backed by the full faith credit and taxing power of a governmental unit, and because the receipts from user charges are subject to greater uncertainty than are tax revenues.

Since the late 1970s, there has been a dramatic increase in the use of tax-exempt revenue bond financing, including airports. In 1987, for example, revenue bonds accounted for an estimated 73 percent of all tax-exempt bond sales, as compared to 34 percent in 1970. With the increasing financial pressures on state and local governments to reserve general obligation funding for non-revenue producing facilities (such as schools), revenue bonds represented the vast majority -- an estimated 92 percent -- of the total dollar volume of airport bond sales over the 1978-1987 period.

In addition to the two general categories of bondholder security outlined above, a few bond issues combine sources of security to produce a hybrid bond. This device offers certain advantages, such as improved ratings and interest costs, without placing undue pressure on a municipality's debt ceiling. As an example, the cities of Charlotte (North Carolina) and Austin (Texas) built or expanded terminal facilities with general obligation bonds secured by the full faith and credit of the cities but serviced from airport revenues -- so called "self-liquidating general obligation bonds."

The competitiveness of an airport in the bond market can be gauged by two conventional indicators of investment quality:

- **Bond ratings** -- a simple system used by major investor services to grade bonds according to investment quality (see text box); and

- **Interest costs** -- the interest paid by the airport to attract investors relative to what other municipal enterprises pay; and

WHAT INVESTMENT-GRADE BOND RATINGS MEAN

Best Grade

Bonds rated Aaa (by Moody's) or AAA (by Standard & Poor's) are graded best. Their exceptionally strong capacity to pay interest and repay principal offers the lowest degree of risk to investors in bonds.

High Grade

Bonds rated Aa1 or Aa (by Moody's) or AA+ or AA (by Standard & Poor's) have very strong ability to pay interest and repay principal, but they are judged to be slightly less secure than best-grade bonds. Their margins of protection may not be quite so great, or the protective elements may be more subject to fluctuation.

Upper-Medium Grade

Bonds rated A1 or A (by Moody's) or A+, A, or A- (by Standard & Poor's) are well protected, but the factors giving security to interest and principal are deemed more susceptible to adverse changes in economic conditions or other future impairments than for bonds in the best- and high-grade categories.

Medium Grade

Bonds rated Baa1 or Baa (by Moody's) or BBB+, BBB, or BBB- (by Standard & Poor's) lack outstanding investment characteristics. Although their protection is deemed adequate at the time of rating, the presence of speculative elements may impair their capacity to pay interest and repay principal in the event of adverse economic conditions or other changes.

SOURCE: Based on Moody's Bond Record (September 1982) p. 144 and Standard & Poor's Ratings Guide, McGraw-Hill (1979) pp. 327-328.

NOTES: Except for the best-graded category of bonds, those bonds in each category that Moody's and Standard & Poor's believe to possess the strongest investment attributes are designated by the symbols 1 and +, respectively. The symbol - designates weaker investment characteristics in a given category.

Standard & Poor's assigns AA ratings to new issues of municipal bonds insured by the American Municipal Bond Assurance Corporation and AAA ratings to new issues insured by the Municipal Bond Insurance Association. Moody's ratings do not reflect the presence or absence of bond insurance.

Bond Ratings

For the 134 airports for which new airport bonds were issued over the past five years, every rated bond has received an "investment grade" from the two major rating services (Moody's and Standard & Poor's Corp). Credit analysts at the rating services rate an airport revenue bond according to a variety of factors, including the financial performance of the airport, the strength of passenger demand, and use agreements with the airlines serving the airport. Financial strength is viewed as a direct function of passenger demand at the airport and credit analysts review both financial ratios and the underlying pattern of passenger traffic.

Some analysts believe that for "origin-destination" airports (those at which most of the passengers either begin or end their journeys) in strong travel markets, even the financial failure or the withdrawal of one carrier might have no influence on the airport's bond rating. For hub airports serving a large proportion of connecting passengers, however, a major airline's poor financial outlook, or a boardroom decision to withdraw some connecting services, could mean a permanent loss of patronage, with important implications for bond rating and the cost of capital.

In the view of the bond rating analysts, the financial picture has not improved significantly for those airports experiencing the most operational growth and dramatic increases in debt financing requirements. For example, Standard and Poor's published credit rating on Denver's December 1982 issue of $185 million of revenue bonds stated that the issue is not rated higher than A "...because of current uncertainties surrounding future airport expansion and the substantial cost associated with whichever alternative is pursued." Similarly, Standard & Poor's published report on $175 million in revenue bonds stated that ..."the primary concern is the magnitude of the capital program being undertaken at the airport, which is expected to cost $1.2 billion by 1990."[3] For this reason, the Chicago bond issue was also denied better than an A rating.

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[3]. ibid.

Airline deregulation, which has freed air carriers from virtually all obligations to serve particular airports, has caused some shift in the relative weight credit analysts give to these factors. In response to deregulation, the investor services today place greater emphasis on the strength of local economic conditions than on use agreements and the financial stability of the airlines serving an airport. The rationale is that, if one airline withdraws service, a strong local economy would simply attract other airlines to pick up the travel business.

Interest Costs

Like municipal bonds in general, airport bonds are sold and traded at prices that reflect both general economic conditions and the credit quality of the airport enterprise (or in the case of General Obligation bonds, the creditworthiness of the issuing government). Under competitive bidding, the airport selects the lowest bid and thus obtains funds at the lowest cost of borrowing. The entire issue will usually be purchased by an underwriter (commonly, an investment brokerage company) or a team of underwriters that, in turn, markets the bonds to institutional and individual investors.

Interest costs differ depending on the type of security and the number of years until the bonds mature. Analysis conducted by Dr. David Lewis indicates that, other things being equal, general obligation bonds for airport purposes draw interest costs that fall about 9 percent below the interest paid on revenue bonds (with interest rates at about 7.8 percent, this translates into about 62 basis points).[4]

Airport bonds issued by the MAC represent an unusual hybrid. Called "General Obligation Revenue Bonds," this debt instrument is secured by the pledge of all operating revenues of the MAC subject to the prior use of such revenue for the payment of outstanding Airport Improvement Bonds. The "General Obligation" feature of the bonds stems from MAC's power to levy taxes on all taxable property in the seven county metro area in order to pay debt service on outstanding General

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4. See Congressional Budget Office, ibid. and Apogee Research, **Airports and Airways**, National Council on Public Works Improvement, May 1987

Obligation Revenue Bonds. Because of this element of security, bonds issued by MAC hold the highest possible bond rating (AAA) and relatively low interest costs.

However, because of the General Obligation element of bonds issued by MAC, the Airport Authority is limited by the State of Minnesota in its authority to issue debt; at present, the Airports Commission has authority to issue debt up to an amount of $62 million.

PRIVATIZATION AND AIRPORT FINANCE

An emerging trend in airport finance, though more prevalent in Canada and Europe than in the United States, is the privatization of airport facilities.[5] Great Britain recently required all large commercial airports to switch to private ownership, though such ownership may range from traditional stock ownership (as with British Airports Authority PLC) to ownership by local municipalities (as with Manchester Airport).

In Toronto, the airport's owner (the federal government of Canada) recently entertained tenders from private firms to build and operate a third terminal at Lester B. Pearson International Airport. As part of their defederalization policy, the Canadian government has stated its willingness to consider private ownership and operation of certain airports.[6] Under this kind of arrangement, finance is arranged by the private entrepreneur who, in turn, retains profits from the operation of the facility. Key questions with such an arrangement concern what sort of public controls (regulations) should be placed on the private operator to restrict potential abuses.

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5. Apogee Research, Inc., The Nation's Public Works: Report on Airports and Airways, (May 1987).

6. See, James F. Hickling Ltd., **New Options for Airport Finance, (Paper prepared for the Government of Canada),** May 1988

AVAILABILITY OF FEDERAL AND STATE AID

Under the recent re-authorization of the Airports and Airways Improvement Act of 1970, the Congress authorized an increase in the Airport Improvement Program from 1 billion a year to more than $1.7 billion a year for five years. Two major uncertainties accompany the program, however. First, Congress has not appropriated the authorized amounts. Secondly, the federal program will expire at the end of five years, probably in advance of the major build-up of long-term capital needs.

MSP is classified as a large airport and large airports have obtained on average, a fifth of their capital from federal sources. There is no reason to expect that ratio to climb in future. Moreover, there are signs that a trust fund approach to federal transportation finance is losing its appeal among the industry (who object to the large cash surpluses in the Aviation Trust Fund) and within Congress, where some oppose the lack of Congressional discretion over the disposition revenues. If the trust fund mechanism is not renewed, the certainty of federal grants in future could change (perhaps for the better, perhaps not).[7]

A very recent trend in the consideration of alternative delivery mechanisms for federal and state dollars is the use of so-called revolving loan funds. Under this concept, a federal or state entity makes capital funds available to a public enterprise on a loan basis (much like a bond but with more flexibility to offer subsidized rates of interest and less rigid forms of security). Since the enterprise is expected to service its debt from user revenues, this approach is thought to encourage greater economic efficiency and financial discipline than out-right grants by forcing the recipient to ensure that the scale and timing of projects aligns with the ability of a proposed facility to generate funds sufficient to pay off interest and principal.

Although this mechanism has not been applied in the case of a major airport, it does offer a feasible means by which a state can increase its participation in

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7. Apogee Research, Inc., Trust Funds: Uses and Misuses, prepared for the National Council on Public works Improvement, (October 1987).

airport development without resorting to the use of very large grants-in-aid. Revolving funds have been used by some states for water-related programs since the 1950s and the current federal wastewater treatment program will be phased out by the early 1990s in favor of a series of state revolving funds. Legislation has been introduced that would use federal grants as seed capital for similar locally controlled airport revolving funds.

III. AIRPORT FINANCE ISSUES FOR MSP: A PRELIMINARY STRATEGIC FRAMEWORK

Although a new strategic policy for the Minneapolis-St.Paul International Airport is still in the formative stages of development, it is not too soon to consider the question of finance. This Section presents a preliminary framework for considering the issues and presents in outline some questions for consideration in developing a comprehensive airport strategy.

A FRAMEWORK FOR POLICY ANALYSIS

The review presented in Section II suggests that airport finance issues for MSP fall into three broad categories:

- **The role of the bond market;**
- **The role of federal, state and local governments; and**
- **The role of the private sector and other innovative sources of finance.**

Although any outlook at this stage is speculative, this Section looks at three categories above as a "financing system" and takes a risk analysis approach in order to gauge where some of the most pressing concerns might lie. The principal risks stem from the fact that several of the options now under study for MSP would require financial resources well above the historic level of capital expenditure for MSP. This in turn might require change in the current mix of roles and instruments under the three categories listed above, possibly entailing relatively less emphasis on the use of the bond market and more state and private sector involvement.

Risks in the Bond Market

At very high levels of capital expenditure, the State might well be unlikely to permit the MAC to pledge the seven county tax base as a secondary source of security in the issue of revenue bonds as it does today. This may be especially true since the state continues to come under pressure to increase capital

expenditure on other facilities and services that depend in various ways on the region's tax base. This in turn would reduce MAC's triple A bond rating and thereby lead to an increased cost of capital.

Additional pressure on MAC's bond rating and cost of capital could arise under the issuance of very large amounts of airport debt if the bond rating agencies were to view the proposed new facilities as being highly dependent upon connecting rather than origin-destination traffic. The combination of very large debt service requirements and a heavy dependency upon a single hub carrier has led credit analysts to voice doubt about the credit strength of hub airports in the past (see Section II). And while this assessment is of course very preliminary, the mere risk of a higher cost of capital in the bond market might well lead us to consider the role of other financing possibilities, including federal and state sources of funds and the role of the private sector.

Future Role of Federal and State Governments

As discussed in Section II, federal funds under the Airports Improvement Program are unlikely to be sufficient to cover more than a fraction of the capital needs of an airport the size of MSP. Moreover, there are no guarantees that the federal program will remain in its current form in the longer term. While we do not foresee a reduction in airport capacity as a federal priority, historic precedent alone suggests that it would not be realistic to view the federal government as a major source of finance.

State governments, however, are adopting a higher financial profile in infrastructure development generally, and a number have established revolving loan funds as described earlier. The preliminary review presented in this paper suggests a strong likelihood that the state of Minnesota will need to consider adopting a greater financial role. The question that the state will need to address is how large a financial role it is prepared to play over the coming years. The answer of course

will depend in part upon the benefits and costs of alternative development approaches and the availability of non-state sources of finance.

Role of the Private Sector and other Innovations

If indeed there is a risk that the bond market and the federal government alone will provide insufficient funds for airport development, serious consideration will need to be given to other, more innovative forms of finance. The privatization of new terminal facilities (or even larger scale privatization) and the use of proceeds from the sale of assets on the existing site are important cases in point.

Of course,such innovations have potential disadvantages. Privatization, for example, can reduce the public's control over important public use facilities. On the other hand, governments can regulate the price and service quality offered by private operators; this is the approach recently adopted by the Thatcher Government in privatizing the Channel Tunnel connecting Britain and France and in the privatization of London's bus routes.

While at this point it is too early to be definitive about the role of innovative sources of airport finance in the MSP region, it is not too early to begin a dialogue regarding their potential contribution.

IV. CONCLUSION

As the Twin Cities begin the serious consideration of various options for airport development, there seems little doubt that such consideration will need to include new approaches to airport finance. The Region is certainly not unique in this respect. Indeed, many financial analysts have pointed to U.S. and foreign airports as an excellent example of creativity and adaptability to changing financial circumstances.[8]

Indeed, in the midst of the present uncertainty over the direction of airport development at MSP, one source of stability is that of finance. As the market for airport securities itself has consistently demonstrated, if a project is economically worthwhile, the financial resources needed will be forthcoming. At the same time however, the mix of financial instruments and mechanisms cannot be expected to remain the same regardless of the level of desired investment. Change is virtually inevitable and the Region will need to begin thinking about the options now.

To facilitate the thinking process, the Metropolitan Council and the University of Minnesota sponsored a one-day seminar on airport finance in Minneapolis on June 17, 1988. Participation (see Appendix) included investment bankers, local financial institutions and a range of other relevant interests. The principal conclusions of the one-day seminar may be summarized as follows;

- Financial criteria should not be used as a basis for gauging the scale and scope of airport investments -- such decisions should be based on a comparison of benefits and costs, including social benefits such as time savings and environmental costs such as noise;

- Finance is unlikely to be a constraint to MSP airport development as long as development plans are conceived on the basis of a proper assessment of benefits and costs;

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8. See for example, Roger Bates, **Airport Finance, Wither or Whither the Market, 1985**

- A large increase in the airport capital investment program could require a shift away from the use general obligation backing for MAC-issued bonds; Bonds may shift to a direct form revenue-based security.

- Although a shift away from general obligation security for airport bonds could cause a reduction in bond rating, the airport will continue to draw premium-grade credit standing. MAC's bond rating could fall from AAA to A due to the dominance of a single air carrier. Statistical evidence indicates that such a fall would lead the cost of capital to MAC to increase by about 9 percent.

- Options to privatize airport facilities should be examined seriously, but very carefully; full-scale privatization could run counter to the public interest unless effective regulation was brought into place. The privatization of certain facilities, such as terminal buildings, appears to offer promise, based upon recent experience in Toronto.

AIRPORT INFRASTRUCTURE FINANCE

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THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

TECHNOLOGY

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INTRODUCTION

Recent innovations in the computer industry fostered a surge of technological renovation within the Nation's air traffic control system. Economic assessments suggest that cost considerations will impede the continued adoption of significant new technologies over the next twenty years. In fact, it appears that continued improvements in efficiency and capacity will depend on new procedures and operational techniques.

Technology encompasses not only instruments and equipment, but also new procedural, operational and design concepts. While this report focusses on the benefits generated by technical improvements, the importance of procedural and operational innovations is increasing.

Technology may create benefits for passengers, airports, and the public in general through:

(1) enhanced cost efficiency,

(2) reduced noise, and

(3) improved terminal and airside capacity.

COST EFFICIENCY

As a direct result of advancements in both aircraft and airfield technology, aviation efficiency has continued to improve over the last 25 years, as demonstrated by two system-wide trends: revenues per passenger mile and flight characteristics.

Revenues Per Passenger Mile

Revenues per passenger mile (in constant dollars) have declined steadily since 1960 (Figure 1). Similar trend can be traced back to the 1930s. This measure reflects both technological improvements as well as the effects of competition on airline costs. While deregulation encouraged some well publicized price wars, however, these data suggest that the trend in revenues is less directly correlated to the end of federal economic regulation and more closely tied to long-term technical and operational improvements.

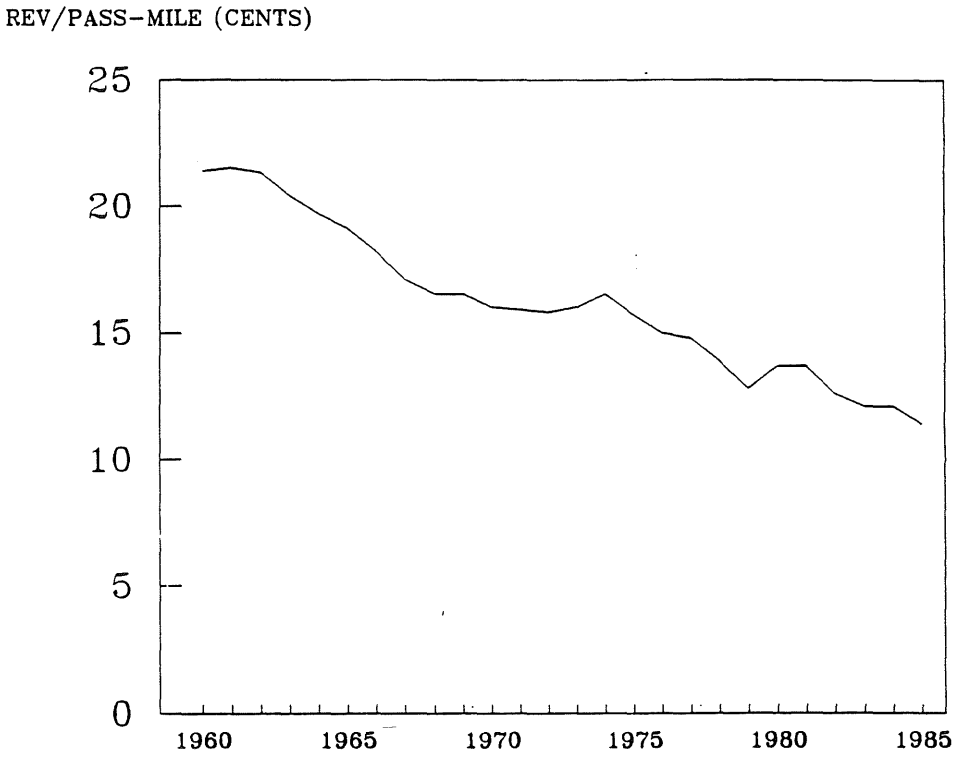


Figure 1. Airline Revenues Per Revenue Passenger Mile

Flight Characteristics

Underlying the reduced costs of air travel are the physical characteristics of flights undertaken. Taken together, average trip length, trip speed, and aircraft load factors indicate the extent to which changes in technology have been manifested in aviation. Between 1960 and 1985, for example, average trip length increased fairly steadily from 583 miles to 759. Average airborne aircraft speed, on the other hand, peaked in the early 1970s at just over 400 miles per hour and has remained comparatively unchanged since (Figure 2). The steady nature of average speed over this period suggests one of two possible explanations: either the optimal flight characteristics, relative to demand, have been attained, or the physical facility constraints together with air traffic control limitations have placed limitations on the implementation of continued technological improvements.

An analysis of aircraft load factors, a measure of the utilization of available space on the average plane, indicates that there may be a degree of correlation between the leveling off of growth in average aircraft speed and the adoption of operational improvements. Since 1971, load factors have shown a dramatic increase from well below 50 percent space utilization to an average, over the last five years, of more than 60 percent (Figure 3). This, together with the increasing use of wide-body and larger-capacity aircraft, has allowed airlines to transport an ever-increasing number of passengers per unit time regardless of changes in aircraft technology.

In essence, airlines have opted for improvements in operational and managerial techniques in lieu of technology. Thus, incremental increases in aircraft speed may have little impact on the system as a whole in the near future. Nonetheless, the United States, the United Kingdom, and France have continued to develop higher-speed technology.

The United States, for example, is currently developing the National Aerospace Plane (NASP). President Reagan introduced the NASP concept in his 1986 State of the Union Address, suggesting that the civilian version of such a plane could take passengers from New York or Washington to Tokyo within two hours. Further, the technology was said to be available, and only needed to be put together in an "innovative fashion." The President's observation on the cruising time for a civilian hypersonic transport needs some clarification. The "Orient Express," as it was named, is in fact closer to a high-speed supersonic transport (capable of speeds of Mach 5), than hypersonic transport (hypothesized to attain of up to Mach 15).[1]

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[1] A hypersonic transport was also proposed for the military (the X-30 program) and funding authorized.

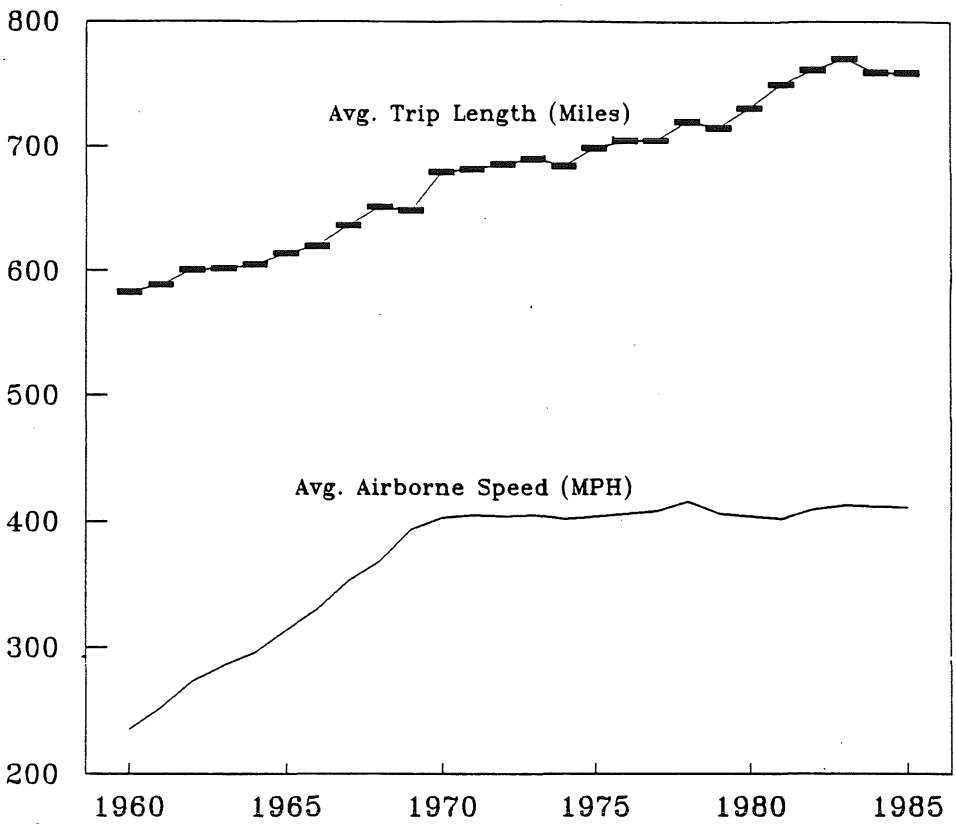


Figure 2. Domestic Trip Characteristics

Source: Federal Aviation Administration data

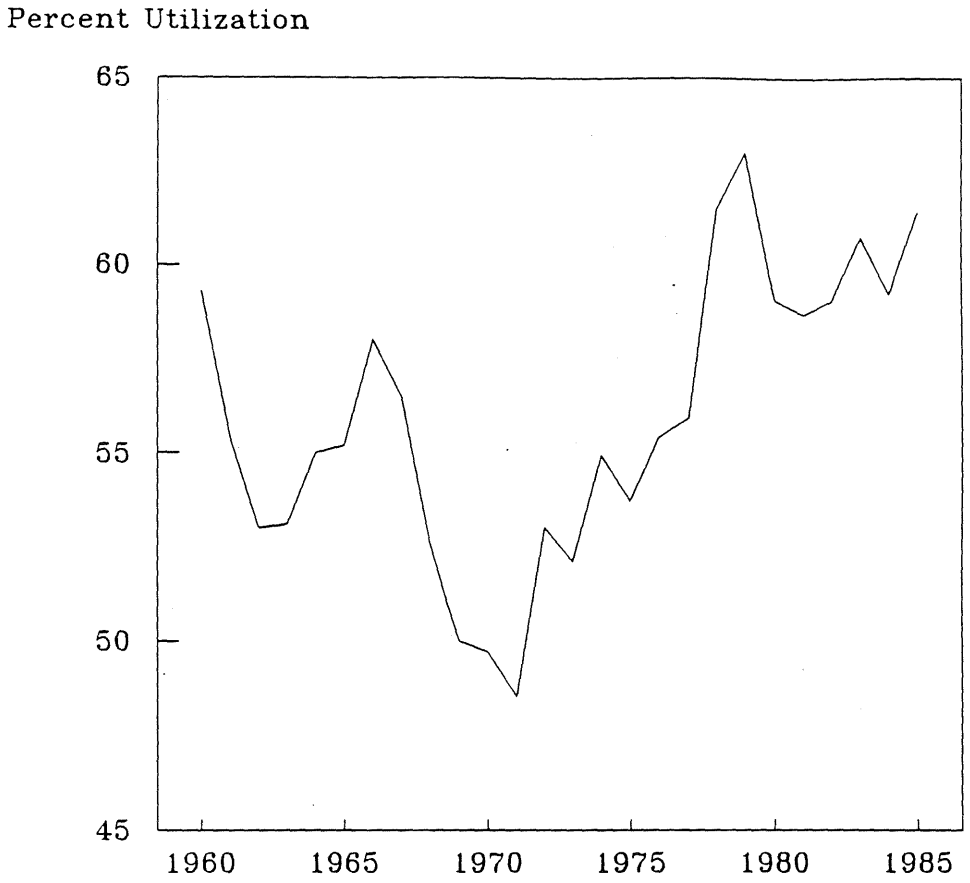


Figure 3. Aircraft Load Factors

Source: Federal Aviation Administration data

Experts generally agree that the technology to fly at hypersonic speeds (between 4,000 and 8,000 miles per hour), may not be developed until well into the 21st century. The U.S. research and development program for a hypersonic plane (the X-30), initially authorized for $700 million over three years in 1986, was designed such that the Department of Defense would, following the research phase, be able to initiate procurement in 1989. (That date was later advance to 1990). While it was originally believed that only the propulsion technology would be the limiting factor in development, ongoing research shows that because of the extraordinarily high temperatures of both the airframe and the engines at hypersonic speeds, materials technology may be just as challenging. Thus, because of technological limitations and budgetary pressures, the X-30 program, while still underway, has effectively stalled.

It is worth noting, however, that although the combination of the individual components may be more difficult than originally thought, the conclusion that engine technology is available for a high-speed supersonic transport may indeed be valid.[2] As conceived by NASA, the transport would ultimately be designed to fly at speeds of Mach 5. Experience has shown, however, that the potential environmental impacts of supersonic flight alone are enough to discourage use. The Concorde (Mach 2), for example, is allowed only in limited areas of the United States. Undaunted, the French are already developing a Mach 3 Concorde. Particularly in light of the development of a Mach 3 airplane, however, the economic benefits (and likelihood) of a high-speed supersonic transport become unclear. Thus, the public policy question is now more one of whether or not to maintain U.S. technological competitiveness and national pride than one of achieving breakthroughs in aviation costs and services.

---

[2] The U.S. decided not to compete with the Concord because of concerns of economic feasibility and budget priorities.

NOISE

The Federal Aviation Administration (FAA) established standards in 1969 which differentiate between levels of noise produced by aircraft. Today, three levels exist: Stage 1, those which do not comply with any standards; Stage 2, those craft which meet the standards first issued in 1969; and Stage 3, those aircraft which comply with the more stringent standards issued in 1977. Stage 3 aircraft contain the best noise technology currently available, and in certain cases represent a reduction of as much as 25 decibels over Stage 1 aircraft, which translates into a perceived noise reduction of as much as 83 percent.

The time has come, however, when the technologies developed to mitigate commercial aircraft noise output are yielding increasingly smaller gains. Because considerable advances have been made since the FAA first issued noise standards in 1969, engine noise is declining as the primary cause of aircraft noise. The technological factor behind this decline is the development of Stage 3 aircraft, which have comparatively quite engines.

Engineers and analysts agree, however, that little can be done in the foreseeable future to reduce airplane noise beyond that of the current Stage 3 aircraft. Thus, the options to expedite the reduction in aircraft noise are effectively limited to

1) national regulatory action designed to expedite fleet turnover,

2) local options which seek to limit the type of aircraft allowed in a region, or

3) local action to alleviate noise impacts through physical facility modifications.

Fleet Composition

To be able to develop precise policy on aircraft technology at any level of government, one must first understand the composition of the current aircraft fleet (by stage) and projections of the "natural" rate of fleet turnover. The FAA estimates that as of 1985, 80 percent of the aircraft fleet was Stage 2 technology, with the balance Stage 3 planes.[3] The

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[3] Stage 2 includes some Stage 1 aircraft, the vast majority of which have either been retrofitted with noise reduction kits or have been exempted from restrictions. Federal Aviation Administration, Report to Congress: Alternatives Available to Accelerate Commercial Aircraft Fleet Modernization, (April 11,

perceived difference between these two types of plane can be considerable. For example, the noise exposed area of a recently introduced Stage 3 aircraft, the Boeing 757, is only 12 percent of the noise exposed area of the Boeing 727, a widely used Stage 2 plane.[4] Except for a minimal number of back-ordered Stage 2 craft in production at Boeing (primarily Boeing 737-200s to be delivered in 1988), all craft currently being manufactured are Stage 3.[5] Nonetheless, the existing Stage 2 fleet represents a considerable investment on the part of the airlines, and when the useful life of a plane averages 25 to 30 years, the replacement rate is likely to be slow.[6] Consequently, the rate at which the current airline fleet is replaced by more advanced technology aircraft, together with future demand, will in large part determine the noise impact of aviation on a given area.

The FAA forecasts that, barring regulatory intervention, virtually all Stage 2 aircraft should be retired by 2010. This forecast corresponds well with those of aircraft manufacturers. Boeing, for example, predicts that all Stage 2 aircraft, which they estimate now comprise 70 to 75 percent of the fleet, should be retired by 2010.[7] The question therefore becomes whether the benefits from an accelerated modernization of the current fleet could justify the costs (Figure 4, Table 1).

Beyond those improvements incorporated into Stage 3 technology, however, few advancements appear likely since the primary source of noise in new designs is no longer the aircraft engine, but air flowing over the aircraft's airframe. In short, while new "high-bypass" engine technology is ultimately expected to reduce engine noise slightly, no reductions similar to those attained between Stage 1 and Stage 3 are anticipated.

1986), p. 5.

[4] Based on the average noise level on take-off from brake release. Kari, John, "Memorandum to the MSP Adequacy Task Force," (December 2, 1987).

[5] Include aircraft over 75,000 pounds maximum certificated weight.

[6] In fact, according to recent analyses, the actual rate of replacement appears to be even slower, as both aircraft manufacturers and airlines have begun to assert that, when properly maintained, there should be no time limit to an aircraft's useful life. (See Aviation Week and Space Technology, July 14, 1988.)

[7] Little, John, Chief of Noise Technology Division, Boeing Commercial Aircraft Co., in presentation of November 12, 1987 before the Metropolitan Council.

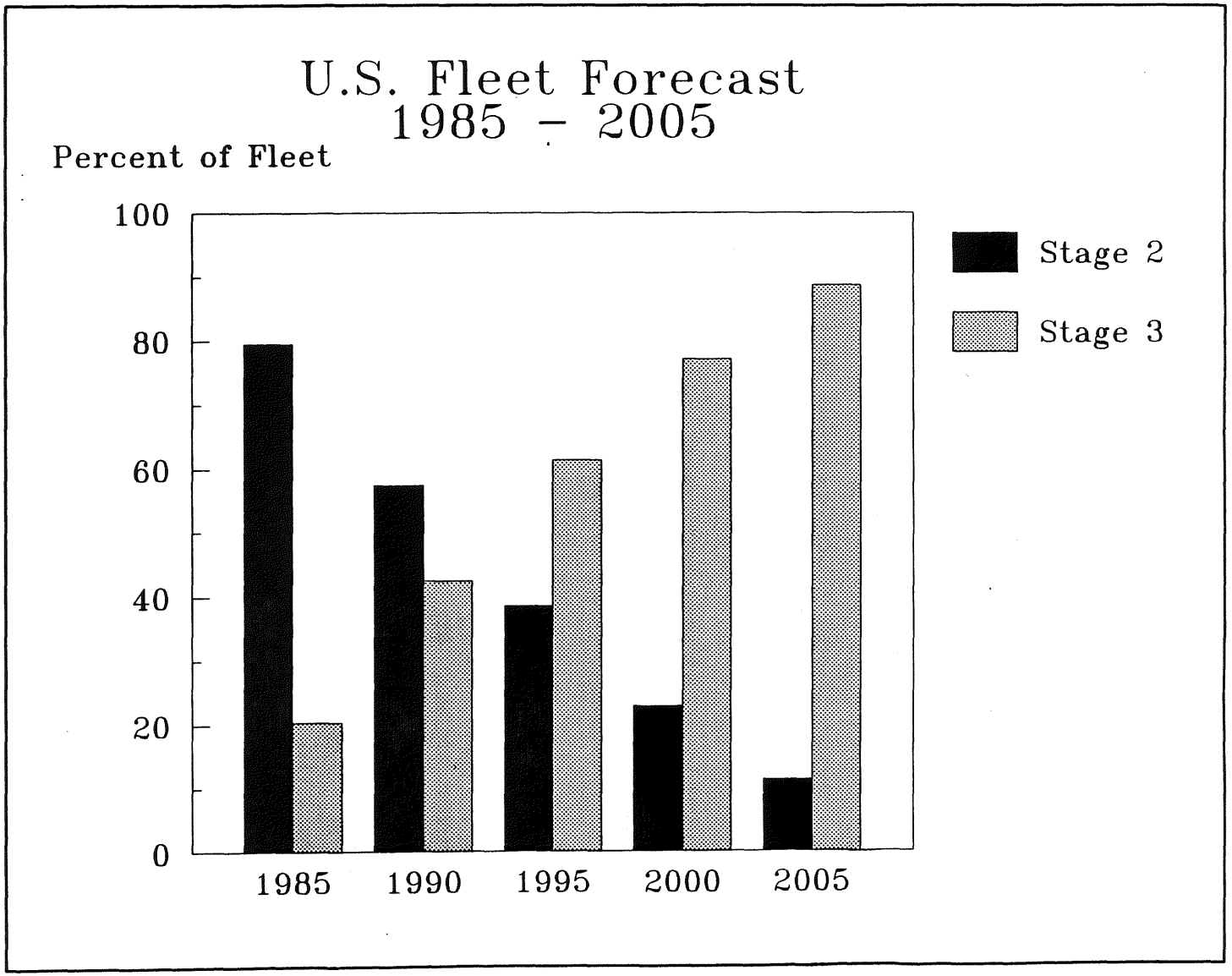

U.S. Fleet Forecast
1985 - 2005
Percent of Fleet
100
80
60
40
20
0
1985
1990
1995
2000
2005
Stage 2
Stage 3

Table 1
U.S. Commercial Fleet Forecast
1985-2010

Year	Stage 2	Stage 3	Total
1985	2,367	608	2,975
1990	2,003	1,481	3,484
1995	1,501	2,383	3,884
2000	958	3,227	4,185
2005	505	3,979	4,484

Source: Federal Aviation Administration

Note: Stage 1 conversions and exemptions are included under Stage 2.

Consequently, attaining the goal of more rapid fleet modernization requires either the implementation of regulations or differential pricing policies, changes which could be enacted at either the federal or local level.

Federal Regulatory/Incentive Programs

The options available to the federal government are relatively clear-cut: either ban all Stage 2 aircraft effective on a given date, or attempt to encourage fleet modernization through economic incentives.

Barring Stage 2 craft on a given date implies that each airline's fleet would, at that point, become non-productive. While certain airlines might be successful in selling Stage 2 aircraft to countries with lower noise standards, estimates suggest that the size of the current Stage 2 fleet would be too large to be absorbed in full by other countries. Consequently, most (if not all) airlines would experience some losses. In consideration of the rate of disinvestment in Stage 2 craft and an optimistic assessment of offsetting sales to other countries, these costs could exceed $9 billion in 1995 (Table 2).[8]

[8] The estimates were developed immediately prior to the Tax Reform Act of 1986 and do not account for the elimination of the investment tax credit or accelerated depreciation rates. A revised estimate would likely show higher costs for air carriers.

Table 2
Air Carrier Costs for Retirement of Stage 2 Aircraft by Date of Fleet Conversion to Stage 3

Year of Conversion	Number of Stage 2 Aircraft	Retirement Cost ($ 1985 Millions)
1995	1,501	$9,082
2000	958	3,822
2005	505	1,183

Source: Federal Aviation Administration

Economic incentives to accelerate fleet modernization include allowing the use of the investment tax credits or accelerated depreciation for new aircraft purchases, and introducing loan guarantees for airlines. The first two could stimulate a more rapid shift with no direct outlays required. There would, of course, be a real federal cost in foregone tax revenues. Loan guarantees -- a mechanism with which the FAA is already familiar -- could also accelerate modernization, although the potential cost is unclear.

Local Options to Reduce Noise

Like the federal government, a locality has a limited set of options for noise abatement. Foremost among these is the adoption of stringent noise standards that would eliminate or greatly restrain Stage 2 traffic. San Francisco, for example, has recently adopted a regulation which would effectively restrict Stage 2 craft operations three years earlier than FAA forecasts suggest will occur without additional incentives.[9]

A related technique would be to charge differential landing fees, imposing higher costs on Stage 2 craft. This strategy has

[9] This regulation (adopted January 22, 1988) has already met with considerable opposition from air carriers and the FAA. See O'Lone, Richard G., "Airlines Oppose New Noise Abatement Regulation for San Francisco Airport," Aviation Week and Space Technology, (January 11, 1988), p. 76.

been employed at Palm Beach International where special environmental fees are assessed specifically to discourage Stage 2 craft from using the airport, particularly at night (Table 3). This approach appears to have been extremely effective with only limited opposition on the part of air carriers. The potential of aircraft (and perhaps traffic) diversions can have significant affects on an airline's flexibility in aircraft fleet use, which may require that higher costs be imposed on that airline. Because of the size of the airport relative to national air travel, however, the San Francisco example will have a much larger impact and will likely face much stronger opposition. Northwest Airlines, for example, claims that the San Francisco regulation would "virtually bring to a halt our cargo operation."[10]

Alternatives to special landing fees or regulations include redesigning runways to redirect traffic over areas of low population or constructing physical barriers to mitigate noise impacts. The first is clearly of limited value at MSP International not only because of its relatively small size but also due to the extent of residential and commercial areas that surround the airport. The second would require the construction of noise barriers and/or the use of noise insulation in affected residences -- a costly proposition that would help, but not solve the problem since flight paths would still affect residential areas.

Table 3
Schedule of Environmental Fees at Palm Beach International

Period of Operation	Fee Schedule	
	Stage 2	Stage 3
Day (0700-2200 Hrs)	$13/operation	No Fee
Night (2200-0700 HRS)	$130 for landing (no takeoffs allowed)	$10/operation

Source: Palm Beach International Airport

Note: County ordinance prohibits Stage 2 takeoffs after 10 p.m. (2200 hours)

[10] Ibid.

CAPACITY

Technological solutions to airport capacity in particular (both physical as well as environmental) have long been recognized as important because of the declining number of viable airport sites and limited space to expand existing airports. There are four approaches to expanding airport capacity, of which only the first three are truly technologically driven:

- Airspace technology,
- Airspace use procedures,
- Atmospheric problem resolution, and
- Airport design.

Table 4 summarizes the types of technologies that are available and which aspects of airport problems they are best suited to solve.

Airspace Technology

The FAA is currently implementing three technologies designed to improve aircraft guidance, surveillance, and control: the microwave landing system; improved surveillance radar; and automated traffic management system.

Microwave Landing System. The Instrument Landing System (ILS), is the current air traffic control system for takeoffs and landings when poor weather conditions mean that visual flight rules can not be used. This system requires a single file, straight-line approach to the runway. That is, aircraft are required to use a unique approach path, thus restricting the potential airport capacity.

The Microwave Landing System (MLS) offers a greater degree of freedom under instrument-assisted conditions by scanning a wide volume of airspace, as opposed to the narrow path of the ILS. This allows more approaches under poor visibility conditions. In addition to improving capacity, MLS is expected to improve safety and reliability. However, due to procedural difficulties, international agreements, and resistance by parts of the aviation community, MLS may not be installed at the majority of large airports for some time.

Table 4.
Technology to Increase Airport Capacity and Reduce Delay (Cont'd)

Technology	Area of application	Purpose	Benefit
Terminal facilities and services:			
Terminal building design.....	Terminal	Increase utility and efficiency of terminal building	Increased capacity; reduced delay
Passenger movers.....	Terminal	Improve circulation in terminal; reduce walking distance	Reduced delay; greater passenger convenience
Ticketing.....	Terminal	Expedite ticket purchase and passenger check-in	Reduced delay
Baggage handling.....	Terminal	Expedite baggage check-in, transfer, and pickup	Reduced delay
Passenger security screening...	Terminal	Make screening faster and more reliable	Reduced delay; improved security
Federal Inspection Service.....	Terminal	Expedite customs and immigration clearance	Reduced delay
Airport access:			
Terminal curbfront design.....	Terminal; landside	Facilitate airport entrance and exit	Reduced delay
Airport circulation roads.....	Landside	Facilitate automobile traffic flow	Reduced delay
Airport ground access.....	Landside	Reduce access time; lessen road congestion	Reduced delay

SOURCE: Office of Technology Assessment, Airport System Development, (August 1984), pg. 63

Table 4.

Technology to Increase Airport Capacity

Technology	Area of application	Purpose	Benefit
Aircraft guidance, surveillance, and control:			
Microwave Landing System.....	Airspace	Improve precision of navigation; make more flexible use of airspace	Increased capacity; reduced delay; less noise impact
Surveillance radar.....	Airspace	Improve surveillance; reduce separation	Improved safety; increased capacity
Traffic management techniques..	Airspace	Improve traffic flow	Reduced delay
Airspace use procedures:			
Reduced lateral separation for parallel and converging runways.....	Airspace	Increase utilization of multiple runways in IMC	Increased capacity
Reduced longitudinal separation.....	Airspace	Reduce in-trail separation	Increased capacity
Separate short runways for small aircraft.....	Airspace	Segregate air traffic by size and speed	Increased capacity; reduced delay
Weather and atmospheric effects:			
Wake vortex detection.....	Airspace	Reduce in-trail separation	Increased capacity
Wind shear detection.....	Airspace	Alert pilots to wind shear	Improved safety; reduced delay
Noise control and abatement:			
Control of aircraft noise.....	Airspace	Reduce aircraft noise	Increased capacity; reduced delay
Aircraft operating procedures..	Airspace	Lessen or distribute noise impacts	Increased capacity; reduced delay
Airport surface utilization:			
Surveillance and control.....	Taxiways	Improve surveillance, control, and guidance of aircraft	Increased capacity; reduced delay; improved safety on ground
High-speed turnoffs and improved taxiways.....	Runway	Reduce runway occupancy time	Increased capacity
Taxiway marking and lighting...	Taxiways	Increase efficiency of taxiway use	Reduced delay
Apron and gate facilities.....	Ramps and aprons	Improve docking at gate; improve aircraft maintenance and servicing	Increased capacity; reduced delay

THE METROPOLITAN COUNCIL
OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

AIRPORT HUB COMPARISON

Working Paper V
August 1988

Prepared By:
APOGEE RESEARCH
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CH2M HILL
Enviroscience

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INTRODUCTION

Amidst industry-wide capital expansion, the demand for services at Minneapolis-St. Paul Airport continues to exceed growth. This report 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:

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

Appendices include statistical detail, runway configuration and orientation documentation, and noise contours.

The Selection Process

The five hub airports selected for detailed analysis were selected 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 1, below, for example, each of the airports selected was similar in terms of operations and population. In addition, each of these airports is currently considering or undertaking major physical expansion to accomodate rapid growth in demand

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.[1] 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.

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

Table 1. 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.

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 2).

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 (Figure 1). 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 (Figure 2). 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.

GENERAL 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 (Table 3). Detail on runway size, orientation, and number is provided in Appendix B.

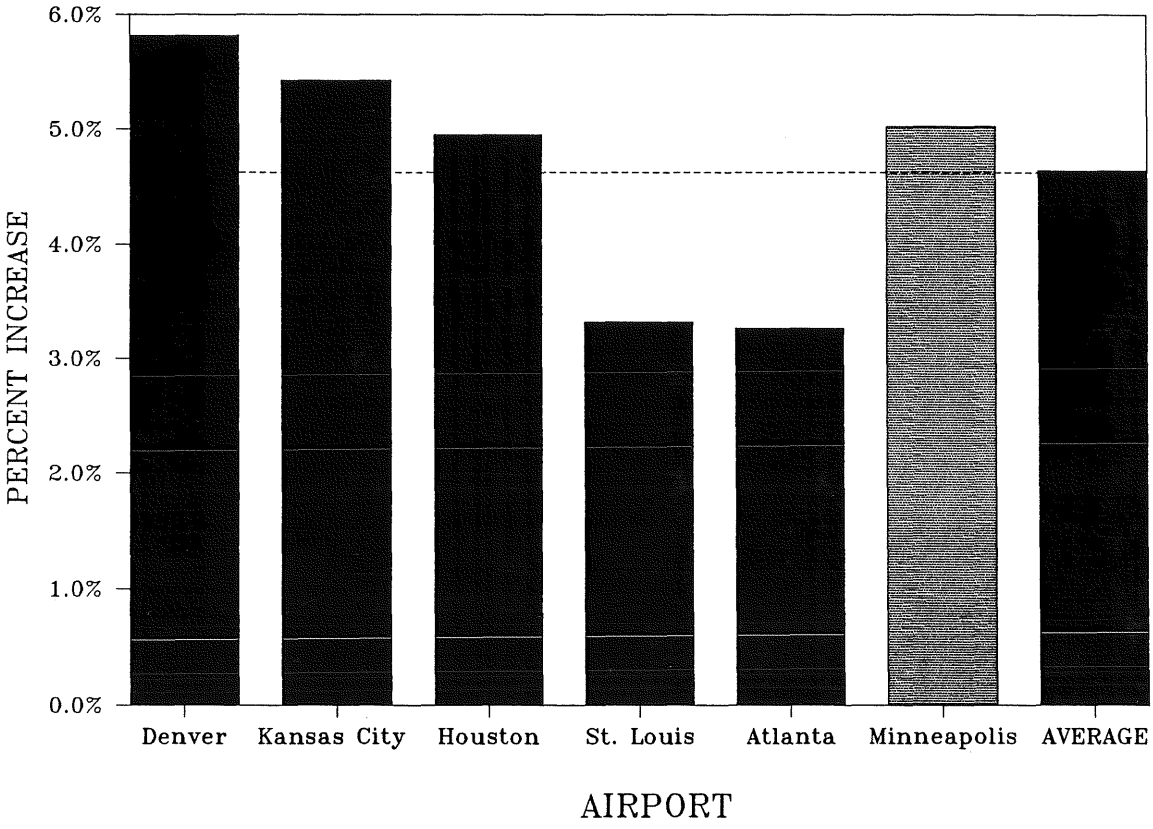
Not surprisingly, the number of enplanements is not necessarily a function of the size of an airport nor the number of runways. In terms of acreage, for example, Kansas City is more than three times the size of Lambert. While Kansas City currently has two commercial and one general aviation runway, Lambert 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.

Table 2.
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

FORECAST GROWTH IN ENPLANEMENTS
1986 - 2000



FORECAST GROWTH IN OPERATIONS
1986 - 2000

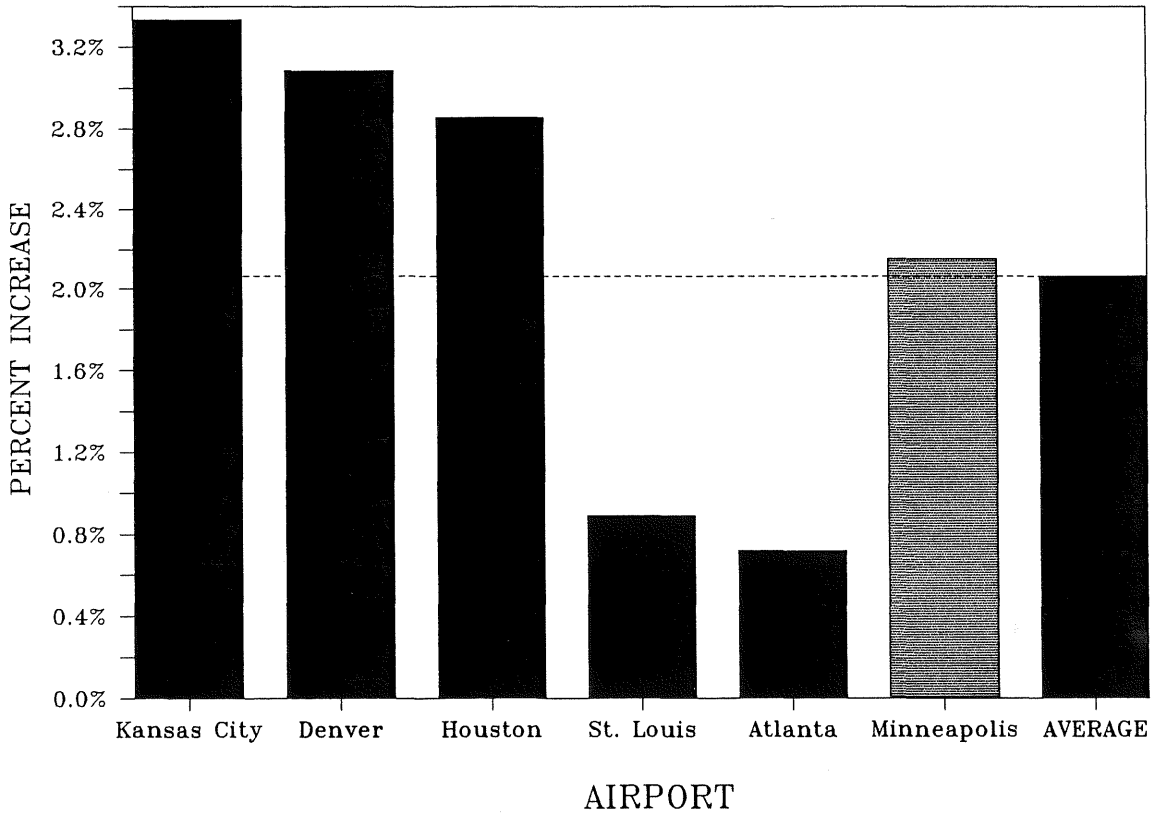


TABLE 3.
AIRPORT COMPARISONS

AIRPORT	PASSENGER ENPLANEMENTS (1986 IN 000s)	RANK: AMONG ALL HUBS	AMONG ALL AIRPORTS	TOTAL OPERATIONS (1986 IN 000s)	RANK: AMONG ALL HUBS	AMONG ALL AIRPORTS
Atlanta (ATL)	22,040	4	2	775	7	2
Denver (DEN)	16,191	7	5	521	10	5
Houston (IAH)	7,050	10	19	298	8	25
Kansas City (MCI)	3,984			206		
St. Louis (STL)	10,149	11	9	461	11	6
Minneapolis (MSP)	8,277	14	14	402	16	12
Average	11,282			444		

AIRPORT	ACREAGE	NO. OF RUNWAYS	PASSENGER ENPLANMTS/ RUNWAY (000s)	ACREAGE/ RUNWAY	PASSENGER ENPLANEMENTS/ ACRE
Atlanta (ATL)	3,753	4	5,510	938	5,873
Denver (DEN)	4,600	4	4,048	1,150	3,520
Houston (IAH)	7,840	3	2,350	2,613	899
Kansas City (MCI)	7,200	2	1,992	3,600	553
St. Louis (STL)	2,300	3	3,383	767	4,413
Minneapolis (MSP)	3,100	3	2,759	1,033	2,670
Average	4,799	3	3,340	1,684	2,988

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 making or planning capital investments to improve their IFR operations capacity (Table 4), and many 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.

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 close 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 runways 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.

Table 4.
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

FINANCIAL INFORMATION

An analysis of financial indicators among airports similarly positioned may suggest where MSP stands in terms of costs and service levels and help to indicate the range of options that might be possible with a new airport. 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.[2]

Atlanta's Hartsfield Airport is by far the largest facility in the sample, followed by Denver and St. Louis. Much the same holds true for the broad financial measures at each airport (Figure 3). Nonetheless, these measures simply reflect fixed levels of demand and the cost to service that demand at each airport. The key factor is that the characteristics of demand at these facilities are similar -- each serves major metropolitan areas as well as the needs of hubbing airlines.

The financial comparison of the airports must, therefore, be made on the basis of ratios. These ratios, derived from the annual financial reports of each airport, provide measures of profitability (operating ratio and net take-down) and debt-servicing capacity (coverage and safety margins).

Profitability

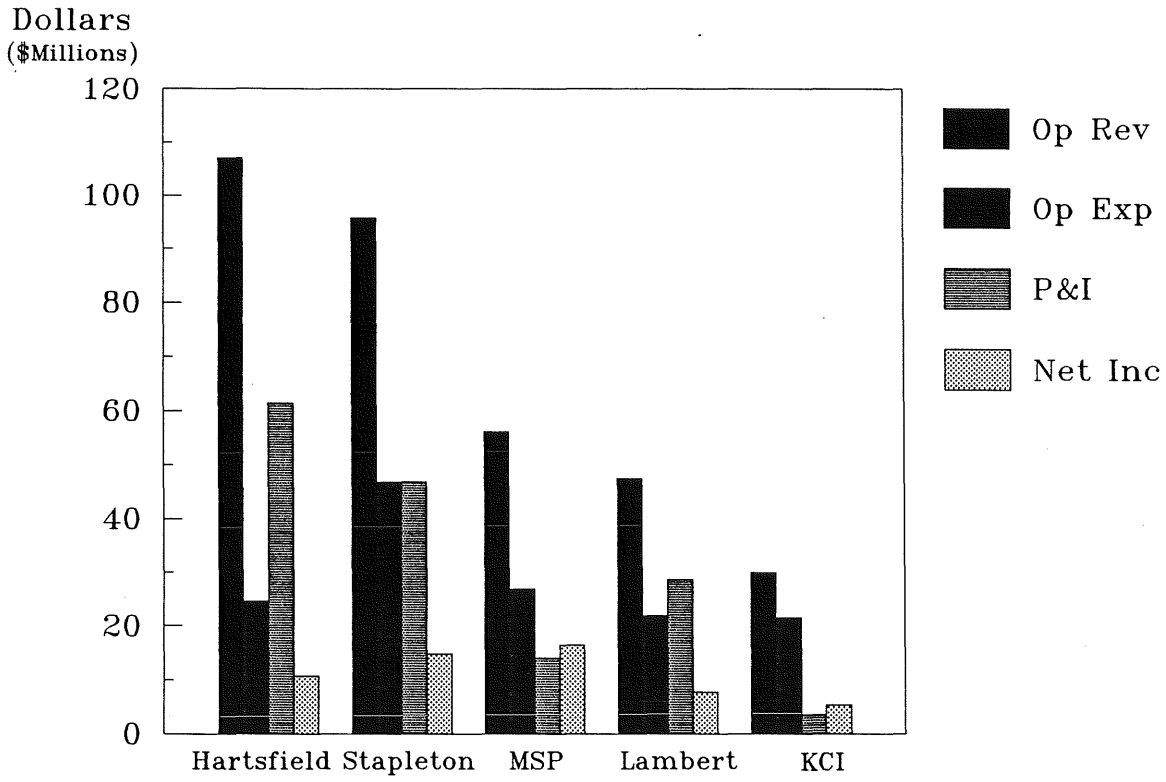
The net take-down, or net revenues divided by gross revenue and income, reflects the degree to which normal operation and maintenance (O&M) expenses influence profitability. In short, a higher value suggests lower O&M costs, and potentially higher profitability. While there is no "correct" value for 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 along with airport size (Figure 4). 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.

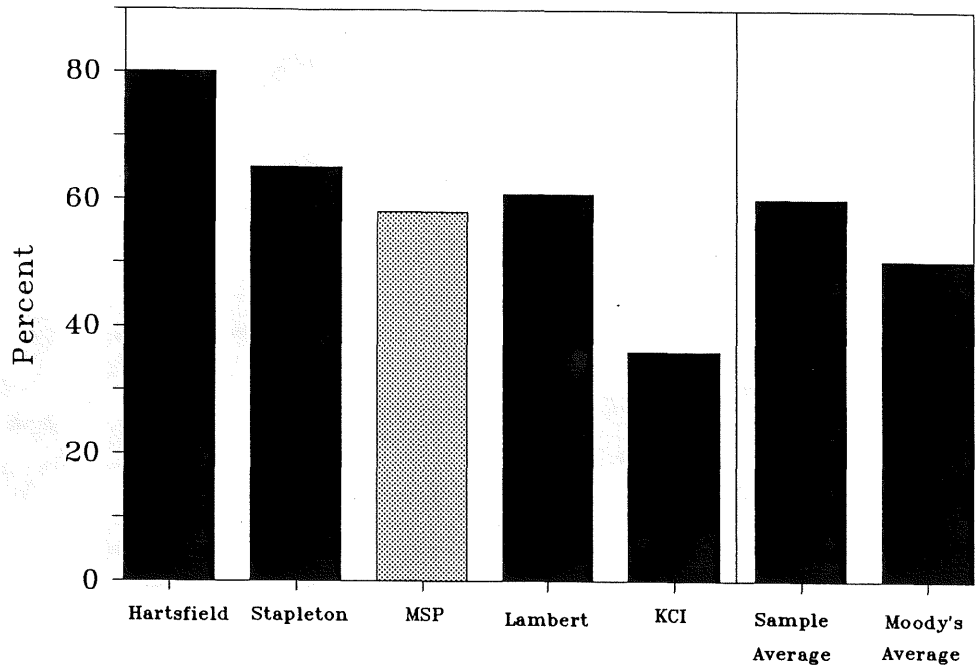
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[2] National averages were taken from analyses prepared by Moody's Investors Services.

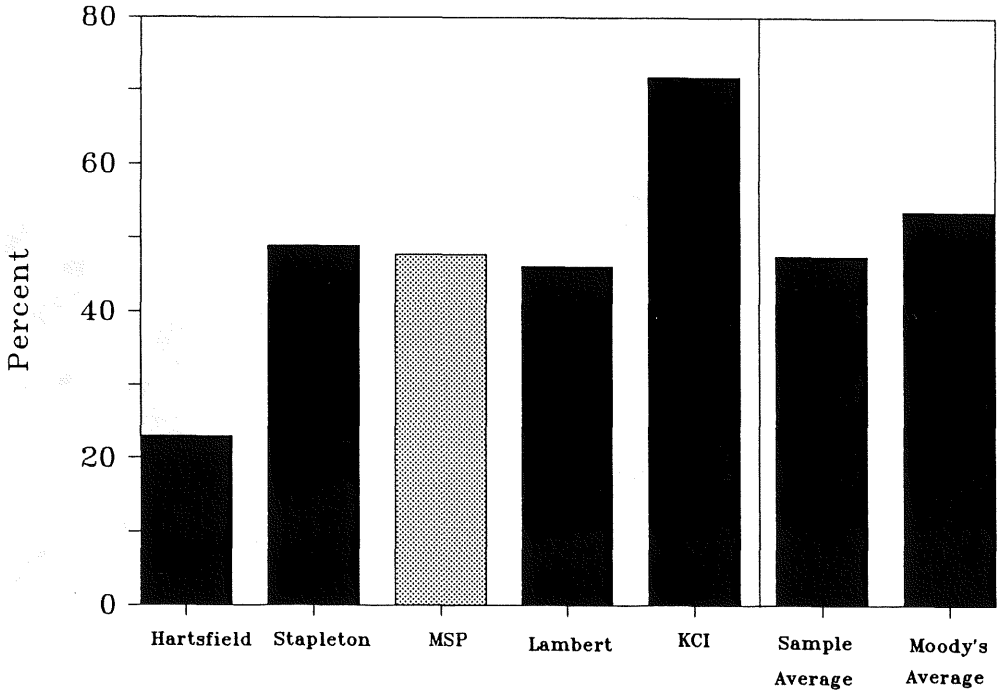
Financial Data of Selected Hubs



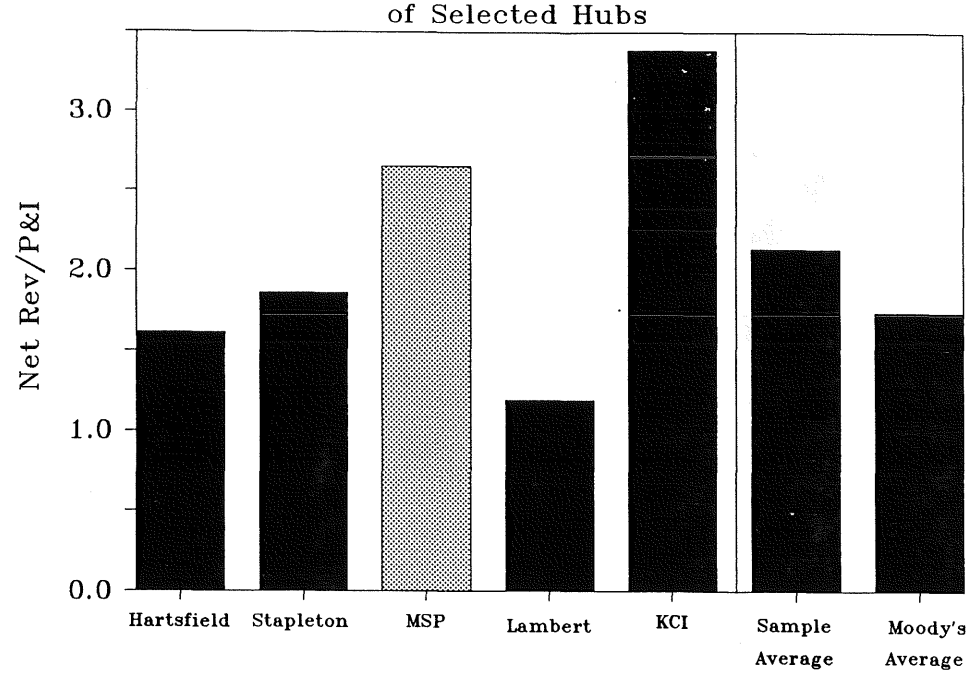
Net Take-Down of Selected Hubs



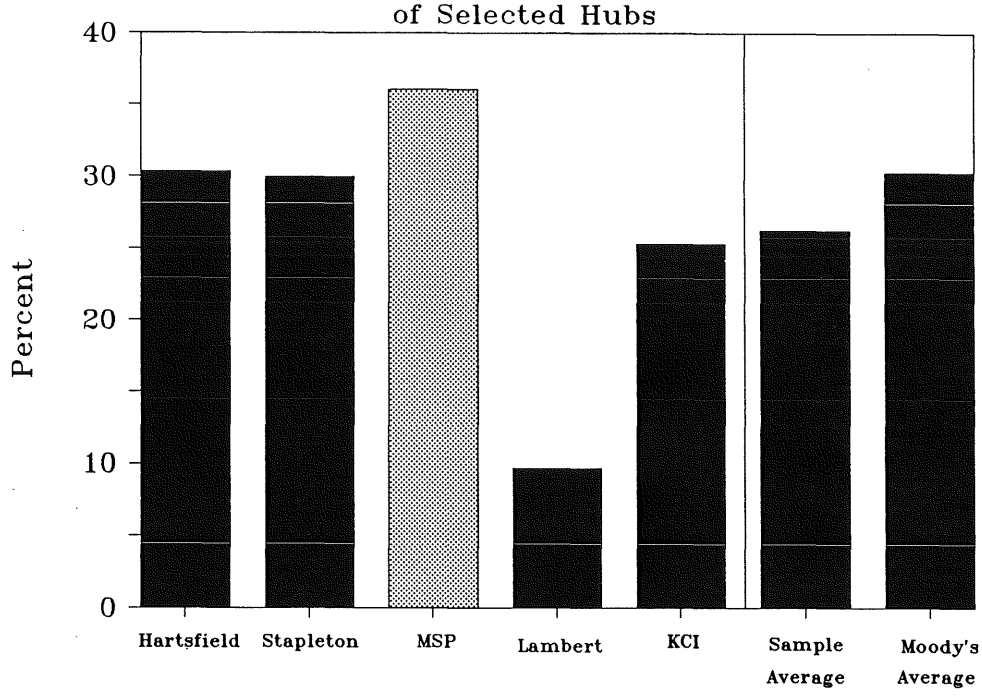
Operating Ratios of Selected Hubs



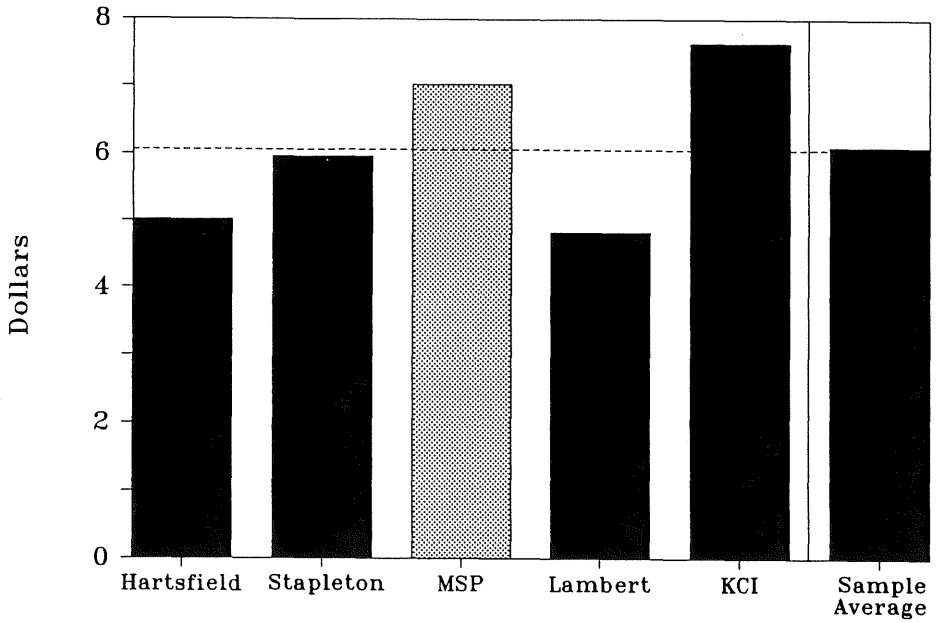
Debt Service Coverage Ratio
of Selected Hubs



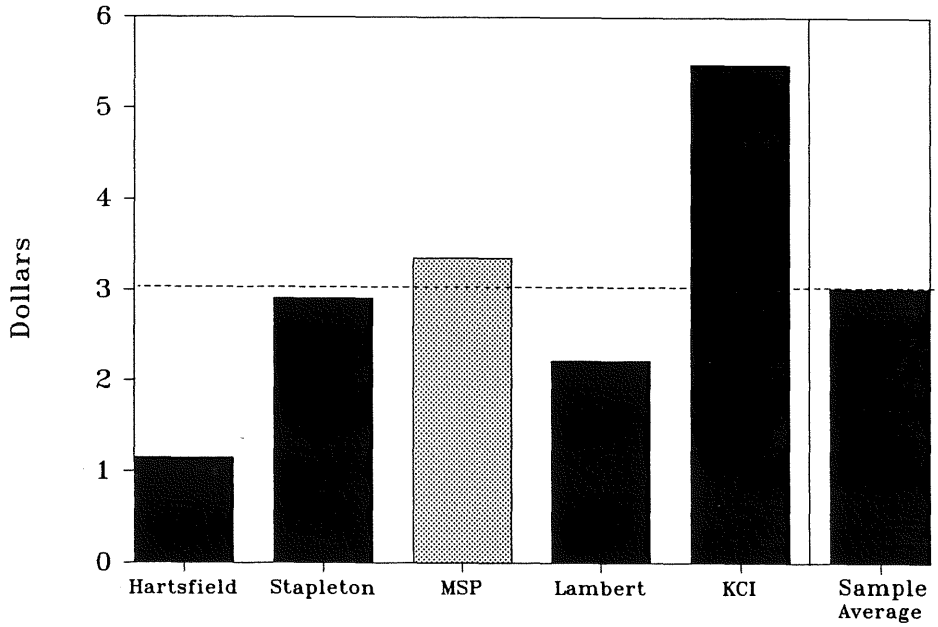
Debt Service Safety Margin
of Selected Hubs



Operating Revenues Per Passenger Enplanment



Operating Expenses Per Passenger Enplanment



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 KCI (Figure 5).

Safety margins, on the other hand, denote additional levels of protection. While the national average is 30 percent, MSP is will 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.

Operating Results

The final measures of hub comparability are those of net operating revenues and expenses on a unit basis. The findings with respect to enplanements reinforce the suggestions made earlier that the larger hubs can attain a higher degree of efficiency. With the exception of St. Louis' Lambert, costs and revenues are closely tied to airport size, with Atlanta's Hartsfield attaining the lowest level for both operating revenues and expenses, and MSP falling roughly in the middle of the range (Figure 6).

APPENDIX A
Statistical Section

TABLE 1
AIRPORT ENPLANEMENTS

	TOTAL ENPLANEMENTS (IN 000s)				% INCREASE COMPOUNDED ANNUALLY
AIRPORT	1986	1990	1995	2000	1986-2000
Atlanta (ATL)	22,040	27,549	31,118	34,586	3.27%
Denver (DEN)	16,191	18,789	28,142	35,731	5.82%
Houston (IAH)	7,050	8,810	11,425	13,878	4.96%
Kansas City (MCI)	3,984	5,409	6,909	8,350	5.43%
St. Louis (STL)	10,149		13,539	16,038	3.32%
Minneapolis (MSP)	8,277		13,577	16,445	5.03%
AVERAGE	11,282	15,139	17,452	20,838	4.64%

	COMMERCIAL ENPLANEMENTS (IN 000s)				% INCREASE COMPOUNDED ANNUALLY
AIRPORT	1986	1990	1995	2000	1986-2000
Atlanta (ATL)	21,115	26,376	29,690	33,010	3.24%
Denver (DEN)	15,924	18,448	27,722	35,233	5.84%
Houston (IAH)	6,934	8,699	11,296	13,732	5.00%
Kansas City (MCI)	3,797	5,226	6,613	8,000	5.47%
St. Louis (STL)	9,783		13,066	15,475	3.33%
Minneapolis (MSP)	7,787		12,338	14,802	4.69%
AVERAGE	10,890	14,687	16,788	20,042	4.60%

	REGIONAL ENPLANEMENTS (IN 000s)				% INCREASE COMPOUNDED ANNUALLY
AIRPORT	1986	1990	1995	2000	1986-2000
Atlanta (ATL)	885	1,174	1,428	1,576	4.21%
Denver (DEN)	267	341	420	498	4.55%
Houston (IAH)	116	112	129	146	1.66%
Kansas City (MCI)	187	243	296	350	4.58%
St. Louis (STL)	371		474	562	3.01%
Minneapolis (MSP)	490		1,239	1,643	9.03%
AVERAGE	386	468	664	796	4.51%

TABLE 2
AIRPORT OPERATIONS

AIRPORT	TOTAL OPERATIONS (IN 000s) 1986	1990	1995	2000	% INCREASE COMPOUNDED ANNUALLY 1986-2000
Atlanta (ATL)	775	832	845	857	0.72%
Denver (DEN)	521	549	721	797	3.08%
Houston (IAH)	298	338	393	442	2.86%
Kansas City (MCI)	206	228	275	326	3.33%
St. Louis (STL)	461		484	522	0.89%
Minneapolis (MSP)	402		478	542	2.16%
AVERAGE	444	487	533	581	2.17%

AIRPORT	COMMERCIAL OPERATIONS (IN 000s) 1986	1990	1995	2000	% INCREASE COMPOUNDED ANNUALLY 1986-2000
Atlanta (ATL)	572	603	615	627	0.66%
Denver (DEN)	369	392	556	625	3.84%
Houston (IAH)	202	254	298	337	3.72%
Kansas City (MCI)	127	148	174	200	3.30%
St. Louis (STL)	299		345	380	1.73%
Minneapolis (MSP)	251		285	320	1.75%
AVERAGE	303	349	379	415	2.50%

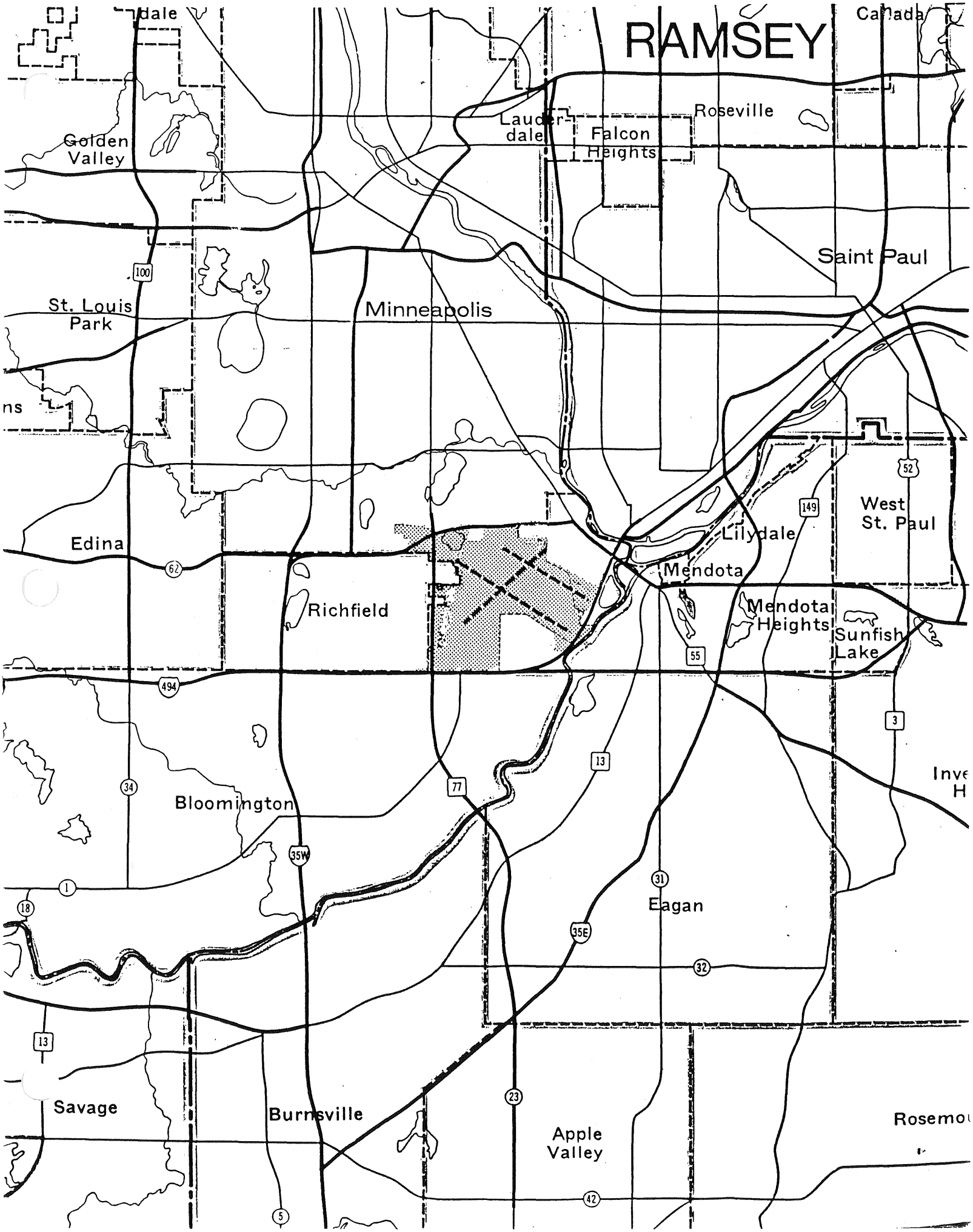
AIRPORT	REGIONAL OPERATIONS (IN 000s) 1986	1990	1995	2000	% INCREASE COMPOUNDED ANNUALLY 1986-2000
Atlanta (ATL)	169	199	202	204	1.35%
Denver (DEN)	102	115	126	138	2.18%
Houston (IAH)	48	30	35	39	-1.47%
Kansas City (MCI)	61	61	74	87	2.57%
St. Louis (STL)	102		85	90	-0.89%
Minneapolis (MSP)	67		126	160	6.42%
AVERAGE	92	101	108	120	1.69%

TABLE 2.
AIRPORT OPERATIONS
(Cont'd)

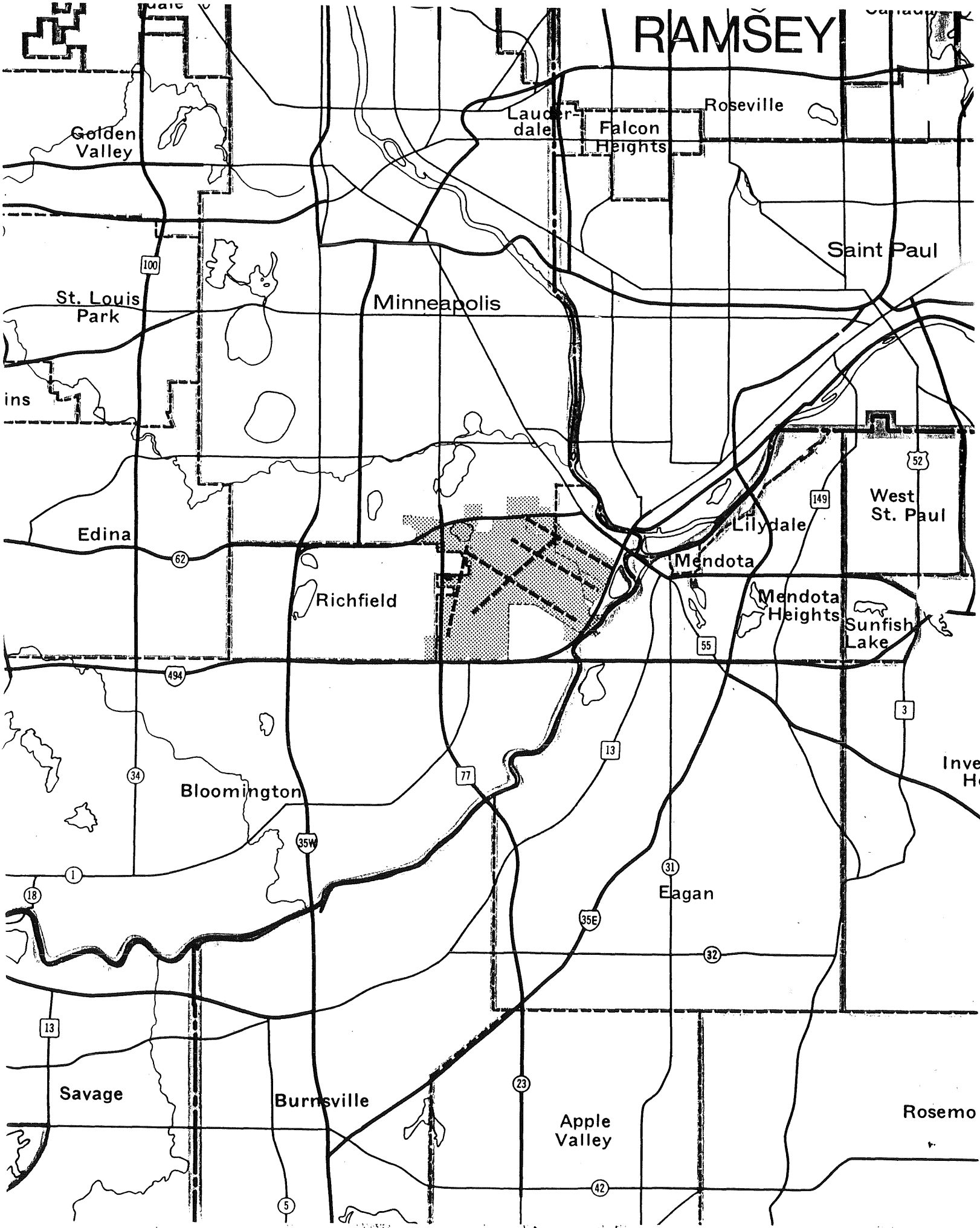
	GENERAL AVIATION OPERATIONS (IN 000s)				% INCREASE COMPOUNDED ANNUALLY
AIRPORT	1986	1990	1995	2000	1986-2000
Atlanta (ATL)	30	27	25	22	-2.19%
Denver (DEN)	46	37	33	30	-3.01%
Houston (IAH)	47	53	58	64	2.23%
Kansas City (MCI)	14	17	24	36	6.98%
St. Louis (STL)	49		43	40	-1.44%
Minneapolis (MSP)	74		60	56	-1.97%
AVERAGE	43	34	41	41	0.10%

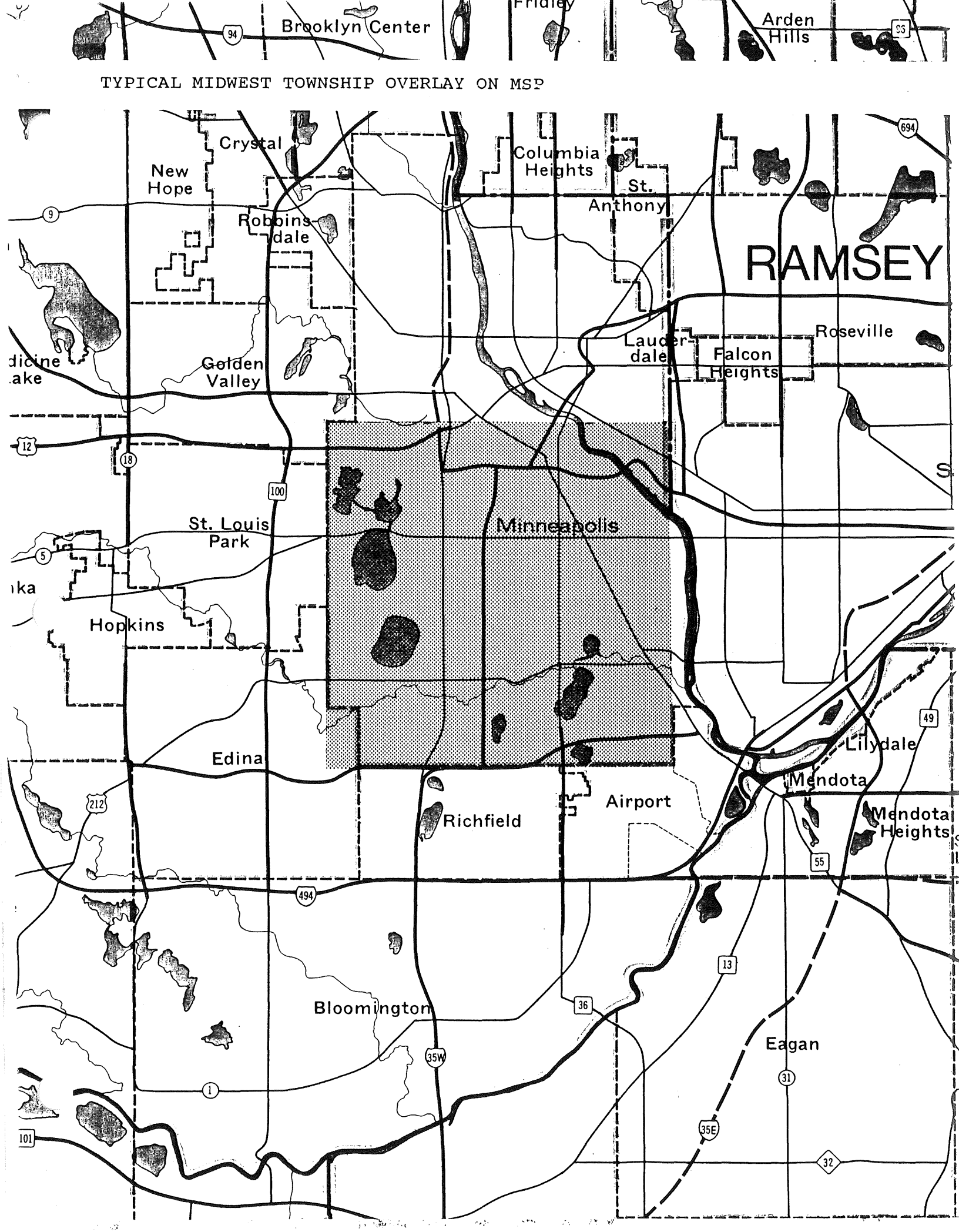
APPENDIX B
Airport Diagrams and Layouts

APPENDIX B:
MSP

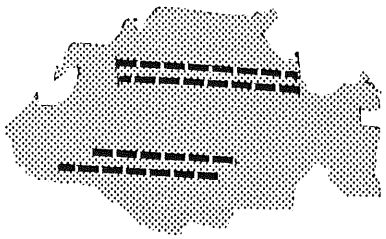

EXISTING SITE
RAMSEY
Golden Valley
Lauderdale
Falcon Heights
Roseville
Saint Paul
St. Louis Park
Minneapolis
Edina
Richfield
Lilydale
Mendota
West St. Paul
Mendota Heights
Sunfish Lake
Bloomington
Eagan
Savage
Burnsville
Apple Valley
100
62
494
35W
35E
77
13
55
52
149
3
31
32
23
42
5
34
18
1

STRATEGY B

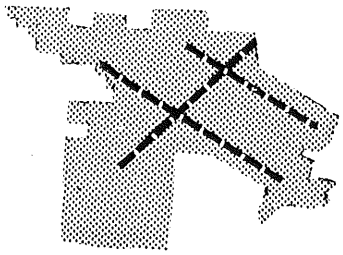

RAMSEY
Roseville
Lauder-
dale
Falcon
Heights
Golden
Valley
Saint Paul
100
St. Louis
Park
Minneapolis
ins
52
149
West
St. Paul
Lilydale
Edina
62
Mendota
Richfield
Mendota
Heights
Sunfish
Lake
55
494
3
13
77
34
Bloomington
35W
31
1
18
Eagan
35E
32
13
Savage
Burnsville
23
Apple
Valley
Rosemo
42
5


Brooklyn Center
Fridley
Arden Hills
94
TYPICAL MIDWEST TOWNSHIP OVERLAY ON MSP
Crystal
New Hope
Robbinsdale
Columbia Heights
St. Anthony
RAMSEY
694
9
Roseville
Lauderdale
Falcon Heights
Golden Valley
12
18
100
St. Louis Park
Minneapolis
5
Hopkins
Edina
212
Richfield
Airport
Lilydale
Mendota
Mendota Heights
49
55
494
13
36
Bloomington
35W
Eagan
1
31
35E
101
32

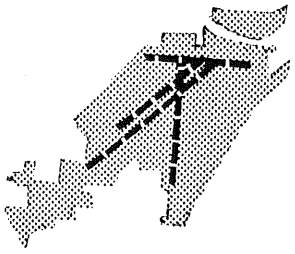
APPENDIX B:
HUBS OF LESS THAN 4,000 ACRES
ATTEMPTING TO SITE A NEW AIRPORT



ATLANTA



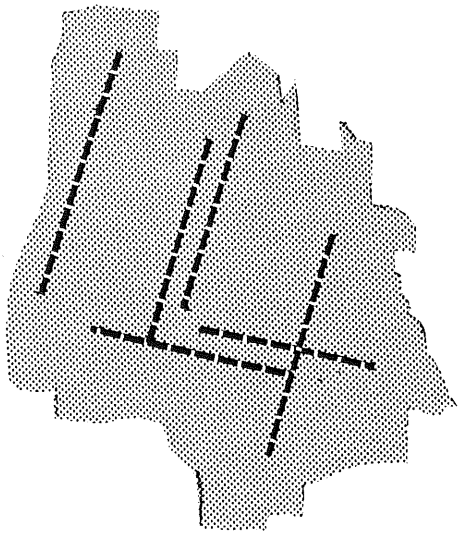
MSP-EXISTING



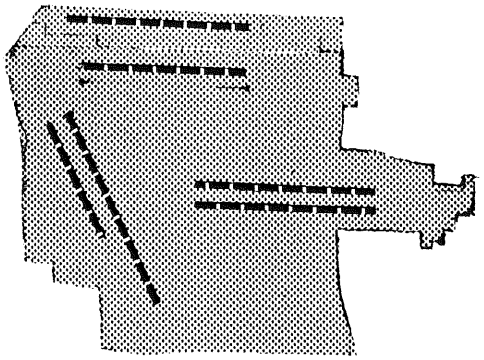
CLEVELAND

APPENDIX B:

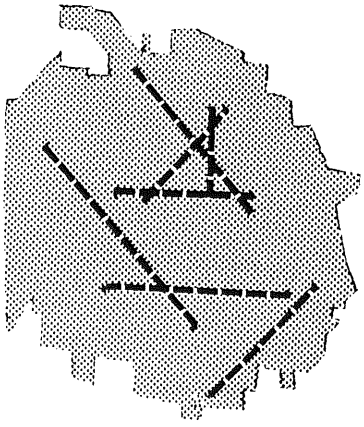
HUBS OF LESS THAN 8,000 ACRES
THAT DEVELOPED NEW, RELOCATED MAJOR AIRPORTS



KANSAS CITY INTERNATIONAL



HOUSTON INTERNATIONAL

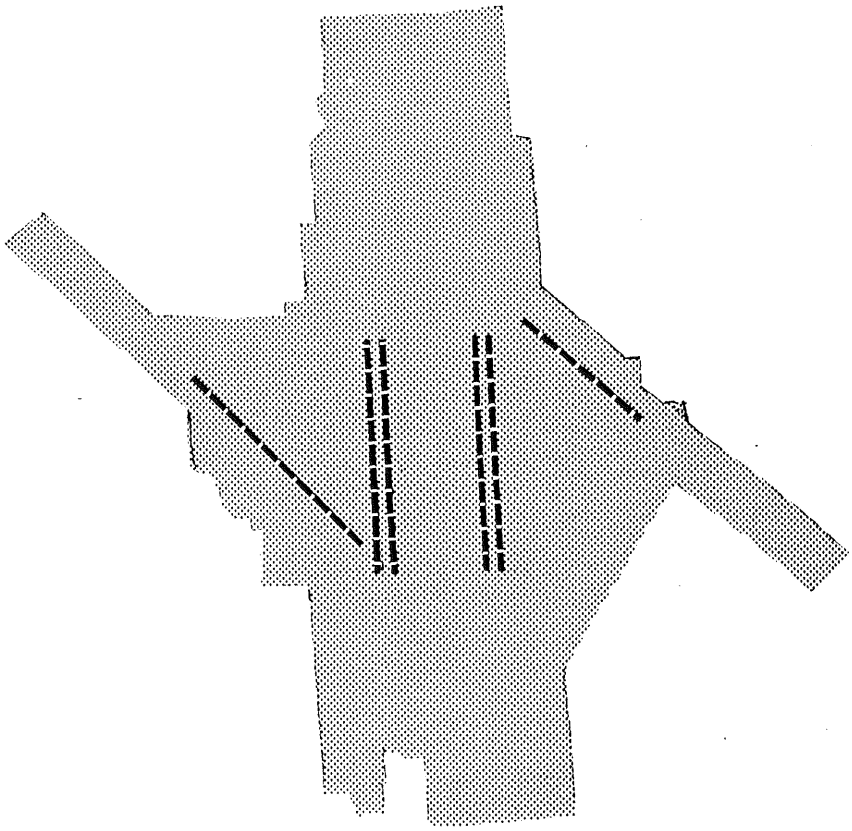


CHICAGO O'HARE

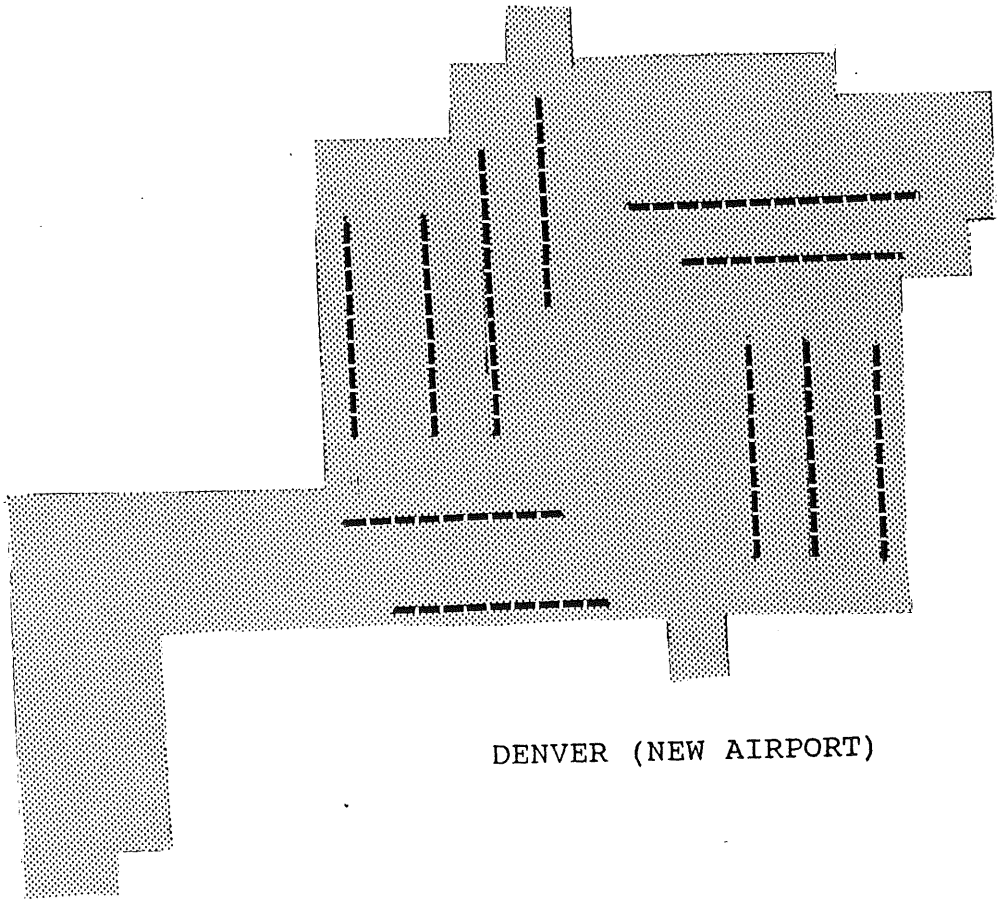
APPENDIX B:

HUBS OF MORE THAN 12,000

WHERE THE HUB IS ESTABLISHED AS A KEY ECONOMIC DEVELOPMENT TOOL

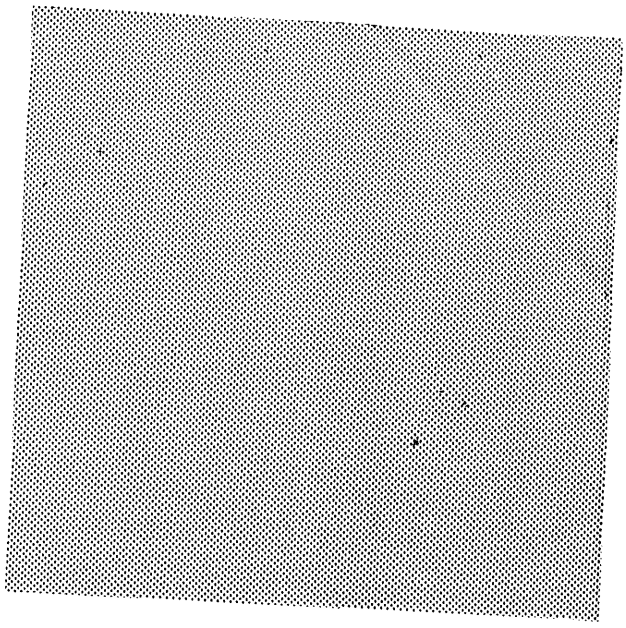


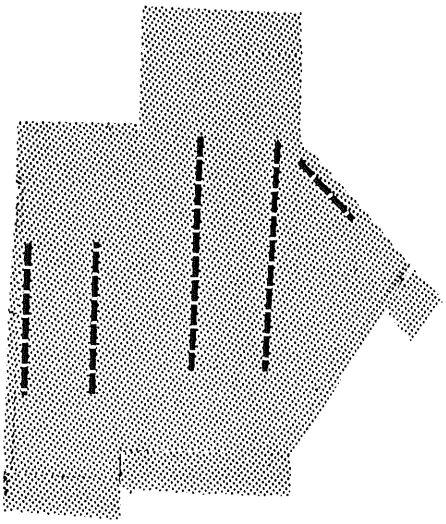
DALLAS/FT. WORTH



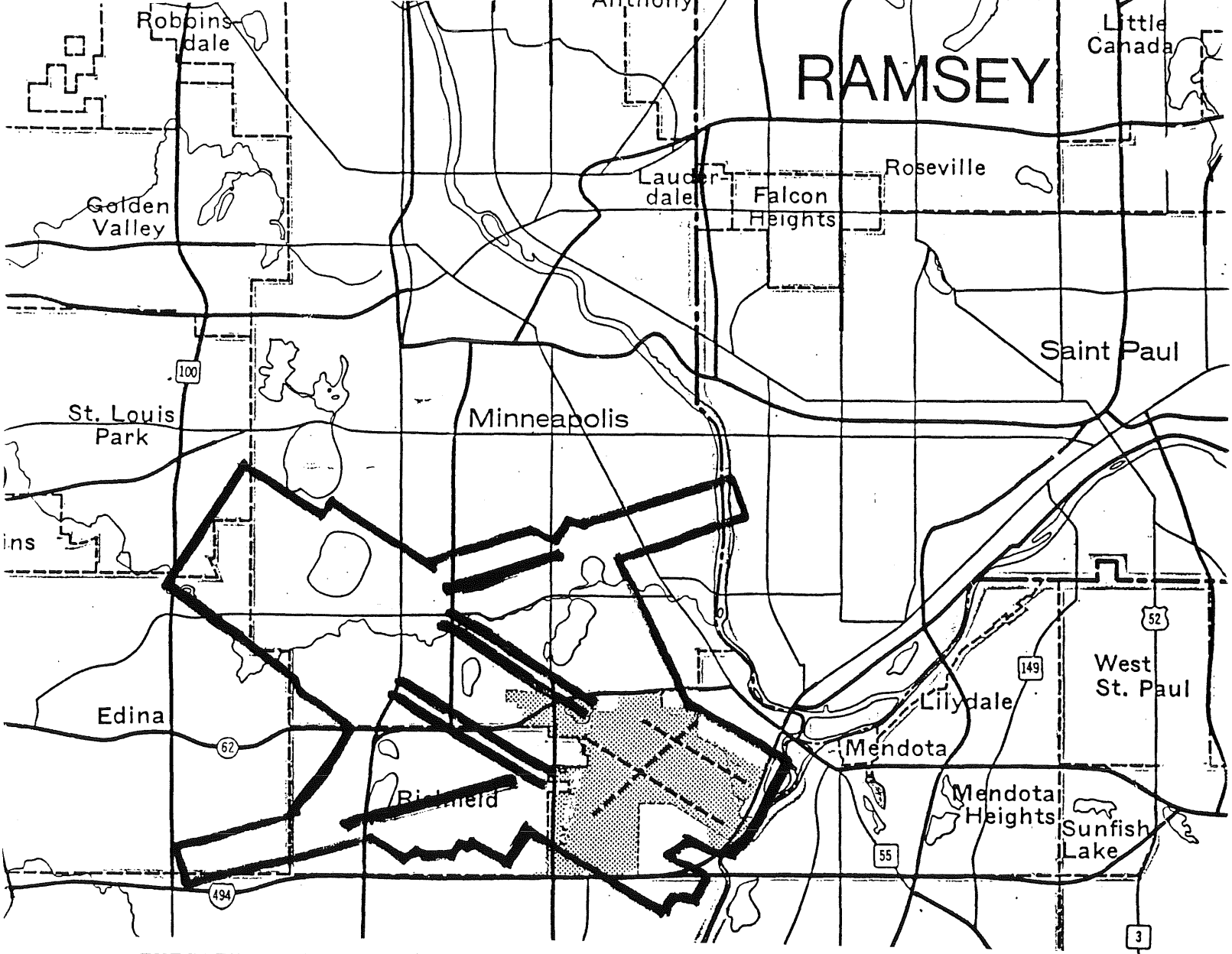
DENVER (NEW AIRPORT)

APPENDIX B:
MSP RELATIVE SIZE

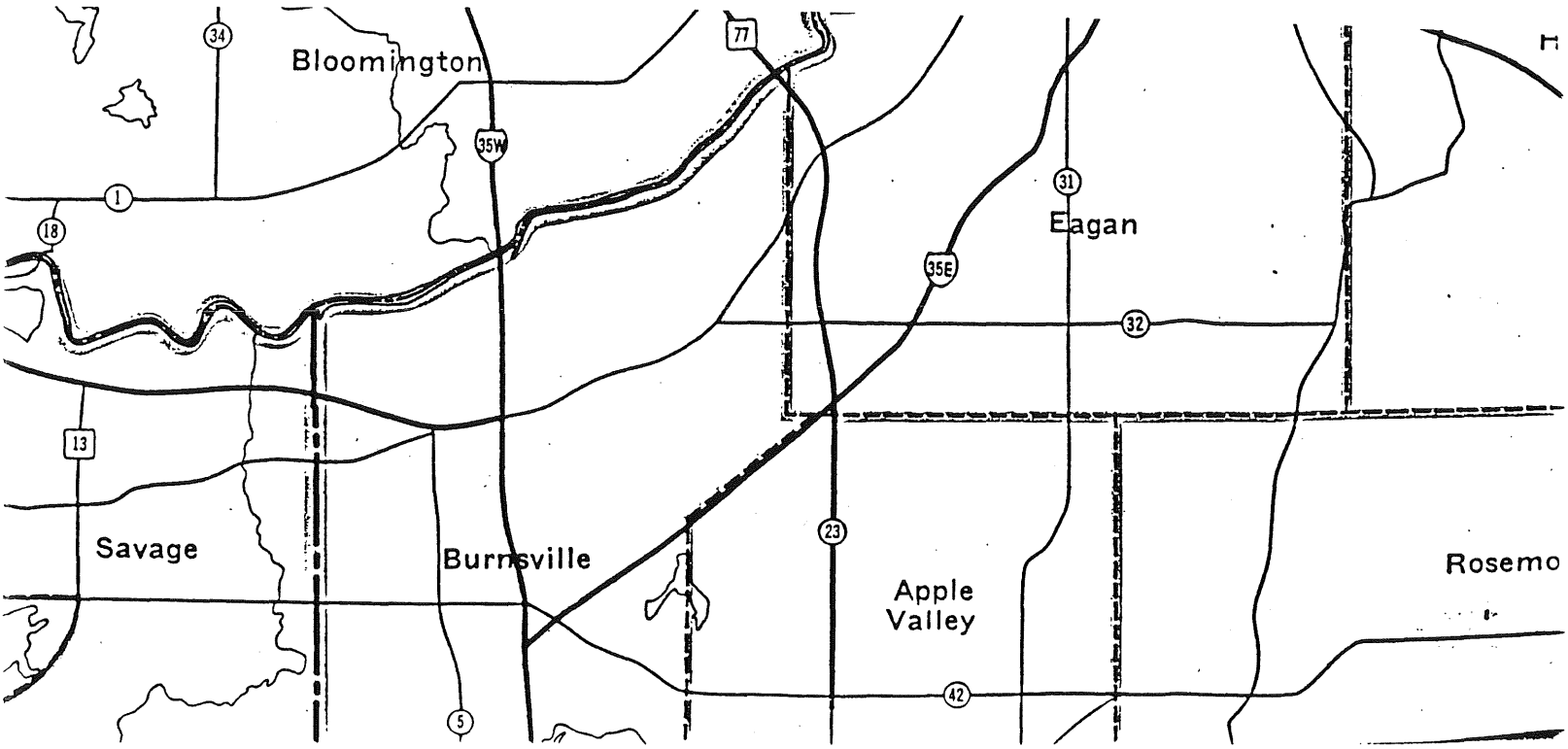




PROPOSED NEW AIRPORT

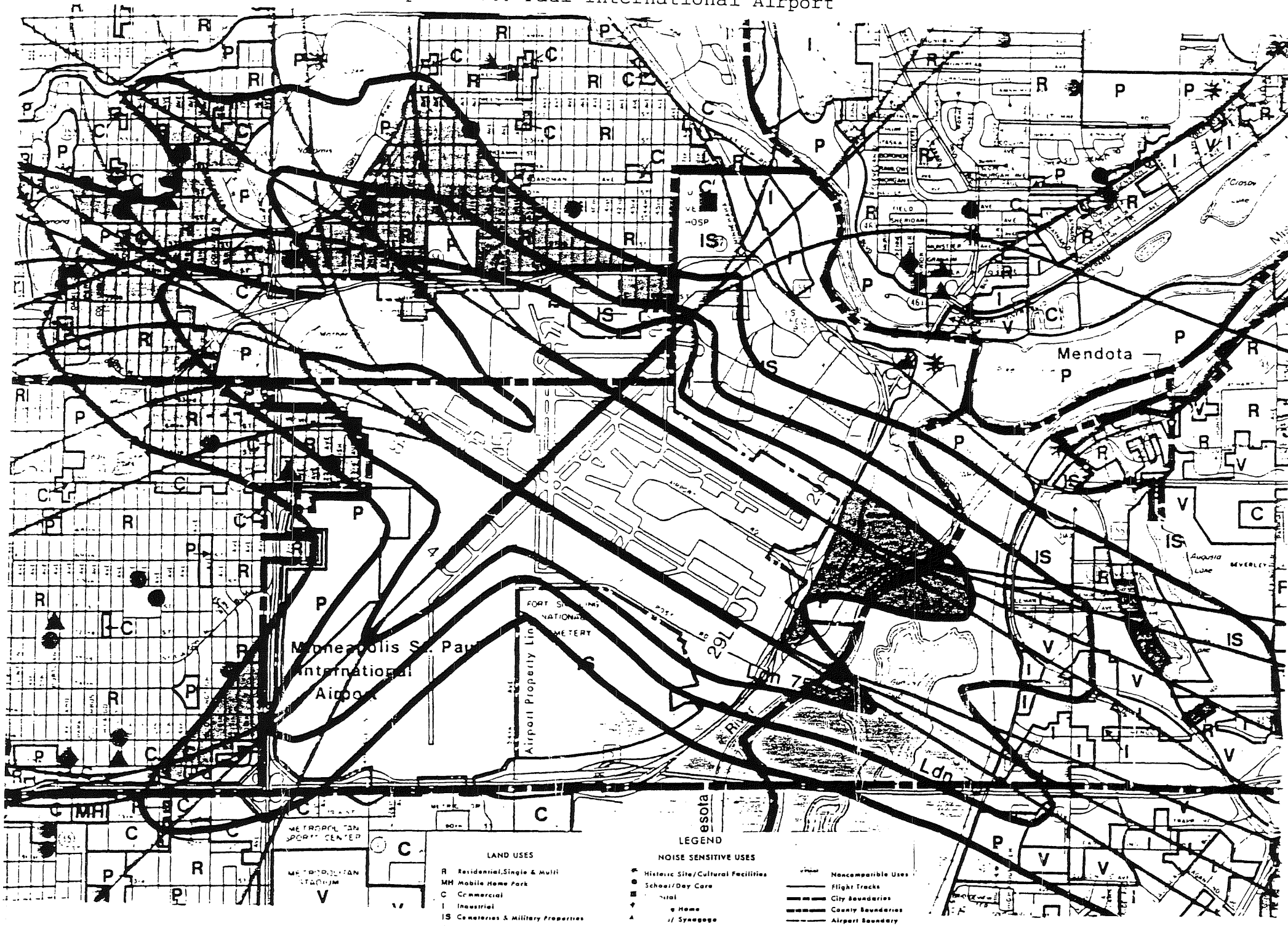


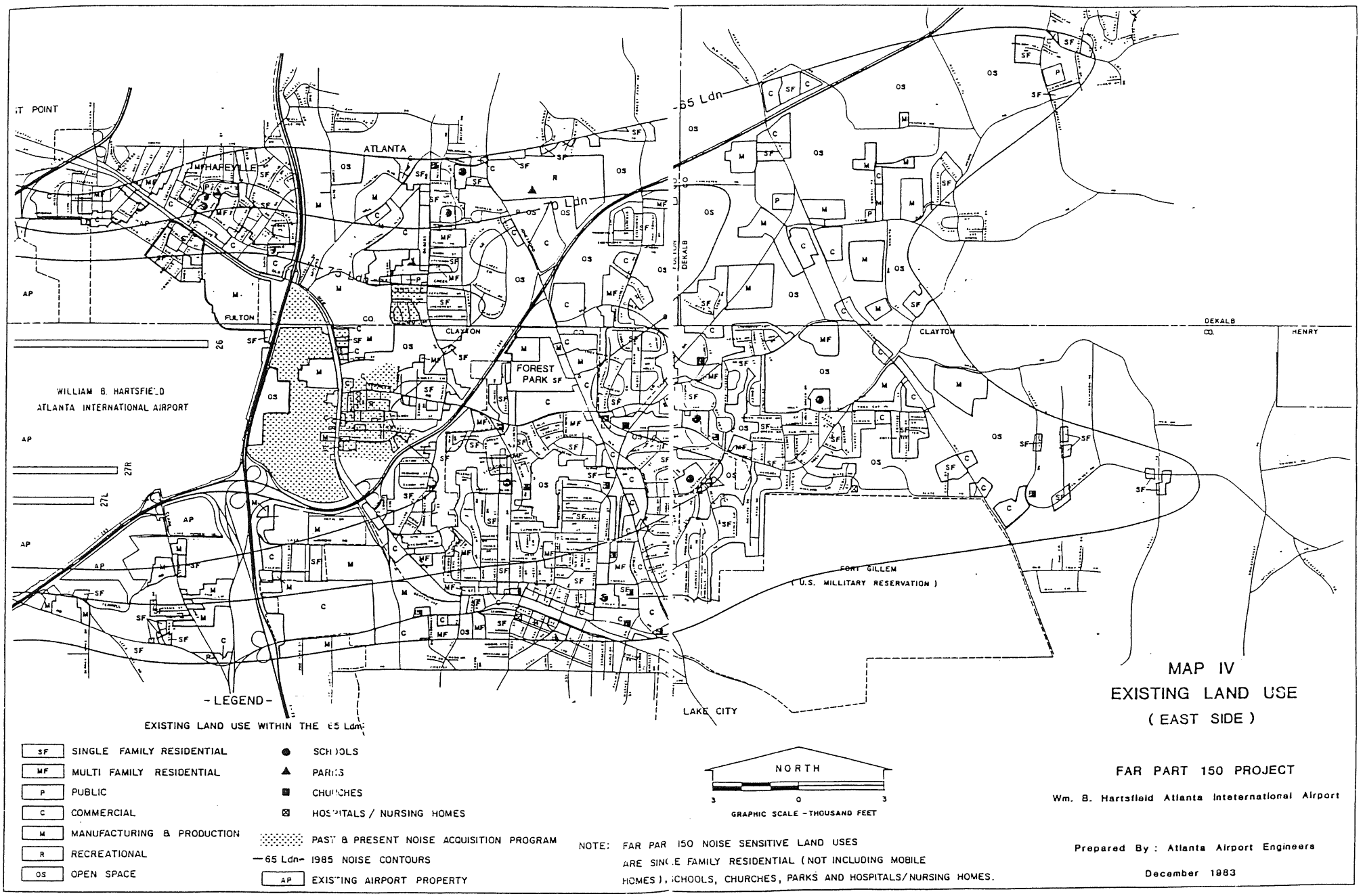
EXISTING SITE RELATIVE TO DALLAS/FT. WORTH AIRPORT



APPENDIX C
Noise Contours and Land Use

Noise Exposure Map: Minneapolis-St. Paul International Airport




ATLANTA
HAPEVILLE
FULTON CO.
CLAYTON
DEKALB
CO.
HENRY
FOREST PARK
WILLIAM B. HARTSFIELD
ATLANTA INTERNATIONAL AIRPORT
FORT GILLEM
(U.S. MILLITARY RESERVATION)
LAKE CITY
65 Ldn
75 Ldn
26
27R
27L
AP
- LEGEND -
EXISTING LAND USE WITHIN THE 65 Ldn
SF SINGLE FAMILY RESIDENTIAL
MF MULTI FAMILY RESIDENTIAL
P PUBLIC
C COMMERCIAL
M MANUFACTURING & PRODUCTION
R RECREATIONAL
OS OPEN SPACE
SCHOOLS
PARKS
CHURCHES
HOSPITALS / NURSING HOMES
PAST & PRESENT NOISE ACQUISITION PROGRAM
65 Ldn 1985 NOISE CONTOURS
AP EXISTING AIRPORT PROPERTY
NORTH
3 0 3
GRAPHIC SCALE - THOUSAND FEET
NOTE: FAR PAR 150 NOISE SENSITIVE LAND USES ARE SINGLE FAMILY RESIDENTIAL (NOT INCLUDING MOBILE HOMES), SCHOOLS, CHURCHES, PARKS AND HOSPITALS/NURSING HOMES.
MAP IV
EXISTING LAND USE
(EAST SIDE)
FAR PART 150 PROJECT
Wm. B. Hartsfield Atlanta Inteternational Airport
Prepared By : Atlanta Airport Engineers
December 1983



N

2000 0 2000 4000

Graphic Scale in Feet

LEGEND

NOISE SENSITIVE

- SINGLE FAMILY
- MULTIPLE FAMILY
- MOBILE HOME PARK
- PUBLIC/QUASI-PUBLIC
- SCHOOL
- HOSPITAL
- RELIGIOUS INSTITUTION (CHURCH, SEMINARY OR CONVENT)
- COLLEGE/UNIVERSITY
- ORPHANAGE
- HISTORIC SITE

NOISE COMPATIBLE

- COMMERCIAL/OFFICE
- OPEN SPACE(PARKS, GOLF COURSE, COUNTRY CLUB OR CEMETERY)
- INDUSTRIAL
- VACANT/AGRICULTURE
- Ldn CONTOUR

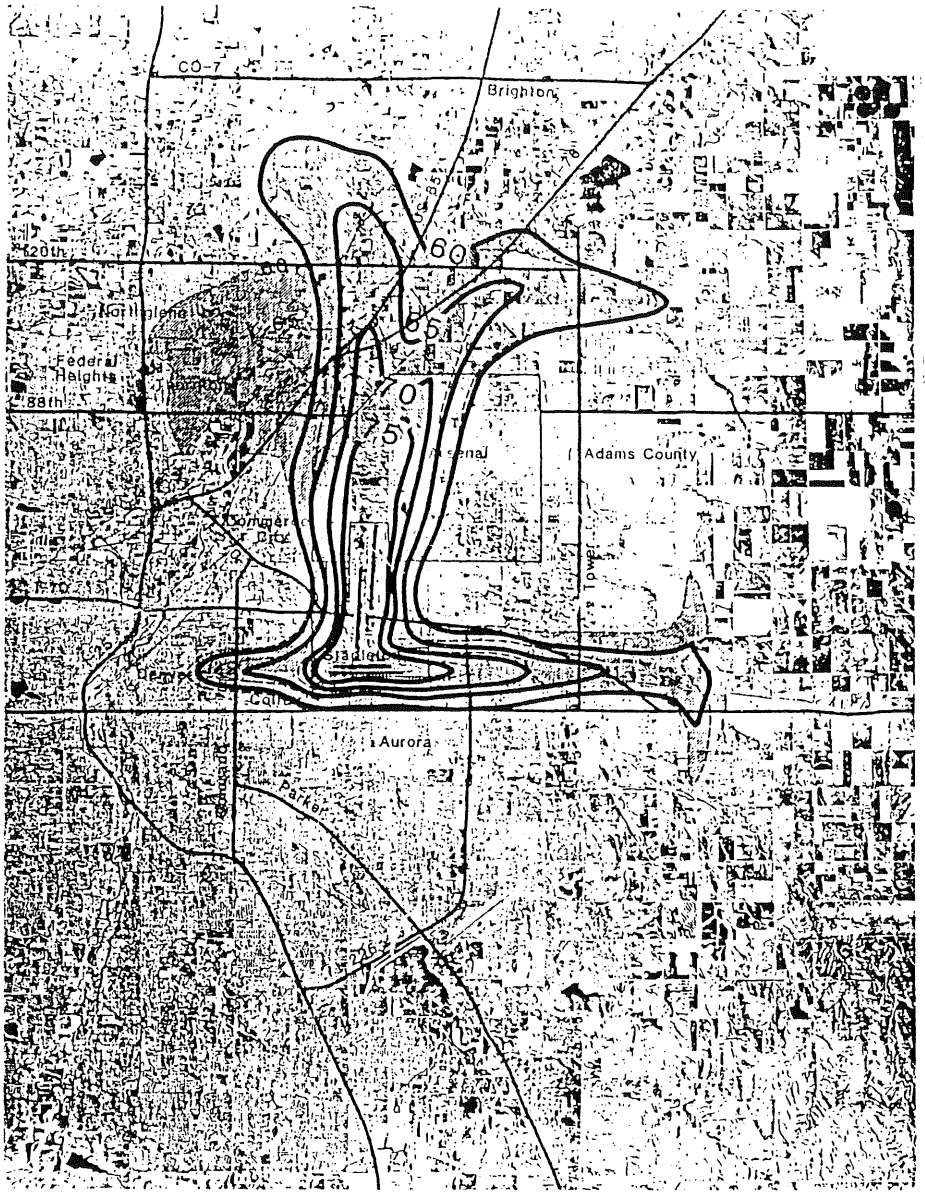
Exhibit F

FAR Part 150 Noise Compatibility Program
Lambert-St.Louis International Airport

1986 Ldn CONTOURS

PEAT MARWICK

February 1987



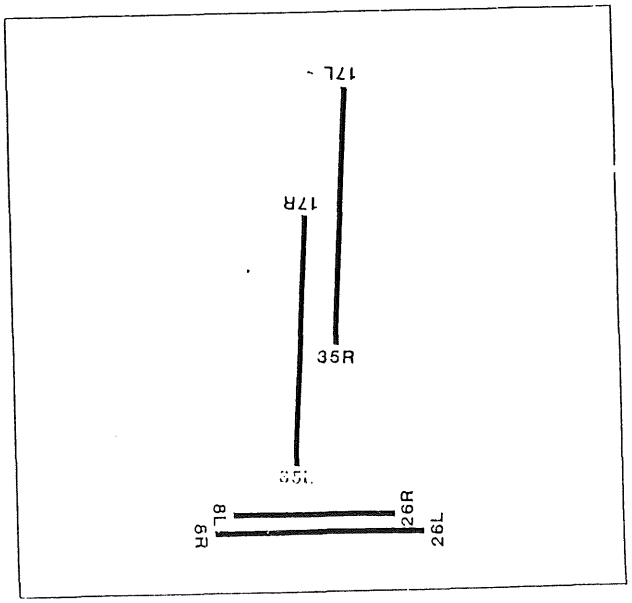
Ldn Contours for 1982 Operations Showing Effects of Proposed Departure Route and Runway Use Changes

This figure shows how the proposed Departure Route Changes and the Realigned Preferential Runway Use System could affect noise levels. The dashed lines show the Ldn contours that result from present operating procedures (1982 operations) and the solid lines show how the contours could be if the proposed departure route and runway use changes were in effect. The shading identifies areas of decreased exposure and areas of increased exposure.

Area of Increased Noise

Area of Decreased Noise

Stapleton Runway Layout



THE METROPOLITAN COUNCIL
OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

AIRPORT NOISE ANALYSIS

October 1988

Prepared By:
APOGEE RESEARCH
Thompson-Hickling
Enviroscience

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CNSI CONTOUR ANALYSIS 7

POLICY IMPLICATIONS 7

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INTRODUCTION

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[1], 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.

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 1. 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.

---

[1] 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).

Table 1.
Relationship of Ldn to Number of Events

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

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.[2]

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.

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

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

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 1) 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 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

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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.

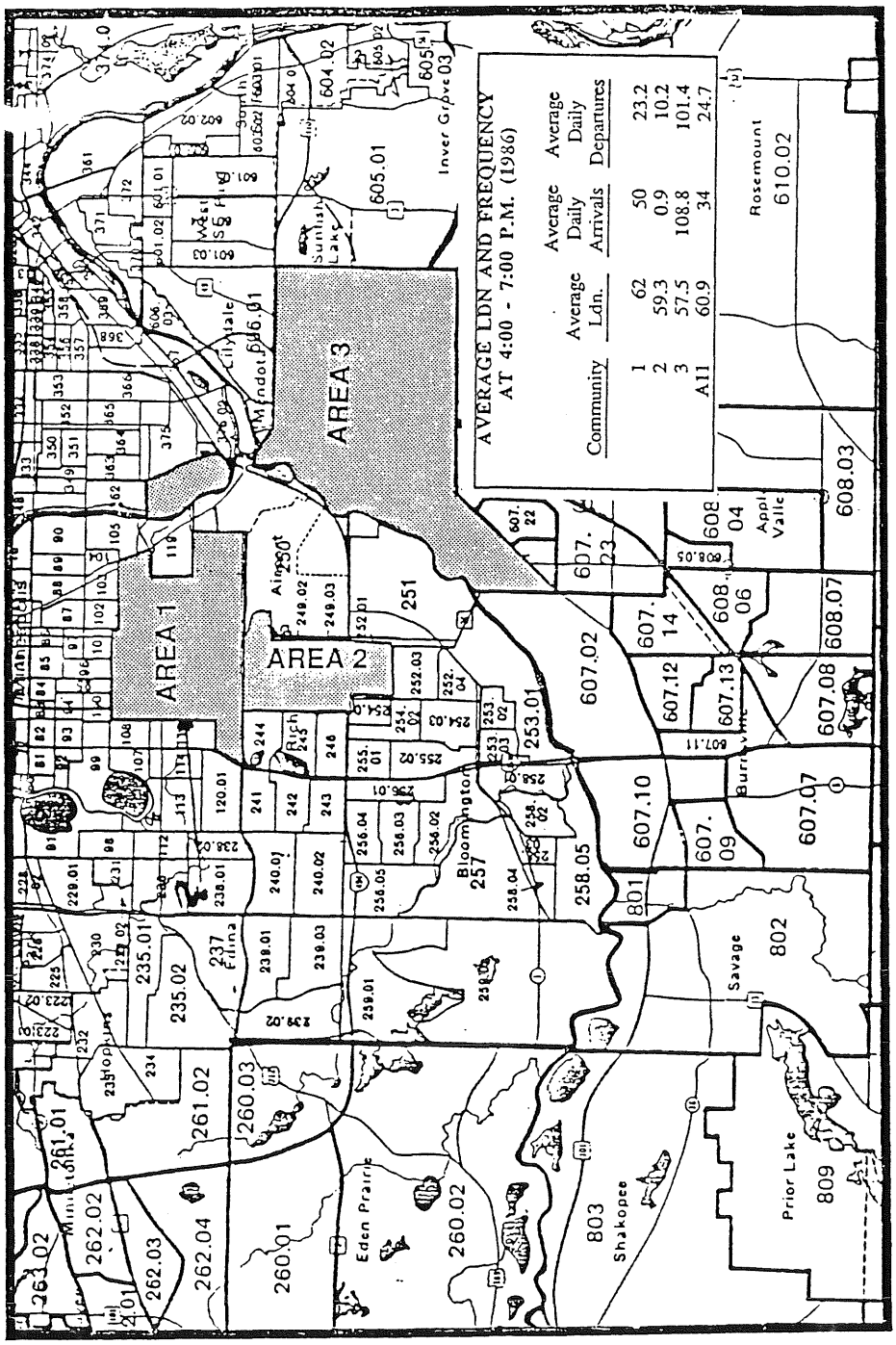


Figure 1. Areas Used for Regression

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 equations and specific hypotheses tested in this analysis are presented in Appendix A. The results of the statistical analysis are reported in a set of 18 tables contained in Appendix B. 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 2 and 3 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 subregions 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.

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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 2:
ORDINARY LEAST SQUARES REGRESSION ESTIMATES
FOR THE 4:00P.M. - 7:00P.M. TIME PERIOD

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-1.85	1.25	-26.19
	(3.26)	(1.42)	(3.33)
Ldn	0.08	0.03	0.10
	(8.27)	(2.11)	(2.27)
Departures	0.06	-3.40	1.74
	(1.78)	(1.92)	(4.90)
Arrivals	0.15	0.52	0.74
	(3.68)	(2.60)	(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 3:
ESTIMATED MEAN ELASTICITIES
FOR THE 4:00P.M. - 7:00P.M. TIME PERIOD

Measure	Community 1	Community 2	Community 3
Ldn Elasticity	1.35	0.58	1.77
Departures 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.

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.

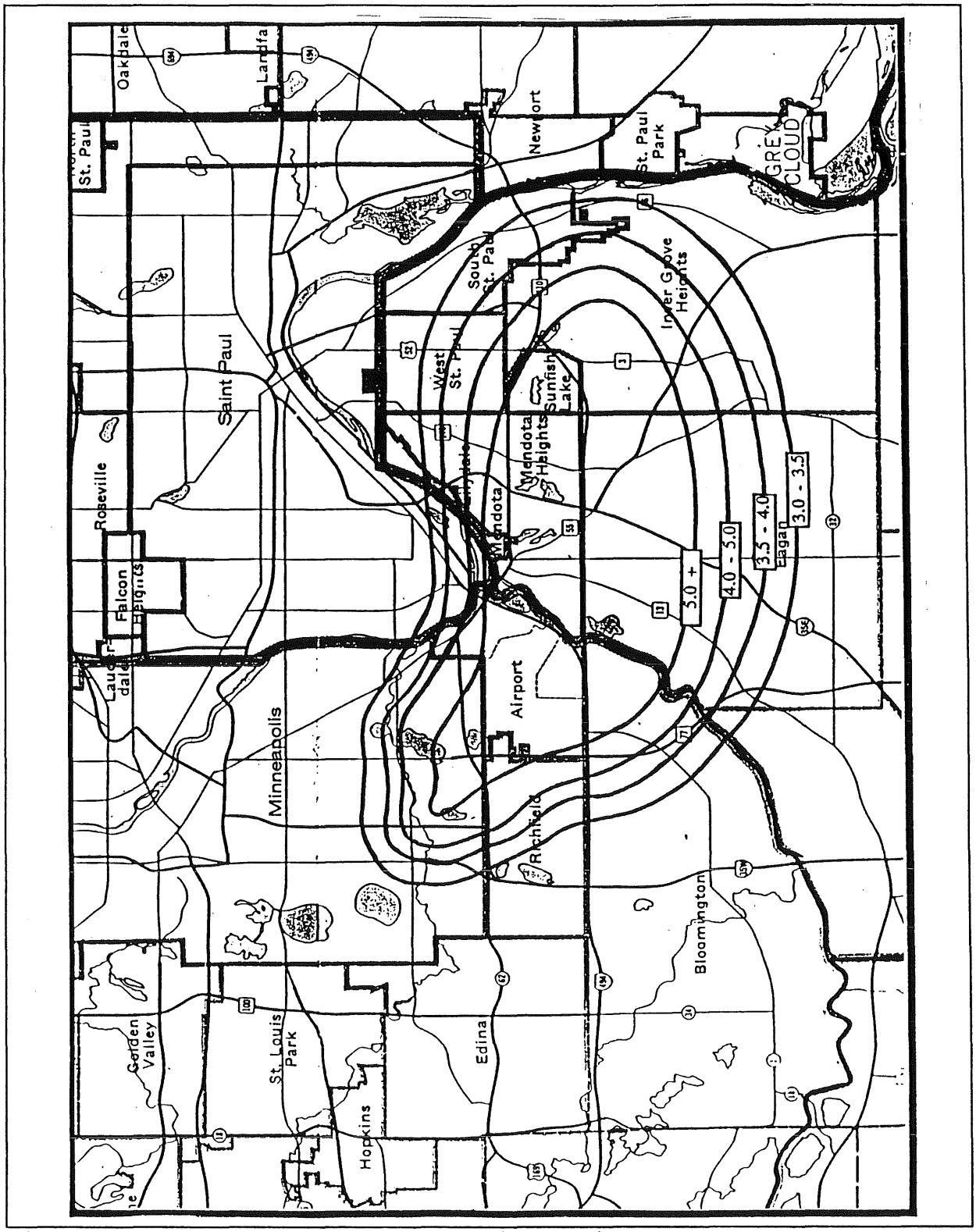


Figure 2. Contour Map of Community Noise Related Stress Index (4:00 p.m. - 7:00 p.m.) Under Strategy A (2008)

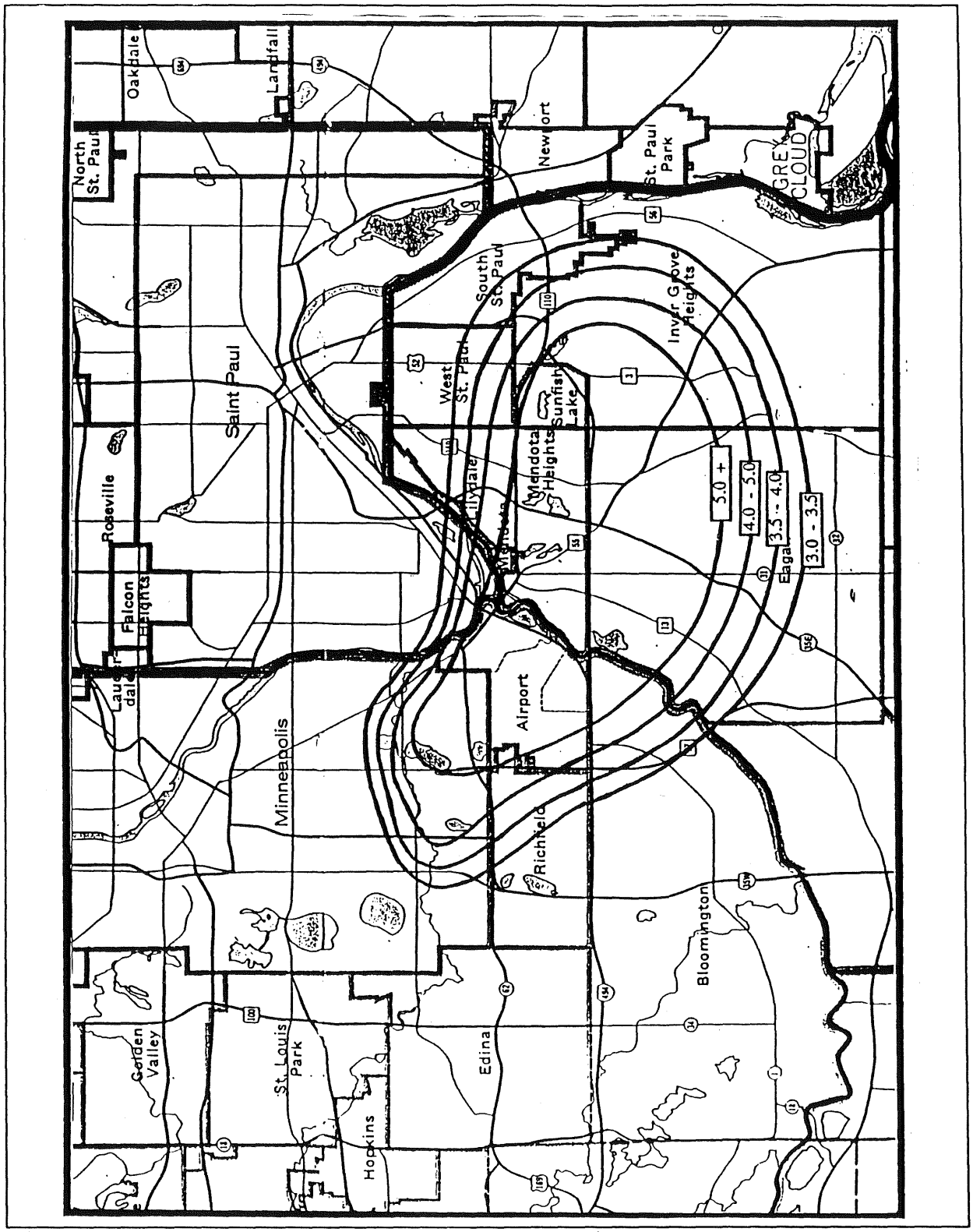


Figure 3. Contour Map of Community Noise Related Stress Index (4:00 p.m. - 7:00 p.m.) Under Strategy B (2008)

APPENDIX A
STATISTICAL ANALYSIS OF
THE CAUSES OF AIRCRAFT NOISE-RELATED STRESS

THEORY AND MEASUREMENT OF NOISE-RELATED STRESS

Peoples' annoyance with aircraft noise has long been attributed to the amount of "noise energy" to which they are exposed over a period of time (an hour, a day, or a year). In developing numerical measures of noise exposure, engineering practice has tended to seek metrics that combine the frequency of single events with the noise-intensity of each event to form single-valued index of noise energy such as Ldn, LEQ, NEF and other similar measures.

The unifying principal underlying all cumulative noise metrics is the behavioral assumption that individuals attach disutility to cumulative A-weighted decibel[5] exposure and are indifferent to the sources of change in the level of exposure. Under the Ldn metric, for example, a ten decibel increase in the intensity of each event has the same impact on Ldn as a ten-fold increase in the frequency of overflights. Mathematically, this means that a small reduction in the average noise intensity of aircraft engines over the course of a day will off-set a large increase in the frequency of single events.

From the viewpoint of acoustical science, the "trade-off" assumptions underlying the Ldn metric are sound. Experiments with human hearing confirm that, measured in perceived decibels, an increase in the noise-intensity of a single event has an equal affect on our perception of sound as the cumulative noise energy of an increased number of single events, each with the same noise-intensity. However, the trade-off assumptions underlying the Ldn metric have never been tested from a **behavioral** point of view. Yet, without realizing it, the lay public has been critical of these assumptions. For example, communities have often expressed doubt in the proposition that stage three engines will leave noise-affected neighborhoods unaffected by growth in the volume of arriving and departing aircraft. Formulated scientifically, this sentiment reflects the hypothesis that individuals attach disutility to an increase in the frequency of audible single events independently of any change in their decibel output measured cumulatively over the course of the day.

Since the 1960s, statistical surveys have established a strong relationship between the Ldn level and the number of people

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[5]. "A-weighted" decibels are manipulated mathematically to reflect aspects of the frequency spectrum to which the human ear is especially sensitive.

severely annoyed with noise. Such surveys side-step however the question of measuring the relative weights that people attach to cumulative noise-energy versus the frequency of overflights. Theoretically, the problem is to drop the strong assumption of human indifference to noise-energy and frequency as sources of noise-related stress and annoyance; empirically, the solution is to reformulate the question from a univariate to a multivariate measurement problem.

A NEW MODEL

To avoid the assumption of indifference to the sources of noise, the Twin Cities Regional study used a heuristic index of aircraft noise-related annoyance based upon the revealed stress levels of individuals themselves. The model then postulates that the noise-related stress index is a function of both the Ldn level and the frequency of overflights, as follows:

$$N(i) = f[Ldn(i), F(i)] \qquad .... (1)$$

where:

N(i) denotes the noise-related stress index level of individual (i);

Ldn(i) denotes the Ldn exposure of individual (i) over a given period; and

F(i) denotes the number of overflights to which individual (i) is exposed over a given period.

PRINCIPAL HYPOTHESES

The functional form of the model should mirror theoretical and behavioral expectations as closely as possible. From previous noise research and new hypotheses developed here, two principal expectations were considered, as follows;

- Flight frequency has a statistically significant influence on noise-related annoyance and stress in addition to any statistically significant influence of Ldn;
- Individuals' noise-related annoyance and stress varies according to time of day and season, a reflection of the differential impact of noise during the conduct of different activities;
- The **change** in individuals' noise-related annoyance and

stress in response to variation in noise conditions will vary depending upon the conditions to which they are initially exposed.

- o Socio-economic factors, such as income and political experience, will affect individuals' stated noise-related stress levels independent of the physical attributes of noise to which they are exposed;

The first hypotheses reflects the fundamental hypothesis established earlier while the second reflects years of well established results from noise research.

The third hypothesis reflects the simple proposition that for an individual who is now exposed to, say, one overflight a day, a doubling of overflights can be expected to create less added annoyance than a doubling of overflights for an individual who is now exposed to 50 overflights a day. In economic jargon, the hypothesis postulates that the elasticity of annoyance with respect to the frequency of overflights varies directly with frequency itself. There is no a priori expectation in the case of Ldn elasticities since individuals' responsiveness will depend on the source of the change in Ldn (noise-intensity versus frequency).

Finally, the fourth hypothesis reflects the proposition that noise-related stress is more intense among those who are skilled at organizing for its reduction -- ie, that stress levels are in part a function of one's perceived power to do something about it. This hypothesis stems from the (typically anecdotal) observation that noise complaints are more prevalent in higher income neighborhoods; it must be stressed however that the heuristic noise annoyance index attempts to measure individuals' actual stress rather than their propensity to complain, indicating that the present exercise does not represent a direct test of the fourth hypothesis.

MODEL FORM AND RESULTS

Hypothesis #1. The model reported here reflects the first hypothesis by estimating equation (1) with linear multivariate least-squares regression analysis. Regression coefficients are then transformed into mean elasticities in order to permit the comparison of the relative influence of Ldn and flight frequency on noise-related stress. As shown in the main text, the addition of the frequency variable adds significantly to the explained variance in the noise-related annoyance index without infecting the equation with multicolinearity. This confirms the hypothesis that frequency conveys disutility independent of cumulative noise energy.

Hypothesis #2. The model reflects the second hypothesis by

estimating separate regression equations for five different daily time periods and all four seasons. The equations reported in the main text confirm previous research indicating that annoyance peaks during the Summer and during the 4pm - 7pm time period.

Hypothesis #3. To mirror the third hypothesis, the Twin Cities region was divided into three sub-regions of roughly homogeneous average daily flight frequency, as follows:

SUB-REGIONAL COMMUNITY	DAILY FREQUENCY	
	Arrivals	Departures
1	50	23
2	1	10
3	109	102

Separate equations were then estimated for each community and statistical tests applied to measure whether the elasticities vary in accordance with theoretical expectations. Specifically, linear regressions were estimated for each community as follows;

$$N(i,j,k) = a + bLdn(i,j,k) + cFA(i,j,k) + dFD(i,j,k) + e....(2)$$

where;

N(i,j,k) denotes the noise-related stress index level for individual (i) in sub-region (j) at time of day or season (k);

Ldn(i,j,k) denotes the Ldn level of individual (i) in sub-region (j) at time of day or season (k);

FA(i,j,k) and FD(i,j,k) denote the frequency of arriving and departing flights respectively, similarly defined;

a,b c and d denote constants to be estimated; and

e denotes random errors of mean zero and constant variance.

This structure yields 27 separate regression equations (data limitations prevented the estimation of separate time of day equations within each season). To test the proposition that the frequency elasticity varies in direct proportion to flight frequency itself, Chow's F-test was applied to determine whether elasticities derived from coefficients c are statistically higher

in sub-regions with higher average overflights.

The results in this case are striking, indicating a near perfect correlation (r = 0.99) between [dN/dF * F/N] -- ie, the elasticity of N with respect to F -- and average frequency, F. Chow tests confirm that sub-regional community 3 has statistically higher frequency elasticities than other sub-regions and that the impact of frequency in sub-region 3 neighborhoods is actually higher than that of Ldn.

Hypothesis #4. The fourth hypothesis was tested by adding to equation (2) separate dummy variables for individual neighborhoods in the sub-region (represented by census tracts). If the coefficients emerge as statistically significant, one could conclude that there are measurable, non-noise related characteristics of neighborhoods that affect noise-related stress levels, as posited in the fourth hypothesis.

All coefficients of neighborhood dummy variables were insignificant, however, indicating the absence of non-noise-related impacts. This does not mean that certain groups are not more prone to organize than other groups; it does mean however that they are not intrinsically more sensitive to noise.

CONCLUSIONS

As traffic volumes grow, the research presented here indicates that neighborhoods lying near or beneath flight paths become progressively more sensitive to added volume. Simulations using the 27 regression equations indicate that in a growth environment, the introduction of stage three aircraft will not necessarily offset the effect on noise-related stress of rising frequency elasticities -- indeed, annoyance can be expected to grow.

These results indicate that quieter engines alone are not the solution to noise as a barrier to expanding airport capacity. Instead, they suggest the need for other policy instruments as well, such as;

- **Land banking activities to create the potential for spreading noise more equitably through the development of new airports.** Land banking undertaken in tandem with capacity expansion at existing airports can prove acceptable as a means of accommodating growth in the short-term and economic even as a temporary measure since the pay-back period on new capacity is typically less than two years. Under a land banking approach, noise-affected communities may see more promise of long-term relief than they do in the quieter engines associated with stage-three aircraft.

- **Compensation mechanisms.** With stage three aircraft providing only partial compensation for traffic growth, other forms of compensation need to be considered as well. Financial compensation, such as property tax relief or one-time payments equivalent to the present value of the time-stream of reduced property values, would help to more fully compensate home-owners under flight paths subject to traffic growth. Because of the large net economic benefits that stem from capacity expansion, there is justification for transferring a portion of such benefits to noise-affected communities through transfer mechanisms like those outlined above. Possible practical approaches include landing fee premiums used to create noise compensation trust funds. The trust fund is then used to finance one-time pay-outs or property tax substitution. This, in effect, transfers some of the net economic benefit of expansion accruing to passengers and airlines to those who "lose" because of noise impacts.

Combinations of these two strategies may prove to be especially powerful, for they are at once consistent with sound principles of public policy and capable of opening a wedge in what is otherwise a seemingly endless standoff between the noise and the capacity interests in airport development.

APPENDIX B
STATISTICAL EQUATIONS

TABLE 1: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE 6:00A.M. - 9:00A.M. TIME PERIOD

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-1.36 (-2.54)	-0.84 (0.98)	-2.98 (0.36)
Ldn	0.05 (5.77)	0.05 (3.44)	-0.01 (0.29)
Departures	0.08 (0.96)	2.08 (-0.32)	0.63 (2.02)
Arrivals	0.12 (2.44)	-0.13 (0.79)	0.51 (0.4)
Statistical Measures			
R^2	0.09	0.04	0.02
F Value	21.98	4.51	1.56

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 2: ESTIMATED MEAN ELASTICITIES FOR THE 6:00A.M. - 9:00A.M. TIME PERIOD

	Community 1	Community 2	Community 3
Ldn Elasticity	1.47	1.38	*
Departures Elasticity	*	*	1.21
Arrivals Elasticity	0.08	*	*

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

TABLE 3: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE 9:00A.M. - 4:00P.M. TIME PERIOD

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-0.06 (0.10)	1.38 (1.59)	1.43 (0.21)
Ldn	0.03 (2.94)	0.01 (0.75)	0.23 (0.27)
Departures	0.11 (1.42)	-4.69 (0.7)	-0.35 (1.52)
Arrivals	0.14 (3.44)	0.21 (1.91)	0.23 (0.26)
Statistical Measures			
R^2	0.07	0.01	0.01
F Value	15.92	2.14	1.17

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 4: ESTIMATED MEAN ELASTICITIES FOR THE 9:00A.M. - 4:00P.M. TIME PERIOD

	Community 1	Community 2	Community 3
Ldn Elasticity	0.81	*	*
Departures Elasticity	*	*	0.86
Arrivals Elasticity	0.13	0.09	*

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

TABLE 5: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE 4:00P.M. - 7:00P.M. TIME PERIOD

Independent Variable	Dependent Variables		
	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

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 6: 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
Departures Elasticity	0.07	0.12	1.81
Arrivals Elasticity	0.08	-0.08	5.81

Note: 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.

TABLE 7: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE 7:00P.M. - 11:00P.M. TIME PERIOD

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-0.44 (0.8)	0.22 (0.24)	-23.65 (3.19)
Ldn	0.05 (5.08)	0.05 (3.19)	0.02 (0.77)
Departures	0.04 (2.86)	2.7 (0.81)	3.62 (4.71)
Arrivals	0.31 (1.21)	-0.29 (1.07)	0.87 (2.67)
Statistical Measures			
R^2	0.10	0.03	0.20
F Value	24.13	3.67	8.08

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 8: ESTIMATED MEAN ELASTICITIES FOR THE 7:00P.M. - 11:00P.M. TIME PERIOD

	Community 1	Community 2	Community 3
Ldn Elasticity	0.98	0.95	*
Departures Elasticity	0.13	*	1.80
Arrivals Elasticity	*	*	7.02

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

TABLE 9: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE 11:00P.M. - 6:00A.M. TIME PERIOD

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	0.19 (0.49)	-0.56 (0.92)	1.92 (0.45)
Ldn	0.02 (3.40)	0.04 (3.54)	-0.01 (0.25)
Departures*	N/A	N/A	N/A
Arrivals	0.18 (2.26)	0.27 (0.07)	0.03 (0.01)
Statistical Measures			
R^2	0.03	0.04	0.001
F Value	9.4	6.29	0.04

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

*Regression based only on LDN and Arrivals as there are zero departures during this time period.

TABLE 10: ESTIMATED MEAN ELASTICITIES FOR THE 11:00P.M. - 6:00A.M. TIME PERIOD

	Community 1	Community 2	Community 3
Ldn Elasticity	0.82	1.35	*
Departures Elasticity**	N/A	N/A	N/A
Arrivals Elasticity	0.07	*	*

Note: 1. Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

**Regression based only on LDN adn Arrivals as there are zero departures during this time period.

TABLE 11: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE SUMMER SEASON.

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	0.06 (0.11	0.8 (0.83)	-27.98 (2.31)
Ldn	0.05 (5.71)	0.05 (3.31)	0.11 (1.91)
Departures	0.005 (2.51)	0.06 (0.38)	0.19 (3.69)
Arrivals	0.02 (3.21)	0.007 (0.52)	0.05 (1.65)
Statistical Measures			
R^2	0.14	0.03	0.16
F Value	34.31	3.88	6.24

Note: 1. Regression coefficients based on citizien noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 12: ESTIMATED MEAN ELASTICITIES FOR THE SUMMER SEASON

	Community 1	Community 2	Community 3
Ldn Elasticity	0.83	0.81	1.53
Departures Elasticity	0.09	*	1.37
Arrivals Elasticity	0.62	*	4.76

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

TABLE 13: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE FALL SEASON

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-1.02 (1.95)	0.74 (0.85)	-20.22 (2.66)
Ldn	0.06 (6.92)	0.04 (2.74)	0.08 (2.12)
Departures	0.006 (1.25)	-0.28 (0.91)	0.13 (4.57)
Arrivals	0.008 (3.60)	0.002 (1.7)	0.05 (1.76)
Statistical Measures			
R^2	0.14	0.03	0.22
F Value	35.37	4.15	8.89

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 14: ESTIMATED MEAN ELASTICITIES FOR THE FALL SEASON

	Community 1	Community 2	Community 3
Ldn Elasticity	1.18	0.76	1.66
Departures Elasticity	*	*	1.69
Arrivals Elasticity	0.08	-0.05	4.53

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

TABLE 15: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE SPRING SEASON.

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-0.65 (1.24)	0.74 (0.85)	-19.26 (2.53)
Ldn	0.06 (6.22)	0.04 (2.89)	0.09 (2.07)
Departures	0.003 (2.43)	0.09 (0.01)	0.13 (4.30)
Arrivals	0.02 (1.62)	0.001 (0.87)	0.05 (1.67)
Statistical Measures			
R^2	0.12	0.02	0.20
F Value	29.74	3.24	8.02

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

TABLE 16: ESTIMATED MEAN ELASTICITIES FOR THE SPRING SEASON

	Community 1	Community 2	Community 3
Ldn Elasticity	1.06	0.76	1.69
Departures Elasticity	0.10	*	1.64
Arrivals Elasticity	0.04	*	4.42

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

TABLE 17: ORDINARY LEAST SQUARES REGRESSION ESTIMATES FOR THE WINTER SEASON

Independent Variable	Dependent Variables		
	Community 1 Noise Annoyance Index	Community 2 Noise Annoyance Index	Community 3 Noise Annoyance Index
Constant	-0.05 (0.10)	1.23 (1.57)	-16.44 (2.46)
Ldn	0.03 (3.84)	0.02 (1.39)	0.05 (1.45)
Departures	0.002 (1.91)	-0.14 (0.38)	0.14 (2.61)
Arrivals	0.01 (1.69)	0.008 (0.92)	0.03 (1.96)
Statistical Measures			
R^2	0.06	0.002	0.10
F Value	15.19	1.15	3.97

Note: 1. Regression coefficients based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

2. T-Ratios are given in parenthesis.

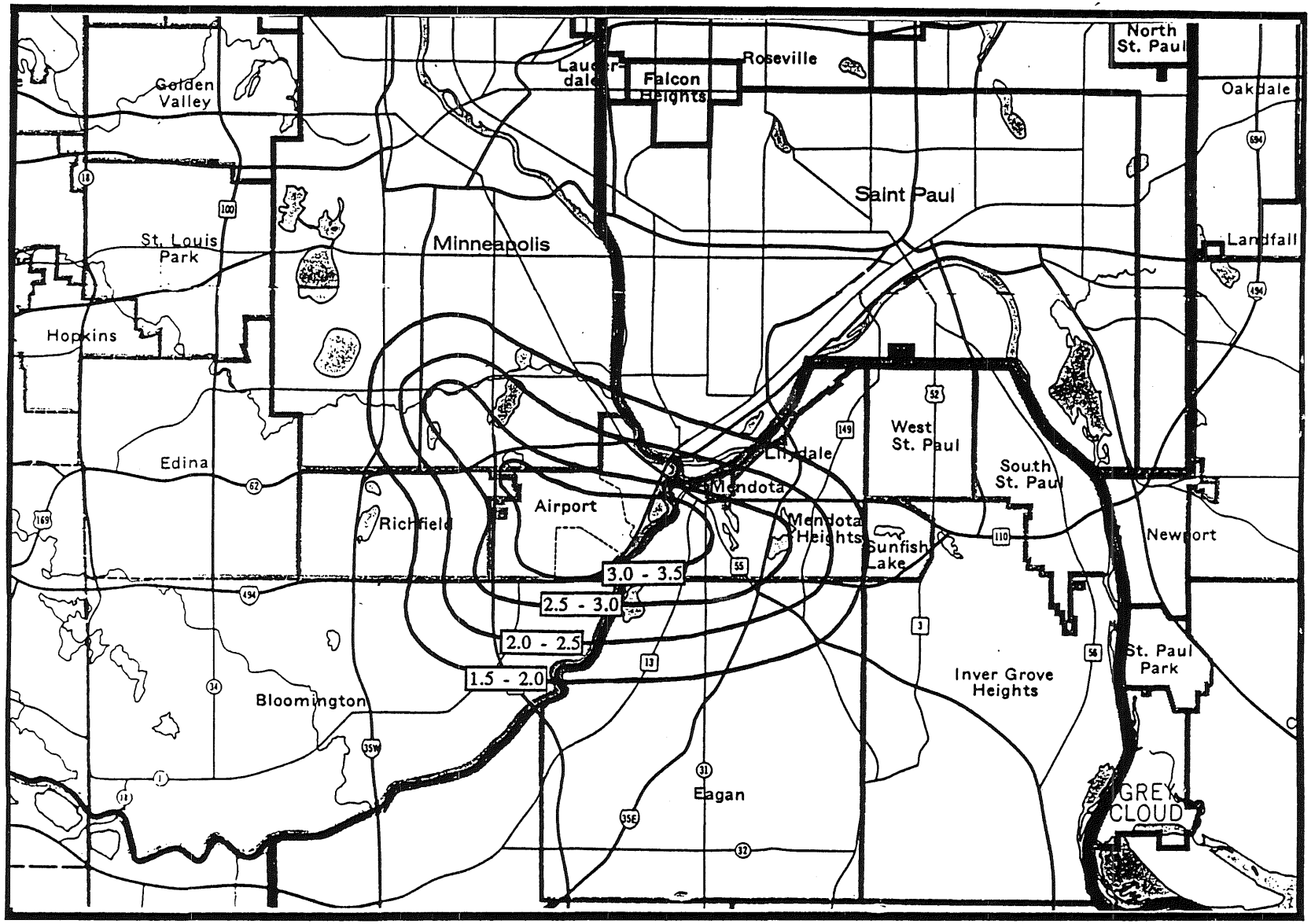
TABLE 18: ESTIMATED MEAN ELASTICITIES FOR THE WINTER SEASON

	Community 1	Community 2	Community 3
Ldn Elasticity	0.87	*	*
Departures Elasticity	0.11	*	1.21
Arrivals Elasticity	0.05	*	6.10

Note: Regression elasticities based on citizen noise annoyance survey (July 1986, Mid-Continent Research, Inc.)

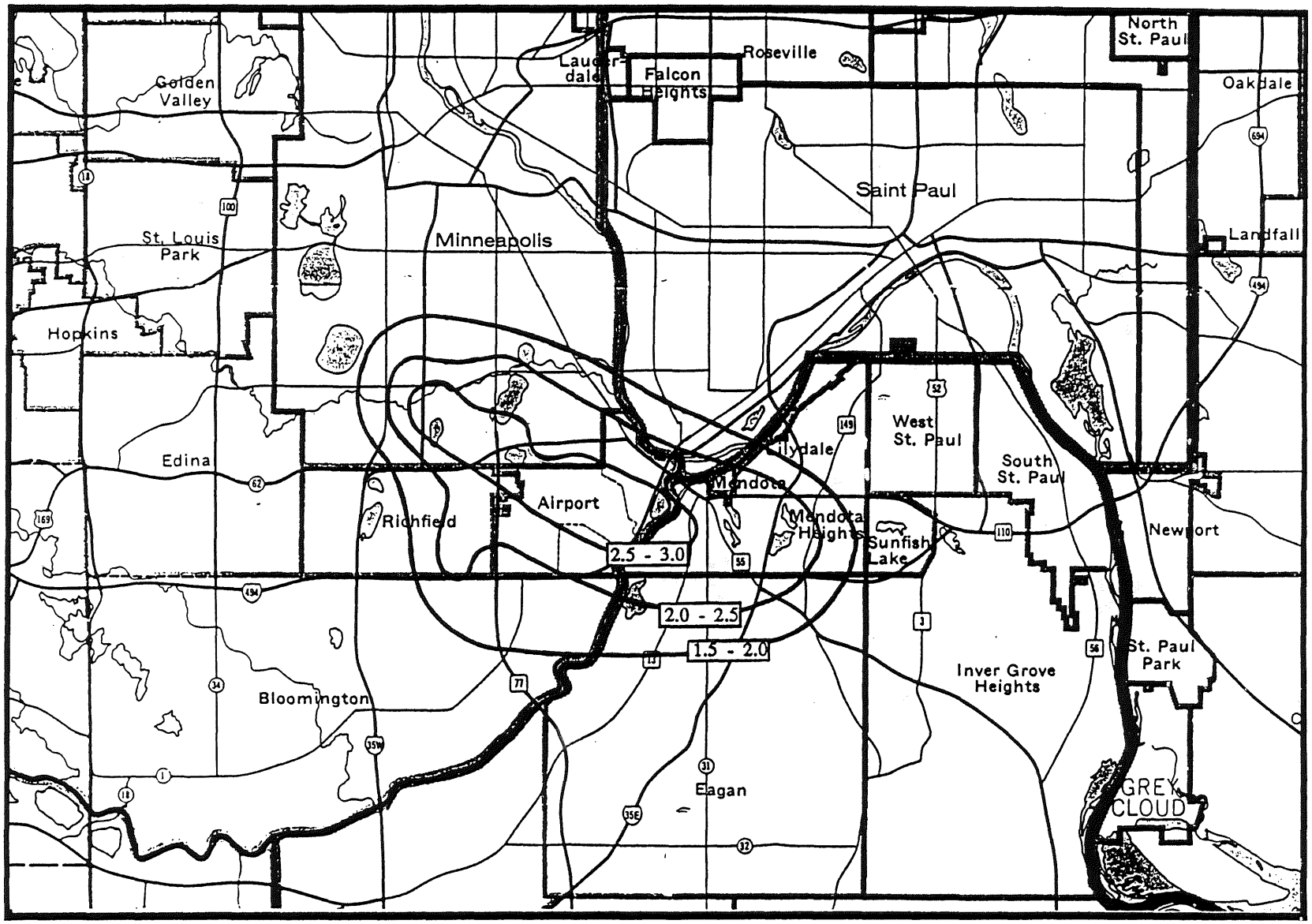
*Not statistically significant. All figures shown are statistically significant at the 95% level or greater.

APPENDIX C
NOISE STRESS MAPS



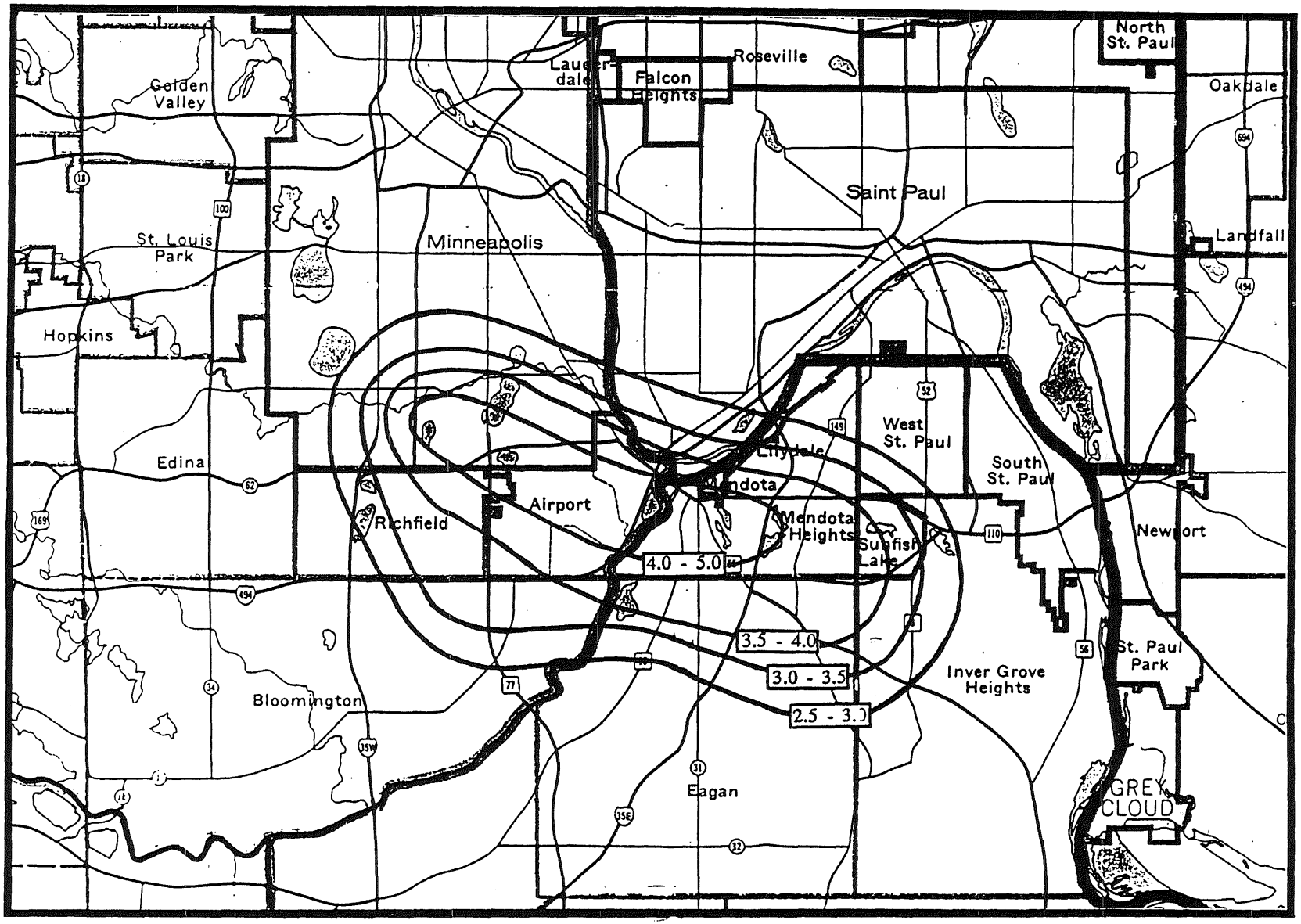
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 6:00am - 9:00am UNDER BASECASE CONFIGURATION

(1986)



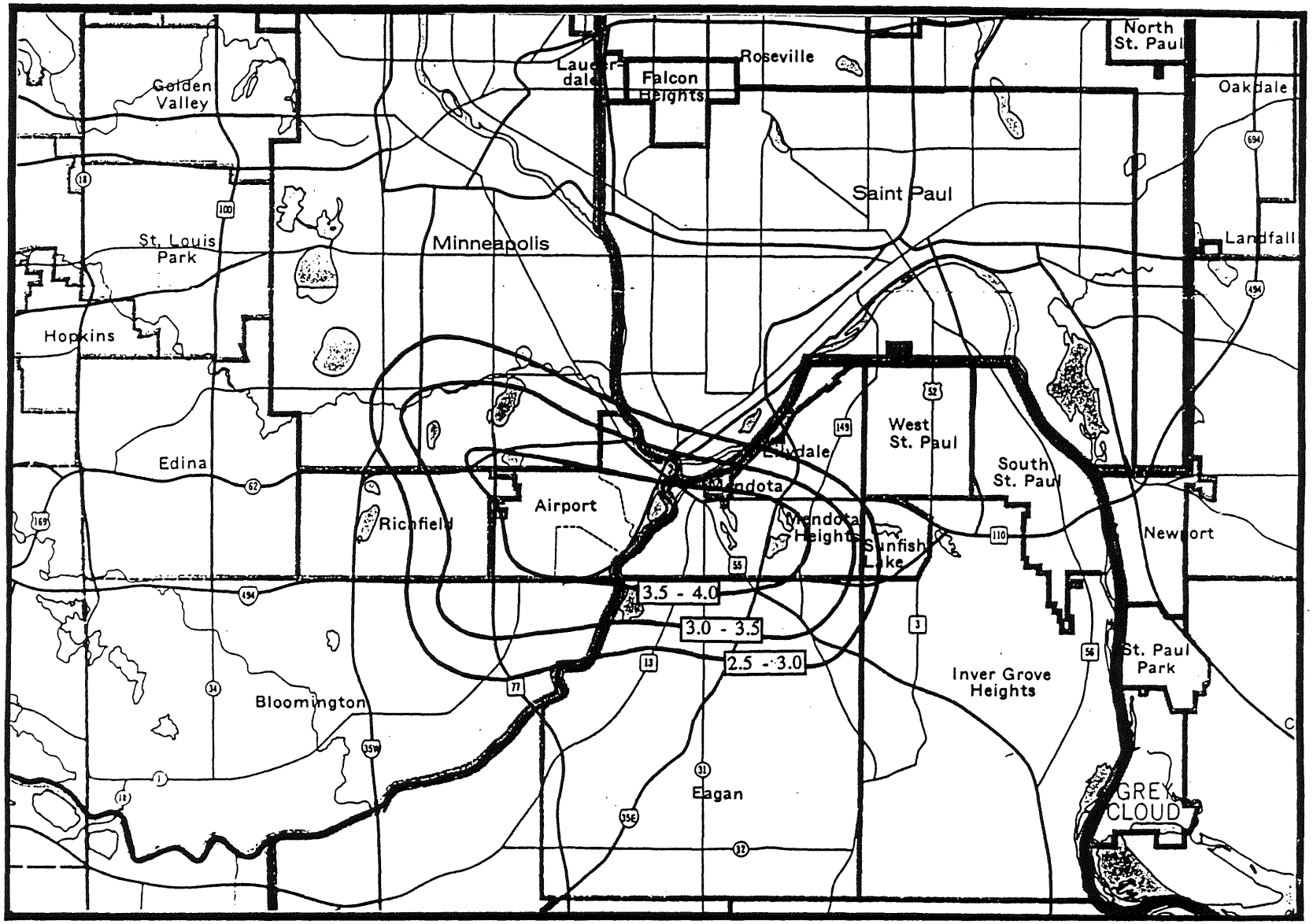
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 9:00am - 4:00pm UNDER BASECASE CONFIGURATION

(1986)



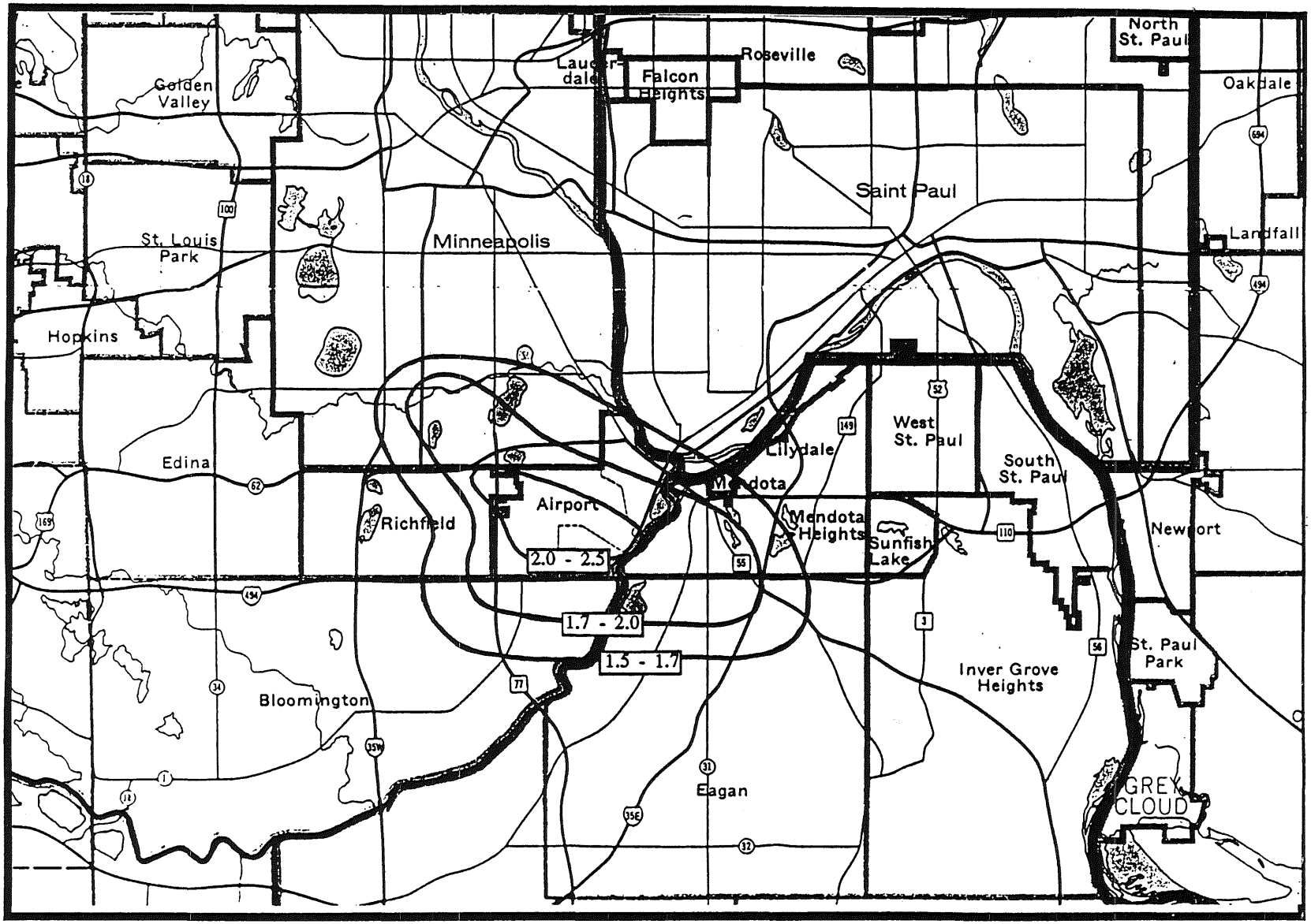
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 4:00pm - 7:00pm UNDER BASECASE CONFIGURATION

(1986)



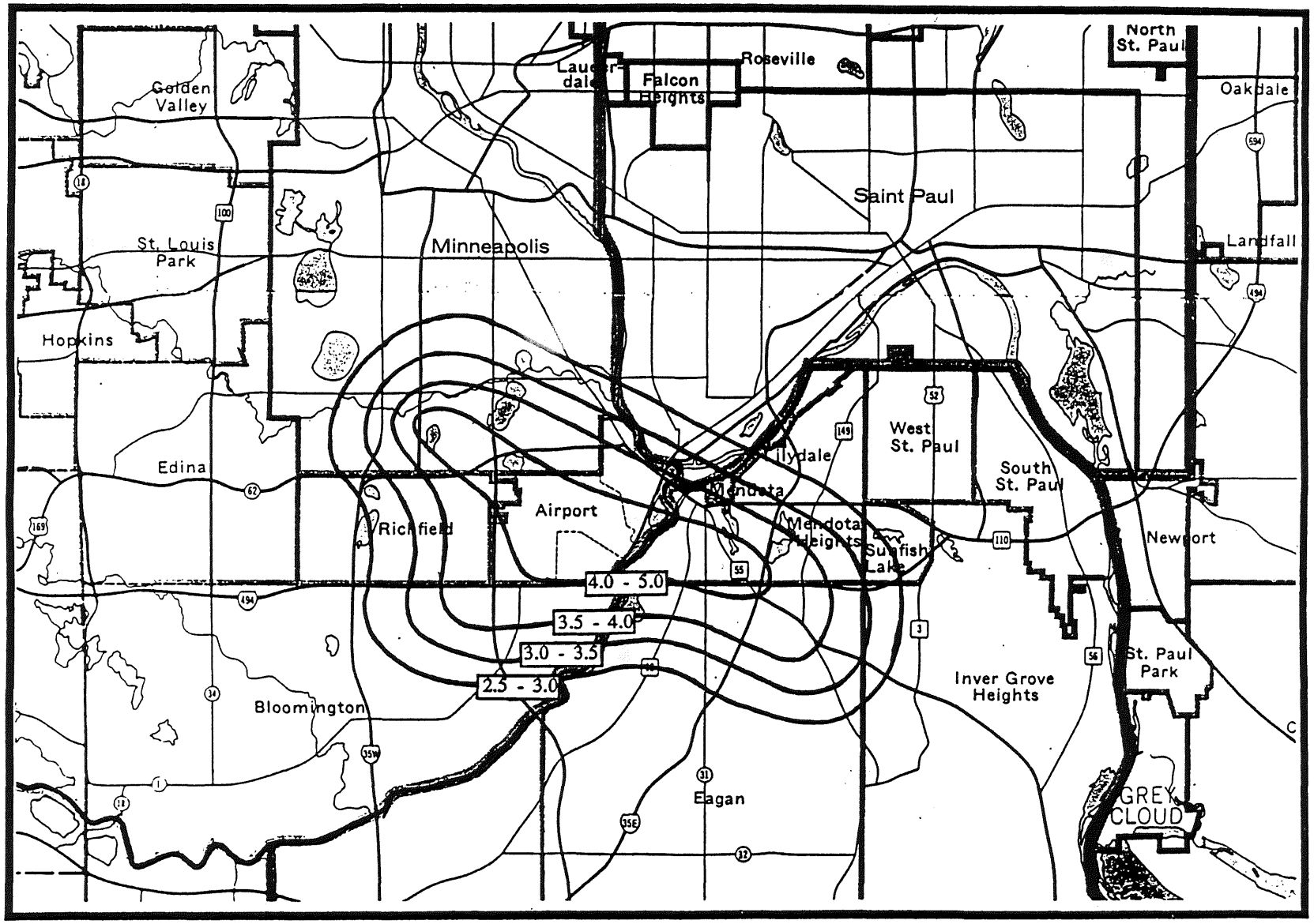
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 7:00pm - 11:00pm UNDER BASECASE CONFIGURATION

(1986)



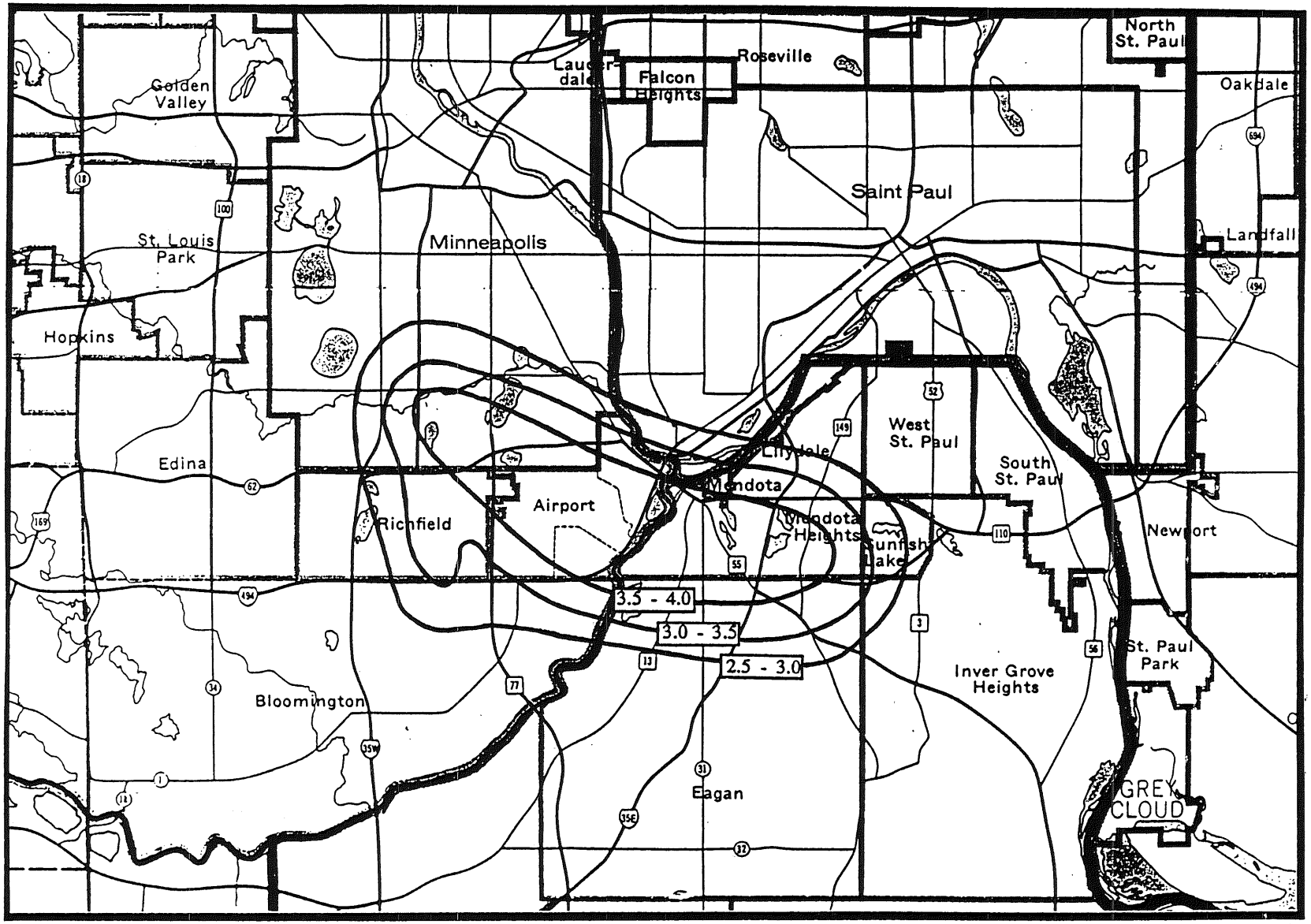
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 11:00pm - 6:00am UNDER BASECASE CONFIGURATION

(1986)



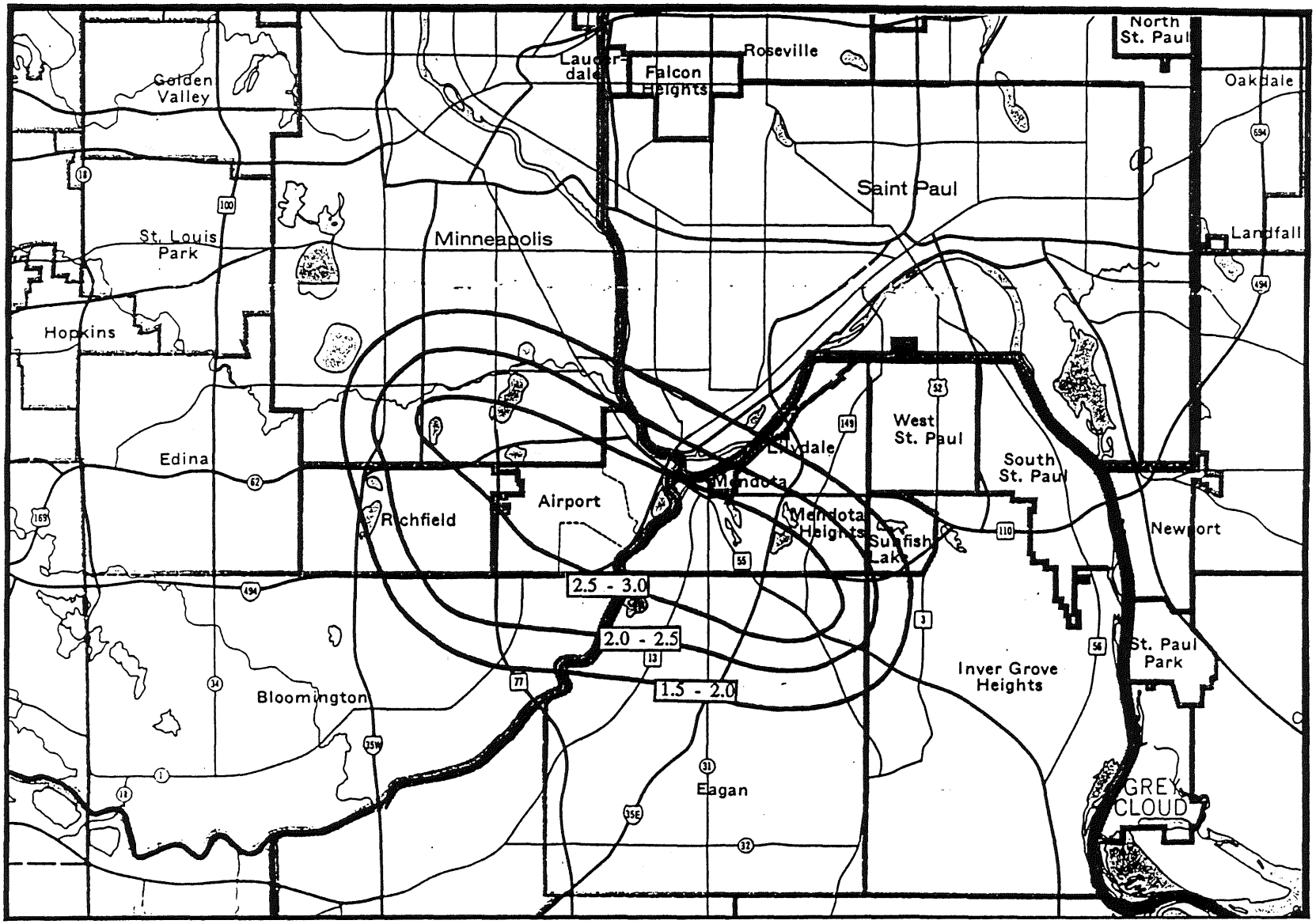
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR SUMMER UNDER BASECASE CONFIGURATION

(1986)



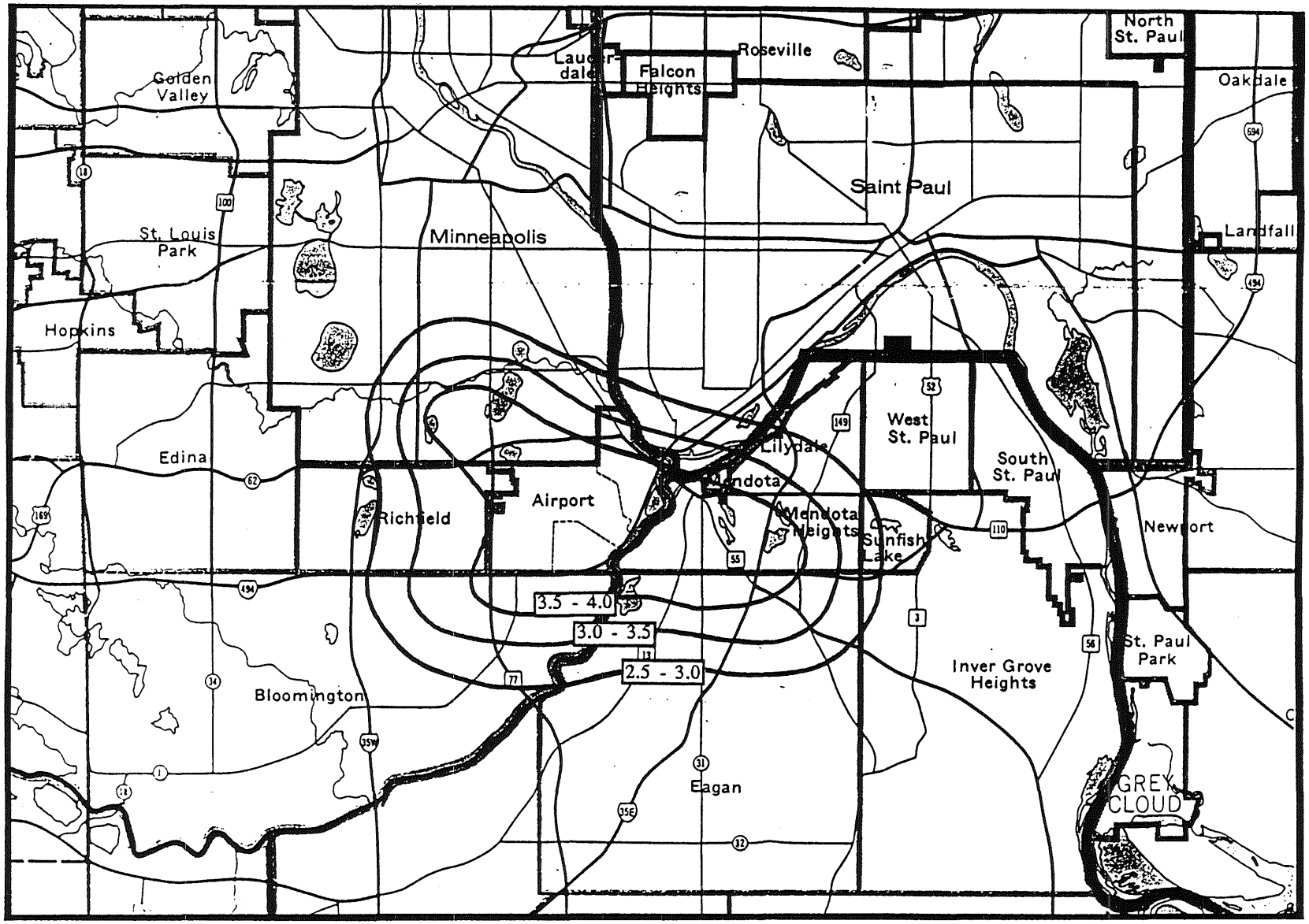
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR FALL UNDER BASECASE CONFIGURATION

(1986)



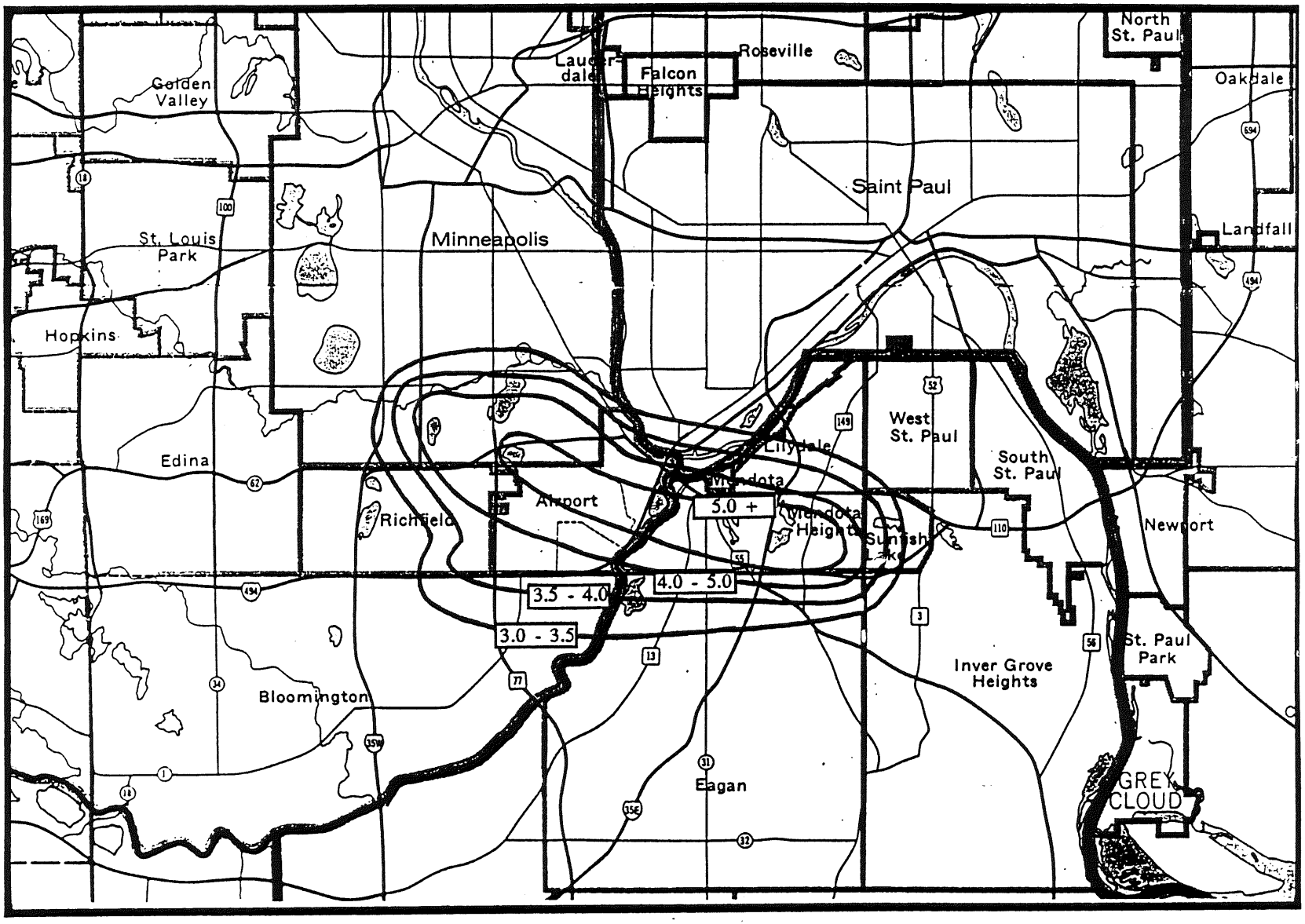
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR WINTER UNDER BASECASE CONFIGURATION

(1986)



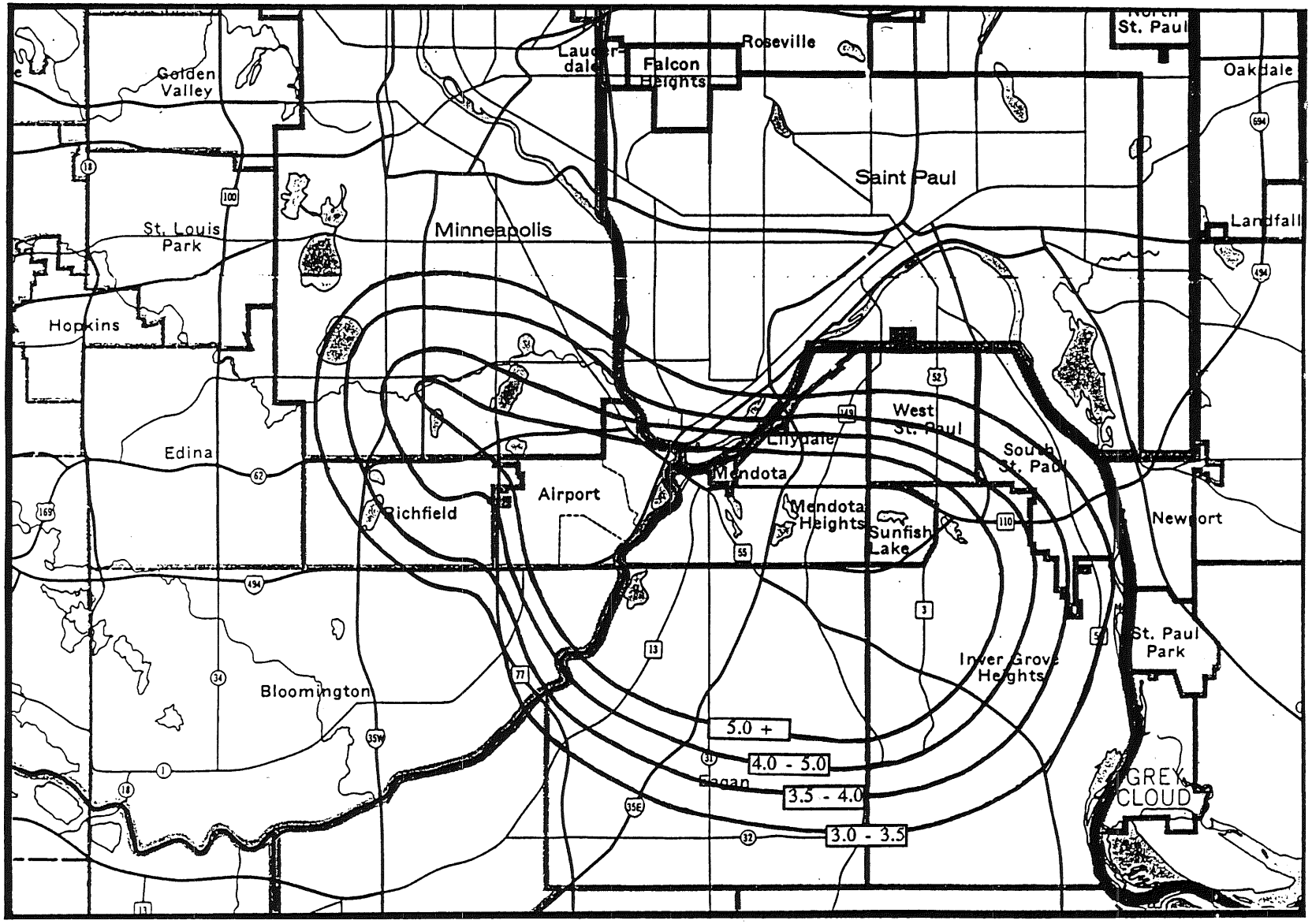
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR SPRING UNDER BASECASE CONFIGURATION

(1986)



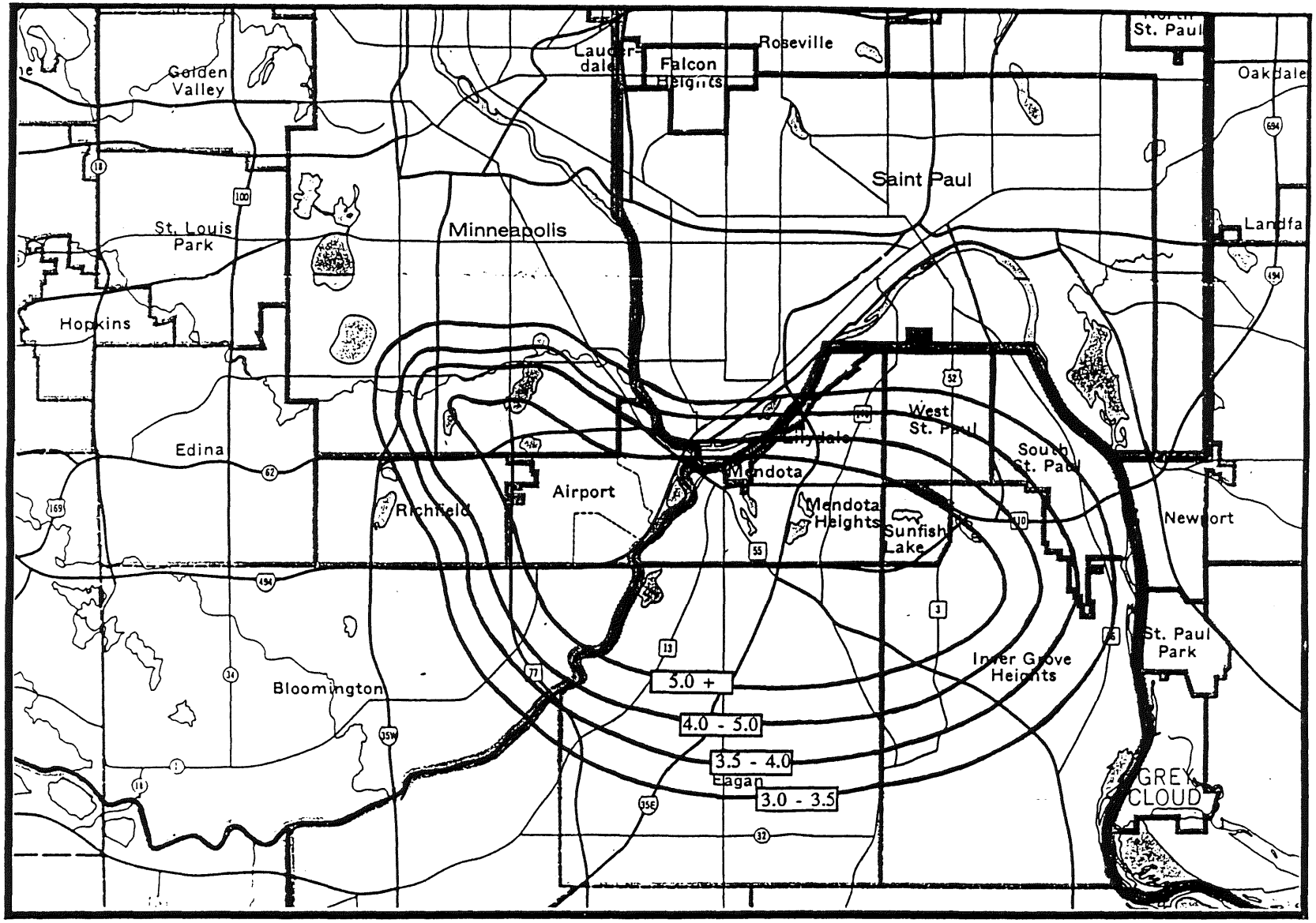
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 4:00pm - 7:00pm UNDER ENAHNCED A CONFIGURATION

(JANUARY 1987)



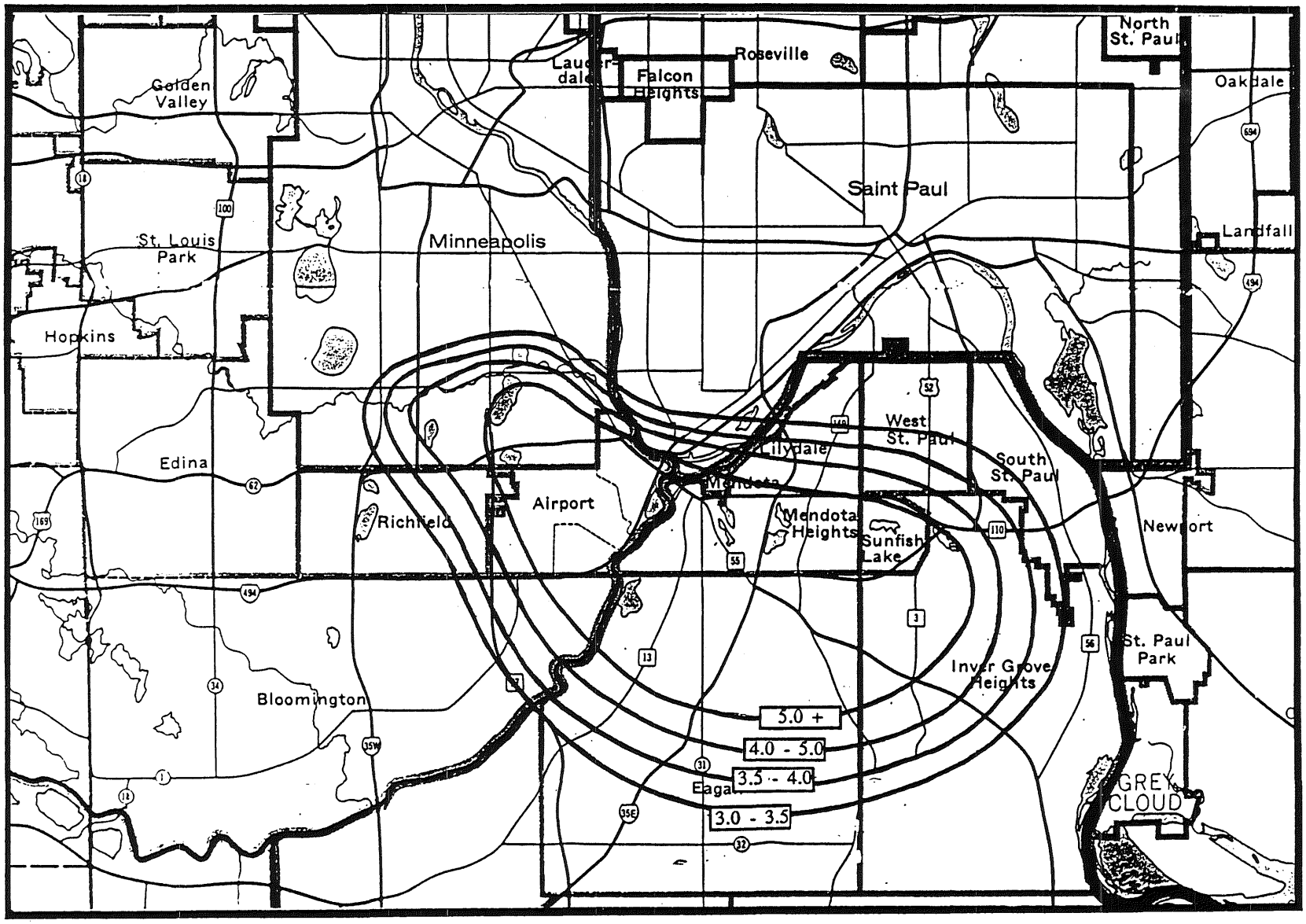
CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 4:00pm - 7:00pm UNDER BASECASE CONFIGURATION

(2008)



CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 4:00pm - 7:00pm UNDER ENHANCED A CONFIGURATION

(2008)



CONTOUR MAP OF COMMUNITY NOISE-RELATED STRESS INDEX FOR 4:00pm - 7:00pm UNDER ULTIMATE A CONFIGURATION

(2008)

THE METROPOLITAN COUNCIL
OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

BENEFIT-COST ANALYSIS OF ALTERNATIVE AIRPORT CAPACITY ENHANCEMENT STRATEGIES

November 1988

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1.0 INTRODUCTION

Eight strategies emerged from the Task Force's analysis of airport development options As shown in Table 1, these run the gamut from the current Capital Plan to closure of MSP in lieu of a new airport by the turn of the century. Each strategy involves alternative development projects and alternative approaches to project timing.

This Working Paper presents the transportation-related analysis of benefits and costs for each option. Section 2.0 outlines the general analytic approach; Section 3.0 presents estimated costs while Section 4.0 presents the projected benefits. The benefit-cost analysis is summarized in Section 5.0.

TABLE 1

ALTERNATIVE STRATEGIES

BASE CASE	• Current Capital Plan--4-22 Extension
STRATEGY A:	• North-South Runway, 1997
STRATEGY B:	• North-South Runway, 1997 • Far Parallel Runway, 2008
STRATEGY C:	
STRATEGY C1:	• North-South Runway, 1997 • Land Banking 1996-1997 NEW Airport, 2008
STRATEGY C2:	• North-South Runway, 1997 • Land Banking, 2003-2004 • NEW Airport, 2015
STRATEGY D:	• Peak Spreading
STRATEGY E:	• New Airport Only, 1999

2.0 GENERAL APPROACH

The economic merits of alternative strategies depend of course upon their expected costs and benefits. Measures of worth differ however depending upon the specific policy question at hand, particularly the choice of an overall development strategy versus the timing of major projects within the strategy. And different measures are relevant to the community as a whole as distinct from the airlines.

Measures of Net Worth and Timing

Two distinct policy questions face a community in the consideration of airport capacity. The first is whether a given investment strategy is worthwhile--whether its net worth -- costs versus benefits over the useful life of the investments -- is positive. The second question is timing -- deciding when should projects begin in order to optimize the use of community resources in general and minimize financial risk. The second question is particularly important in the case of investments whose benefits are expected to increase as growing use (ie, passenger traffic) draws progressively greater value from the investment. For such projects, it is possible for the overall net worth to appear favorable because of very large benefits projected for the distant future. Waiting a long time for a project to start paying off has two disadvantages, however. One is that the community could put the money to better use until the pay-off appeared more imminent. The second is that distant forecasts are inherently more uncertain, making projects with distant pay-offs considerably more risky than those offering a relatively quicker return.

Net Worth. Table 2 explains the three measures of net worth used in this study (net present value, rate of return and the benefit-cost ratio). Each conveys a different message. The benefit-cost ratio is a convenient signal of an individual project's worth -- a ratio above 1.0:1 means the project is foreseen to yield benefits in excess of costs and is thus economically worthwhile. The benefit-cost ratio is a poor guide, however, to a project's net worth <u>in comparison with competing projects.</u> If alternative projects or strategies are to be ranked, they should be compared on the basis of their net present values -- the present value of benefits minus the present value of costs.

A project's internal rate of return indicates whether it is likely to yield a comfortable margin over and above the minimum desired rate of return (the discount, or "hurdle" rate) but, again, it should not be used to rank competing strategies.

Timing. Table 2 also explains the two measures of timing used the study. The principal test is called the first-year benefit ratio. Hickling, which favors a conservative approach to public investment decisions on the scale under consideration here, suggests that projects commence only if their first-year benefit ratio is foreseen to exceed the prescribed hurdle rate of return; if not, the project or strategy should be delayed, allowing the benefit stream to further overtake the cost. A ratio above the hurdle rate indicates that the project will begin to earn the desired rate of return in the first year of operation, and is thus well timed.

TABLE 2

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.

The pay-back period is less definitive that the first-year benefit ratio, but is does provide a good intuitive feel for the riskiness attached to a given project or strategy.

Categories of Benefits and Costs

Benefit-cost analysis involves the comparison of real resource costs with real resource benefits -- Table 3 presents the categories of costs and benefits included in the present analysis.

It should be noted that employment income-induced multiplier effects associated with the airport, either directly or indirectly, are not included in the benefit-cost analysis. This is because infrastructure-related employment does not necessarily create real resource gains to a local economy since some of those working in infrastructure-related jobs would find employment elsewhere in the absence of airport-led demand for their services. To be sure, the so-called "economic impact" of an airport is an important element of a community decision on airport capacity. It must, however, be dealt with outside the context of benefit-cost analysis.

Measures of Worth from the Community and Industry Perspective

Because of the phenomenon that economists call "externalities", a project deemed worthwhile in the eyes of some can be wasteful in the eyes of others. For the community at-large, investments that reduce airport delays convey economic benefits in the form of time savings and reduced aircraft operating costs. Time savings translate into more time for productive work and the economy as a whole is thus better off. An individual airlines, however, cannot "internalize" such benefits; that is, it cannot translate higher productivity throughout the economy directly into cost savings or enhanced profit. For an airline, the only benefits that can enter directly into its judgement on the merits of a given airport investment are savings that it can parlay into better company performance, namely savings in fuel, labor and other operating expenses.

To accommodate the interests of different parties to airport investment decisions, Hickling estimates all measures of net worth and timing for both the community at-large and the airlines. Measures aimed at the community at-large include time savings and reduced airline costs while airline measures include only the latter.

Risk and Uncertainty

Benefit-cost analysis requires a great many forecasts and assumptions, all of which are subject to uncertainty. To allow for the risk associated with these uncertainties, the analysis developed here uses RAP, the Risk Analysis Process applied in earlier parts of study.

In summary, each and every assumption is assigned a probability distribution and calculations of net worth and timing are permitted to vibrate according to simultaneous random variations in the distributions associated with each variable. The result is a probability distribution for each measure of net worth and timing

TABLE 3

CATEGORIES OF TRANSPORTATION COSTS AND BENEFITS

COSTS

- Captial costs
- Incremental operating and maintenance costs

BENEFITS

- Passenger time savings due to reduced delay
- Aircraft savsings in O & M due to Reduced delay

that depicts both the expected value and the risk of falling below minimum required returns.[1]

Key Assumptions

Although many detailed assumptions must be made in an analysis on the scale under consideration here, the principal economic assumptions may be summarized in five categories, as follows;

- o Discount rate;
- o Real airline operating costs;
- o Fuel prices;
- o Airline labor productivity and costs; and
- o The value of passengers' time.

Assumptions developed for this study are summarized in Table 4. Perhaps the most difficult of all areas is that of valuing passenger time savings. For some years now, a number of analysts have held the belief that only savings in excess of about five minutes have any real economic significance. More recently however, unpublished FAA-sponsored research, as well as research at Oxford University in England, suggests that all time savings are useful and should thus be valued. These latter studies observe that many traffic schemes in cities save only minutes or seconds, yet no one finds themselves with spare minutes here and there -- we appear to put these minutes to productive use.

Standard practice over the years has valued time savings at the hourly wage rate of business travellers and about one-quarter of that for non-business travellers. On the grounds that some work gets done in flight, however, some analysts apply only a portion of the wage rate to assess the value of time savings.

To account for the uncertainties outlined above, this study adopted current FAA-recommendations for the expected value of time savings, but assigned a heavily skewed probability distribution that effectively assumes a high likelihood that the value of time savings is only one-third the expected value. This means that all related benefit computations are highly conservative, and more likely to understate than overstate the value of time savings due to reductions in delay.

Establishing the Base Case

Benefits and costs of alternative strategies are measured in this (or any) study in relation to a state in which no major capacity expansion takes place. It is critically important, however, that the baseline reflect the fact that even without major expansion, the MAC and the airlines will do everything they can to maximize the airport's productivity.

---

1. For a full description of RAP, see Working Paper II, **Analytic Framework**

TABLE 4

KEY ASSUMPTIONS USED IN 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.

The MAC, for example, can be expected to build new runway exits that reduce occupancy times; add new taxiways; and make other, similar improvements to enhance the capacity of the airport as it currently exists -- ie, two main runways and a crosswind runway. The MAC can also be expected to engage in demand management techniques, such as the shifting of general aviation to off-peak times and reliever airports.

Likewise, airlines can be expected to adjust schedules and aircraft sizes to accommodate heavy peaking, although their ability to do so will be limited by the need to maintain good connections for hubbing passengers and limitations on shifting aircraft among routes.

And finally, the FAA can be expected to introduce new airspace and ground control technology that improves airport capacity.

The baseline established for this study thus assumes maximum productivity from the existing site and in this way avoids the overestimation of incremental benefits associated with strategic alternatives.

Distributional Assumptions and Policy Implications

Benefit-cost analysis measures only the economic efficiency of alternative strategies and makes the assumption that all outcomes are fair and equitable. Obviously, however, this assumption is unlikely to hold true in practice. A strategy with a high rate of return will likely make people in high noise neighborhoods worse off; in general, even when a project makes most people better off, it is a rare public project that does not leave at least someone, somewhere, worse off than before.

Does this mean that benefit-cost analysis is flawed? Not at all. It simply means that the distributional, or "fairness" issues must be dealt with separately. Benefit-cost analysis does offer some very useful guidelines however for helping resolve the fairness issue. Namely, if the net benefits of a project are large enough to generate sufficient resources to compensate the "losers" while still leaving some net returns overall, the project can be said to be both efficient and equitable (a project that leaves everyone better off and no one worse off is said to be "socially optimal"). Equity depends, of course, upon finding and applying a mechanism to ensure that the losers actually receive just compensation, such as extra levy against airlines or passengers to create a fund to help high noise neighborhoods.[2] This issue is dealt with in our Working Paper on noise analysis and in the final Section of this paper.

---

[2]. See, Working Paper 8, **Noise Analysis**

3.0 COSTS

Cost estimates for individual project options were developed in an earlier working paper.[3] Table 5 merges project costs into the principal alternative strategies, expressed in constant 1988 dollars. Appendix A, Tables A1 through A5 translate the costs for each strategy into a time stream of expenditures based upon the start date, estimated construction period and cost profile of each project. Appendix A provides graphic presentations of the expenditure flows under each strategy. Table 6 presents the discounted, present value of the expenditure flows reported above for each strategy. It is this value that enter directly into the benefit-cost calculations reported in Section 5.0.

---

[3]. See Thompson-Hickling Aviation, **Alternative Airport Design Concepts,** July 1988

TABLE 5

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.

TABLE 6

PROJECTED COSTS IN PRESENT VALUE -- 1988-2020
(in Millions of Dollars)

	DIRECT COSTS			DIRECT COSTS & SAFETY ZONES		
	10% Lower Bound	Mean	10% Upper Bound	10% Lower Bound	Mean	10% Upper Bound
STRATEGY A	346	393	448	802	917	1,059
STRATEGY B	538	607	689	1,003	1,131	1,289
STRATEGY C1	820	914	1,010	1,300	1,439	1,598
STRATEGY C2	551	617	690	1,017	1,141	1,288

4.0 BENEFITS

The benefits of alternative airport capacity options stem from common origins, namely reduced delay. The quantification of benefits thus involves three key steps, as follows;

- o Establish full airport simulation capability;
- o Simulate delay under the base case scenario;
- o Simulate delay reductions under alternative strategies; and
- o Value delay savings in monetary units.

Simulation Capability

An advanced computer simulation tool called PC-ADSIM is used in our airport planning procedures to quantify airport performance. Validated at Chicago O'Hare Airport, ADSIM is the Federal Aviation Administration's principal tool for airport capacity analysis and simulation and is now being used by FAA capacity task forces throughout the country. PC-ADSIM is Hickling's version of ADSIM; it is identical to the FAA version in all respects except that PC-ADSIM operates on a personal computer whereas ADSIM is available for mainframe computers only. The PC version is far less costly to operate and thus permits a wider range of options to be considered within a given budget.

PC-ADSIM is a discrete event simulation model that calculates travel time, delay and flow rate data to analyze components of an airport, airport operations and operations in adjacent airspace. The model works with airport data on actual schedules by aircraft type, class and airline, airport layout, actual operations and air traffic control procedures. The simulation model provides the following information;

- o Hourly or quarter-hourly delays caused by each user-specified ATC separation;
- o Arrival and departure delays by hour (or quarter-hour) by aircraft class, by runway, by airfield components and by airfield operations;
- o Delays for runways crossing and taxiway queue links;
- o Travel times for various segments of departure and arrival operations; and
- o Composite hourly (or quarter-hourly) flow rates, travel times and delays for arrivals and departures.

The model operates in two modes. The "short form" focuses on runway and runway exit-related delay whereas the "long-form" simulates taxiway, apron and gate hold-induced delays as well. The analysis presented here uses the short-form to quantify runway and runway exit-related delays only.

Base Case Simulation

Simulating delay under the base case involves the following major steps;

- o Specification of base-year infrastructure and changes through the year 2018;
- o Quantification of base-year aircraft/airside operations;
- o Specification of base-year and future-year air traffic control procedures through the year 2018;
- o Specification of base-year and future-year runway use configurations through the year 2018; and
- o Base-case simulation and forecasting.

Base-Year and Future Year Infrastructure. Base-year and future-year infrastructure is depicted in Figures 1 and 2 (white areas plus cross-wind extension; runways marked in black represent alternative strategies tested below). Future-year development is based upon the current MAC capital plan.

All details shown in Figures 1 and 2 were "digitized" and entered into PC-ADSIM as a basis for simulation.

Base-Year Aircraft-Airside Operations. Figures 3, 4 and 5 display the details of the aircraft-airside operations survey conducted by the consulting team over a three day period in August 1988. August was chosen as it represents the peak month; the survey is designed to yield data for an average day in the peak month as a basis for simulation and capacity planning.

Results in the form of runway occupancy times and exit probabilities are displayed in Figure 4. These results were digitized and entered into ADSIM for base-year simulation.

Air Traffic Control Procedures. Base-year separations and ground control procedures used in this analysis mirror those in operation during the August survey period. The base-year simulation thus represents an exact representation of airport-airspace operations on the day simulated.

Future-year separations through the year 2020 are based upon the technology-capacity analysis developed by the consulting team and expert panels, as reported in our capacity analysis Working Paper.

Runway Use Configurations. Runway use configurations assumed in this analysis are summarized in Figures 6 and 7. Figure 6 presents general guidelines developed by the MSP tower staff. Figure 7 is based upon more detailed analysis and interviews with tower staff.

Daily and hourly runway use patterns fluctuate in response to weather conditions, noise reduction policies and maintenance exigencies. However, patterns shown in

MSP LIDAR & EXIT IDENTIFICATION
(CURRENT & PROPOSED)

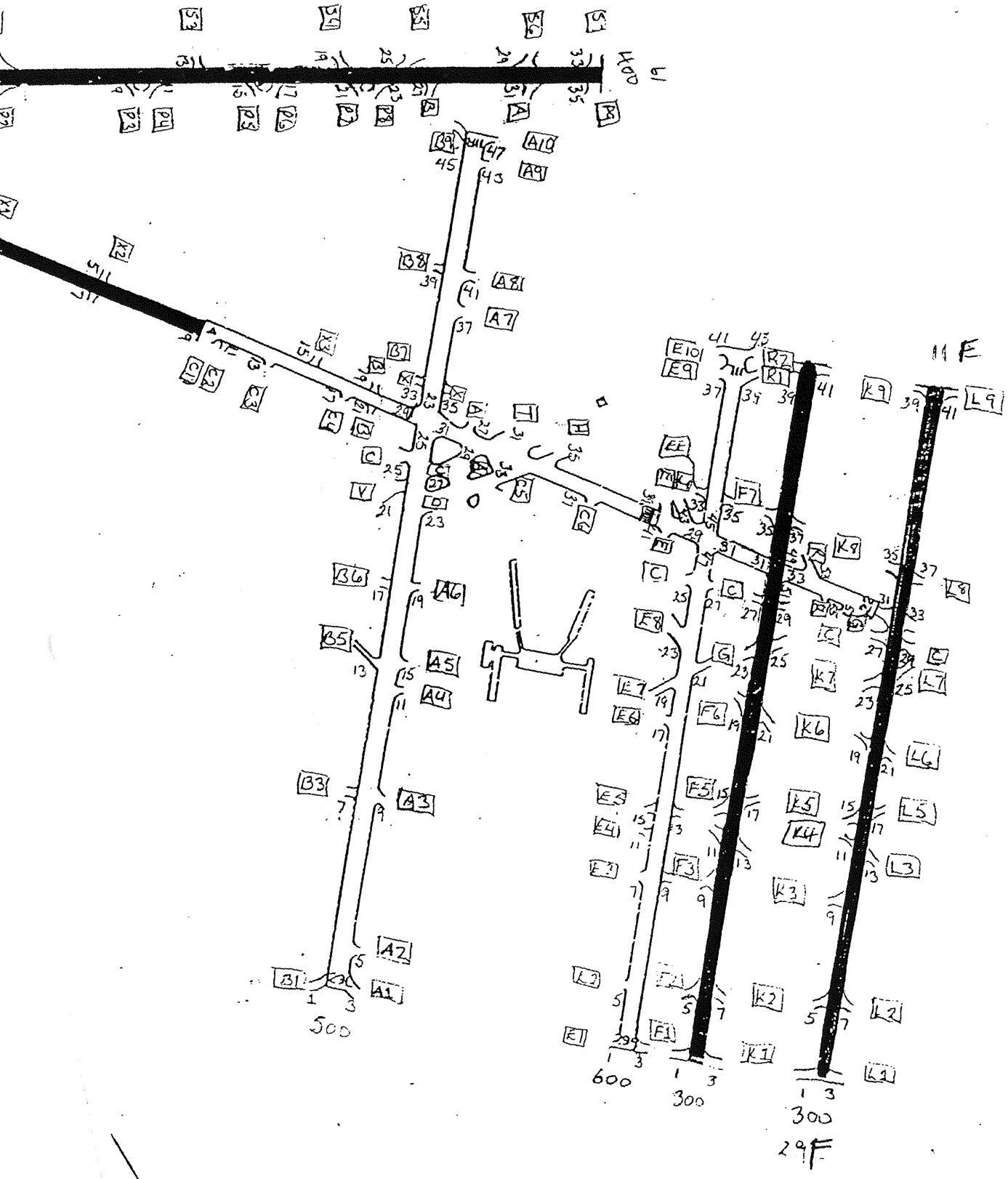


FIGURE 2

MSP RUNWAYS AND EXIT DISTANCES
(CURRENT & PROPOSED)
(DISTANCES IN HUNDREDS OF FEET FROM RNWY END)

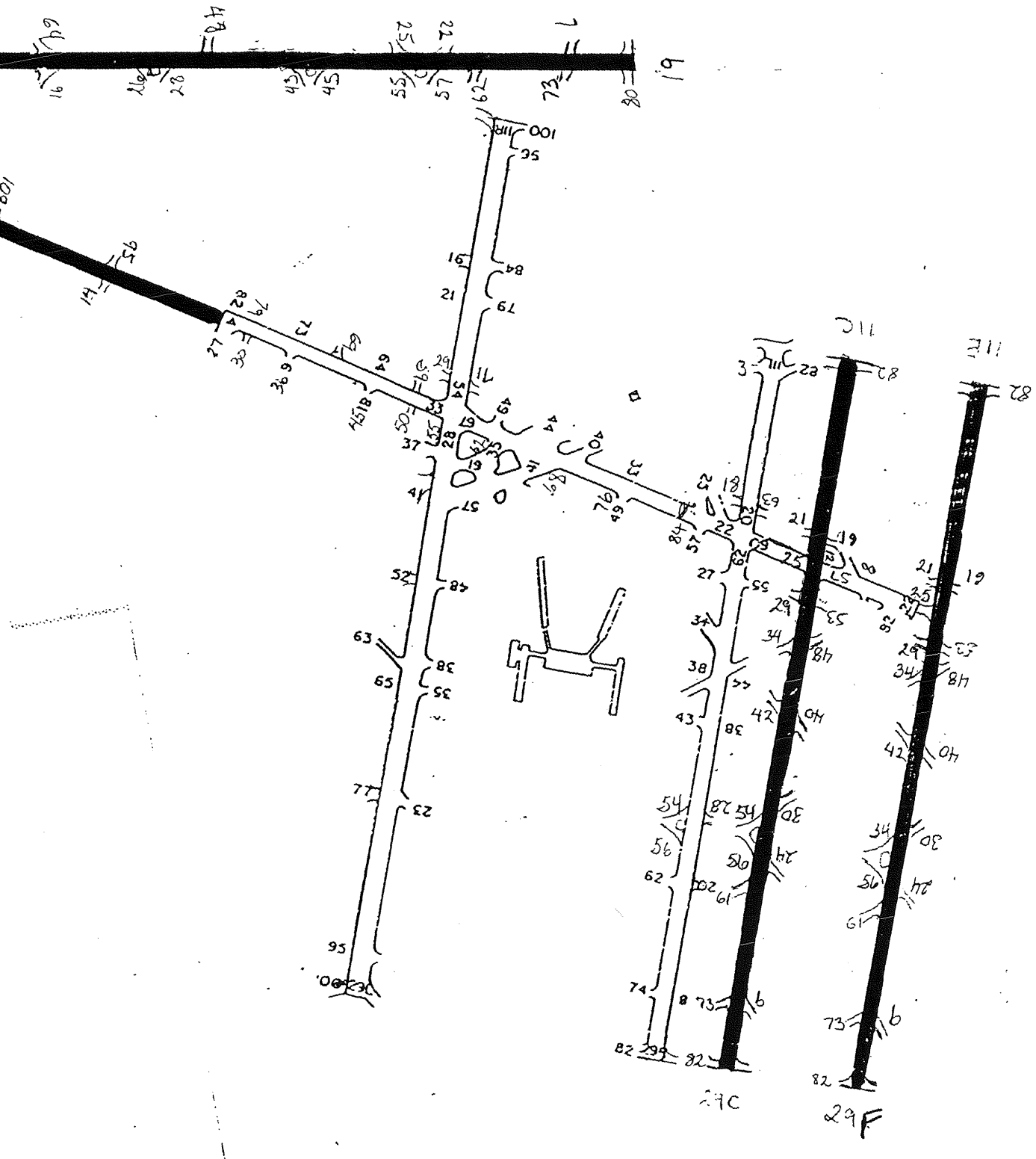


FIGURE 3

AIRCRAFT/AIRSIDE SURVEY

- collect three consecutive days of data -- about 8 to 12 hours per day;
- must have arrival and departure peaks in the survey period (ask tower when these occur and when they feel the best times are);
- best days are usually Tuesday, Wednesday, and Thursday, with traffic usually growing every day to peak on Thursday;
- conduct survey under VFR conditions -- usually find exit probabilities and R.O.T.s do not differ significantly between VFR and IFR; in any case, note weather and runway conditions of survey period;
- it is best to have one individual per active runway to collect both arrival and departure data:

  Arrival Data -- Aircraft Type - S1 for small single engine
  - S2 for small twin engine
  - L for large (727,737,DC9 etc.)
  - H for heavy (747,DC10,L1011, etc.)

  or actual aircraft if it can be identified;

  -- time over threshold (clock time)

  -- time completely exited runway (clock time)

  -- exit aircraft used (see diagram)

  Departure Data -- Aircraft type (see above)

  -- time of roll (starts to roll to begin its departure)

  -- time to wheels-up

  -- runway intersection used to depart (GA)

- may wish to keep track of separations to see how close they comply with 78-8A (this is the main reason for collecting departure data);
- corroborate with tower once data is collected.

ADDITIONAL INFORMATION

- check with tower those items I identified in the model input data sheets;
- check with tower the general conditions that exist for use of each runway - when is 4/22 used? is it used as a convenience (eg. due to winds, aircraft arrival or departure fix)? is it used consistently or ad hoc? Which aircraft do they assign to 4/22? Are the same runways used for both arrivals and departures? Are aircraft assigned according to fix?
- get tower map of airport with exits and distances marked (from Connie)

FIGURE 4

MSP AIRCRAFT GROUND OPERATIONS SURVEY

Runway:

Rwy. Cond.:

Departures

Date:
Weather:
Temp:

Aircraft Type (S1, S2, L, H or actual A/C)	Clock Time		Intersection Used
	Time of Roll	Time of Wheels off Ground	

FIGURE 4 (cont'd)

MSP AIRCRAFT GROUND OPERATIONS SURVEY

Runway:	Arrivals	Date: Weather: Temp:
Rwy. Cond.:		

Aircraft Type (S1, S2, L, H or actual A/C)	Clock Time		Exit Used
	Time Over Threshold	Time Completely Exited Runway	

FIGURE 5

SURVEY SUMMARY

RUNWAY 29L

RUNWAY EXITS

AIRCRAFT CLASSIFICATION		A1	A2	A3	A4	A5	B5	A6	D	V	C	A	RW22	A7	A8	A10	A9
	DISTANCE	0	500	2300	3500	3800	3700	4800	5700	5700	6100	?	6700	7900	8400	10000	9500
1	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%	4.6%	4.4%	0.0%	36.0%	38.8%	0.0%	11.9%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	NA	NA	NA	52.0	56.0	53.0	NA	62.7	59.1	NA	72.5
2	% UTILIZATION	0.0%	0.0%	0.0%	0.5%	0.2%	0.4%	2.0%	26.7%	6.8%	16.8%	22.6%	0.7%	20.3%	1.2%	0.0%	1.7%
	R.O.T. (seconds)	NA	NA	NA	39.5	32.0	35.0	41.0	47.5	55.9	50.5	51.9	54.0	60.0	66.3	NA	71.0
3	% UTILIZATION	0.0%	0.0%	0.0%	4.2%	0.0%	40.6%	0.0%	18.3%	37.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	48.0	NA	46.6	NA	52.5	53.1	NA	NA	NA	NA	NA	0.0	0.0
4	% UTILIZATION	0.0%	0.0%	0.0%	50.9%	0.0%	0.0%	0.0%	0.0%	49.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	54.0	NA	NA	NA	NA	52.0	NA	NA	NA	NA	NA	0.0	0.0

FIGURE 5 (cont'd)

SURVEY SUMMARY

RUNWAY 29R

RUNWAY EXITS

AIRCRAFT CLASSIFICATION		R1	R2	E10	E9	RW22	C	E8	G	E7	E6	E3	E2	E1
	DISTANCE	7900	8200	8200	7900	6000	5500	4800	4400	4400	3800	2??	800	0
1	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	% UTILIZATION	3.7%	0.0%	0.0%	7.5%	13.2%	16.8%	39.0%	0.9%	5.9%	13.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	67.3	NA	NA	59.6	48.8	48.9	46.9	52.0	40.5	40.1	NA	NA	NA
3	% UTILIZATION	0.0%	0.0%	0.0%	2.5%	4.3%	22.1%	26.4%	0.0%	18.8%	25.9%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	77.0	43.7	48.2	44.8	NA	40.9	39.5	NA	NA	NA
4	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	21.2%	10.9%	0.0%	0.0%	59.9%	7.9%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	64.0	33.0	NA	NA	45.3	24.0	NA	NA

NOTE: 29R WAS NOT USED FOR ARRIVALS FOR PART OF THE SURVEY PERIOD DUE MAINTENANCE

FIGURE 5 (cont'd)

SURVEY SUMMARY

RUNWAY 11L

RUNWAY EXITS

AIRCRAFT CLASSIFICATION		R1	R2	E10	E9	RW22	C	E8	G	E7	E6	E3	E2	E1
DISTANCE		300	0	0	300	2200	2700	3400	3600	3900	4300	6200	7400	8200
1	% UTILIZATION	ERR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	2.3%	3.3%	13.1%	63.4%	15.8%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	NA	38.5	86.0	41.3	44.0	55.9	58.6	NA
3	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	5.8%	14.0%	5.2%	10.7%	26.9%	37.4%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	31.0	37.5	56.0	38.0	48.0	57.1	NA	NA
4	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	48.2%	15.3%	0.0%	36.6%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	41.5	39.5	NA	47.3	NA	NA	NA	NA

FIGURE 5 (cont'd)

SURVEY SUMMARY

RUNWAY 11R

RUNWAY EXITS

AIRCRAFT CLASSIFICATION		A1	A2	A3	A4	A5	B5	A6	D	V	C	A	RW22	A7	A8	A10
	DISTANCE	10,200	9,[illegible]	7[illegible]	6,[illegible]	6,2[illegible]	6,300	5,200	4[illegible]	4[illegible]	3,7[illegible]	3,300	3[illegible]	2[illegible]	1,[illegible]	[illegible]
1	% UTILIZATION	39.0%	61.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	68.3	80.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	% UTILIZATION	0.0%	1.6%	21.4%	52.6%	5.3%	5.4%	9.7%	1.0%	0.6%	1.1%	1.3%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	71.0	53.2	52.4	51.2	51.7	52.6	44.0	50.0	31.0	58.5	NA	NA	NA	NA
3	% UTILIZATION	0.0%	0.0%	25.6%	7.0%	0.0%	8.6%	6.1%	3.4%	24.9%	17.4%	7.1%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	66.3	54.0	NA	67.0	47.0	26.0	48.3	33.8	55.0	NA	NA	NA	0.0
4	% UTILIZATION	0.0%	0.0%	0.0%	19.8%	0.0%	15.3%	0.0%	0.0%	31.3%	7.3%	12.8%	0.0%	13.5%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	39.5	NA	61.0	NA	NA	41.7	29.0	51.0	NA	54.0	NA	0.0

FIGURE 5 (cont'd)

SURVEY SUMMARY

RUNWAY 22

RUNWAY EXITS

AIRCRAFT CLASSIFICATION		C1	C3	C4	RW11R	RW11L	A	T	C5	H	C6	E	J
	DISTANCE	8200	7300	6400	5400	2000	4900	4400	4400	4000	3300	2500	2500
1	% UTILIZATION	22.9%	20.0%	57.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	R.O.T. (seconds)	72.0	63.0	60.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	% UTILIZATION	4.4%	19.5%	50.8%	7.6%	0.0%	8.6%	0.0%	7.7%	0.0%	1.5%	0.0%	0.0%
	R.O.T. (seconds)	57.0	57.0	48.2	44.6	NA	38.9	NA	35.6	NA	32.3	NA	NA
3	% UTILIZATION	0.0%	17.5%	23.9%	0.0%	0.0%	7.0%	0.0%	29.1%	12.1%	3.6%	6.7%	0.0%
	R.O.T. (seconds)	NA	53.5	48.7	NA	NA	43.0	NA	44.5	37.0	22.0	20.5	NA
4	% UTILIZATION	0.0%	0.0%	0.0%	0.0%	0.0%	35.2%	0.0%	0.0%	32.8%	32.0%	0.0%	0.0%
	R.O.T. (seconds)	NA	NA	NA	NA	NA	45.0	NA	NA	42.0	41.0	NA	NA

FIGURE 6

Current and Possible Runway Configurations Minneapolis Airport

I. Current Configurations
- A. Straight 29 L&R
  - 1. Dual locals
    - a. Arrive 60 Depart 60 --Total 120
  - 2. Single local
    - a. Arrive 60 Depart 40 --Total 100
    - b. Arrive 40 Depart 60 --Total 100
- B. Straight 11 L&R same as 29's
- C. Arrive 29L&R Depart 22
  - 1. No hold short restrictions on 29's
    - a. Arrive 60 Depart 20 --Total 80
  - 2. 29L landings hold short of 22
    - a. Arrive 60 Depart 30 --Total 90
- D. Arrive 4 Depart 11 L&R
  - 1. No hold short on 4
    - a. Arrive 36 Depart 30 --Total 66
  - 2. All but heavy hold short 11L
    - a. Arrive 36 Depart 44 --Total 80
- E. Any single runway
  - 1. Arrive 36 Depart 30 --Total 66
  - 2. Arrive 30 Depart 36 --Total 66

II. Possible Configurations
- A. Arrive 29L and 29R holding short 4/22 Depart 4
  - 1. Arrive 60 Depart 30 --Total 90
  - 2. Departures would have to be mostly westbound
- B. Arrive 22 Depart 11 L&R
  - 1. Arrive 36 Depart 30 --Total 66
- C. Arrive 11L and 4 holding short of 11L
  - 1. Arrive 60 Depart 40 --Total ~~100~~ 90
  - 2. Airspace changes need for north and eastbounds
- D. Arrive 29L holding short 22 and Arrive 22 Depart 29R
  - 1. Arrive 50 Depart 30 --Total 80
  - 2. Airspace changes necessary to accomodate Departures
- E. Arrive 11 L&R Depart 22
  - 1. Arrive 60 Depart 20 --Total 80
  - 2. Airspace changes necessary

FIGURE 7

Base Configuration

1988

	Arrivals			Departures	
FIX:	1	11L	EAST	5	11L
	2	11R	FLOW	6	11R
	3	11R		7	11R
	4	11L		8	11L
	1	29R	WEST	5	29R
	2	29L	FLOW	6	29L
	3	29L		7	29L
	4	29R		8	29R

1988,2008,2018

Reflect 4-22 extension (benefits West flow only)

	Arrivals			Departures	
FIX:	1	11L	EAST	5	11L
	2	11R	FLOW	6	11R
	3	11R		7	11R
	4	11L		8	11L
FIX:	1	29R	WEST	5	29R
	2	29L	FLOW	6	22
	3	29L		7	22
	4	29R		8	29R

FIGURE 7 (CONT'D)

Ultimate A

4-22 extension
18-36 (N-S) runway addition
11L-29R for parallel addition

2008, 2018

Arriavals			Departures	
1	22	EAST	5	11L
2	22	FLOW	6	11C
3	18		7	11R
4	18		8	11R
1	29R	WEST	5	29R
2	29L	FLOW	6	29L
3	36		7	29L
4	36		8	29C

FIGURE 7 (CON'T)

Enhanced A

4-22 extension
18-36 (N-S) runway addition

1998, 2008, 2018

Arrivals			Departures	
1	22	EAST	5	11L
2	22	FLOW	6	11R
3	18		7	18
4	18		8	18
1	29R	WEST	5	29R
2	29L	FLOW	6	29L
3	36		7	29L
4	36		8	29R

Figure 7, those used in the simulation and delay measurement process, represent the optimal hourly operations for VFR and IFR conditions; measured delays may thus be interpreted as arising solely from capacity limitations.

Base Case Delay Simulation and Forecasting. The simulation of base-year (1988) delay produced a mean estimated total annual delay at 75,577 hours, or 14.1 minutes per aircraft under the base case. Future-year delays under the base case are projected on the bases of traffic forecasts developed in an earlier Working Paper and the various assumptions outlined above. Appendix B, Tables B1 and B2 summarize the results for each year.

The results are summarized in Tables 7 and 8. As Table 7 shows, delay under the base case can be expected to climb to about 50 minutes per aircraft by the year 2008, even with the added runway exits, the crosswind extension and the new air traffic control technology expected. Further analysis of the scope for peak spreading under the base case is explored later in this paper. It finds that average delay in the base-year would decline from 14.1 minutes to 10.9 minutes under a sharp peak spreading program; by the year 2008, however, peak spreading would have virtually no impact at all on base case delay.

Table 8 analyzes current delays by length of delay and source.

Delay Under Alternative Strategies

Simulating delay under alternative strategies follows the same program of research as that outlined above for base case analysis. New runways are added to the ADSIM program, as shown in Figures 1 and 2 (dark lines). Exit probabilities for the new runways were estimated statistically from the analysis of existing exit utilization and distance between exits.

Figure 7 displays the runway usage patterns developed for each strategy. These patterns are based upon interviews with tower staff and constraints imposed by the Adequacy Task Force. The principal constraint operates on the new north-south runway, for which no northern departures are permitted.

Appendix B, Tables B1 and B2 display the total and average delays estimated for each strategy in each year over the 1988-2018 analysis period. Delay reductions are calculated as the difference between delay under the base case and delay under the strategy in question. The results are summarized in Table 7. As the Table shows, strategy C1 offers the minimum delay path through the year 2018.. Whether strategy C1 is cost-beneficial is explored in Section 5.0.

Valuation of Delay Savings

Using the assumptions outlined in Table 4 above, Tables 9 and 10 translate the estimates of reduced delay under each strategy into monetary terms. Table 9 presents the unit savings per aircraft and per aircraft hour (ie after allowing for passenger load factors) while Table 9 displays the total savings by year in each category of delay.

TABLE 7

TOTAL AIRCRAFT DELAY AND AVERAGE DELAY

YEAR		CURRENT AIRPORT *	STRATEGY A	STRATEGY B	STRATEGY C1	STRATEGY C2
1988	TOT DELAY (HRS)	75,577	75,577	75,577	75,577	75,577
	AVG DELAY (MIN)	14.10	14.10	14.10	14.10	14.10
1998	TOT DELAY (HRS)	216,858	61,591	61591	61,591	61,591
	AVG DELAY (MIN)	29.72	8.44	8.44	8.44	8.44
2008	TOT DELAY (HRS)	439,731	107,420	93,875	21,987	107,420
	AVG DELAY (MIN)	50.41	12.32	10.76	2.52	12.32
2018	TOT DELAY (HRS)	1,251,415	547,500	378,983	62,571	62,571
	AVG DELAY (MIN)	109.96	48.11	33.30	5.50	5.50

* Includes Current Capital Improvement Program.

TABLE 8

PERCENTAGE OF FLIGHTS DELAYED BY LENGTH OF DELAY

LENGTH OF DELAY (MINUTES)	GATE HOLD (%)	TAXI OUT (%)	TAXI IN (%)	TOTAL
0	93.7%	7.9%	16.3%	18.4%
1 - 14	3.8%	79.9%	80.9%	72.8%
15 - 29	1.5%	10.2%	2.2%	7.3%
30 - 59	0.7%	1.7%	0.5%	1.3%
60 +	0.3%	0.3%	0.1%	0.2%
TOTAL	100.0%	100.0%	100.0%	100.0%
% OF DELAY	9.6%	64.0%	26.3%	100.0%

SOURCE: Airport Capacity Enhancement Plan, DOT, 1988
(Figures are for 1986)

TABLE 9

YEAR	AIRCRAFT O&M SAVINGS PER HOUR OF A/C DELAY			VALUE OF TIME SAVINGS PER HOUR OF A/C DELAY		
	LOWER 10%	MEAN	UPPER 10%	LOWER 10%	MEAN	UPPER 10%
1988	$1,005	$1,116	$1,239	$677	$2,030	$2,320
1989	$998	$1,107	$1,229	$677	$2,030	$2,320
1990	$994	$1,103	$1,225	$677	$2,030	$2,320
1991	$990	$1,099	$1,220	$677	$2,030	$2,320
1992	$990	$1,099	$1,220	$677	$2,030	$2,320
1993	$992	$1,101	$1,222	$677	$2,030	$2,320
1994	$994	$1,103	$1,225	$677	$2,030	$2,320
1995	$996	$1,105	$1,227	$677	$2,030	$2,320
1996	$998	$1,107	$1,229	$677	$2,030	$2,320
1997	$1,000	$1,110	$1,232	$677	$2,030	$2,320
1998	$1,002	$1,112	$1,234	$677	$2,030	$2,320
1999	$1,005	$1,116	$1,239	$677	$2,030	$2,320
2000	$1,009	$1,120	$1,243	$677	$2,030	$2,320
2001	$1,013	$1,124	$1,248	$677	$2,030	$2,320
2002	$1,017	$1,129	$1,253	$677	$2,030	$2,320
2003	$1,021	$1,133	$1,257	$677	$2,030	$2,320
2004	$1,024	$1,137	$1,262	$677	$2,030	$2,320
2005	$1,028	$1,141	$1,267	$677	$2,030	$2,320
2006	$1,032	$1,145	$1,271	$677	$2,030	$2,320
2007	$1,036	$1,150	$1,276	$677	$2,030	$2,320
2008	$1,040	$1,154	$1,281	$677	$2,030	$2,320
2009	$1,043	$1,158	$1,286	$677	$2,030	$2,320
2010	$1,047	$1,162	$1,290	$677	$2,030	$2,320
2011	$1,051	$1,167	$1,295	$677	$2,030	$2,320
2012	$1,055	$1,171	$1,300	$677	$2,030	$2,320
2013	$1,059	$1,175	$1,304	$677	$2,030	$2,320
2014	$1,062	$1,179	$1,309	$677	$2,030	$2,320
2015	$1,066	$1,183	$1,314	$677	$2,030	$2,320
2016	$1,070	$1,188	$1,318	$677	$2,030	$2,320
2017	$1,074	$1,192	$1,323	$677	$2,030	$2,320
2018	$1,078	$1,196	$1,328	$677	$2,030	$2,320
2019	$1,081	$1,200	$1,332	$677	$2,030	$2,320
2020	$1,085	$1,205	$1,337	$677	$2,030	$2,320

TABLE 10

DOLLAR BENEFITS OF DELAY SAVINGS ($ MILLIONS - 1988)

	AIRCRAFT O&M DOLLAR SAVINGS ($ MILLIONS)				TIME DOLLAR SAVINGS ($ MILLIONS)				TOTAL DOLLAR SAVINGS ($ MILLIONS)			
YEAR	OPTION A	OPTION B	OPTION C1	OPTION C2	OPTION A	OPTION B	OPTION C1	OPTION C2	OPTION A	OPTION B	OPTION C1	OPTION C2
1988	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1989	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1990	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1991	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1992	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1993	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1994	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1995	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1996	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1997	$162	$162	$162	$162	$296	$296	$296	$296	$458	$458	$458	$458
1998	$173	$173	$173	$173	$315	$315	$315	$315	$488	$488	$488	$488
1999	$193	$193	$193	$193	$351	$351	$351	$351	$544	$544	$544	$544
2000	$214	$214	$214	$214	$387	$387	$387	$387	$601	$601	$601	$601
2001	$234	$234	$234	$234	$423	$423	$423	$423	$657	$657	$657	$657
2002	$255	$255	$255	$255	$459	$459	$459	$459	$714	$714	$714	$714
2003	$276	$276	$276	$276	$495	$495	$495	$495	$771	$771	$771	$771
2004	$297	$297	$297	$297	$531	$531	$531	$531	$828	$828	$828	$828
2005	$319	$319	$319	$319	$567	$567	$567	$567	$885	$885	$885	$885
2006	$340	$340	$340	$340	$603	$603	$603	$603	$943	$943	$943	$943
2007	$362	$362	$362	$362	$639	$639	$639	$639	$1,000	$1,000	$1,000	$1,000
2008	$383	$399	$482	$383	$675	$702	$848	$675	$1,058	$1,101	$1,330	$1,058
2009	$428	$462	$573	$428	$750	$809	$1,005	$750	$1,178	$1,271	$1,578	$1,178
2010	$473	$524	$665	$473	$825	$916	$1,161	$825	$1,298	$1,440	$1,826	$1,298
2011	$518	$588	$757	$518	$901	$1,023	$1,318	$901	$1,419	$1,611	$2,075	$1,419
2012	$563	$652	$850	$563	$976	$1,130	$1,474	$976	$1,539	$1,781	$2,324	$1,539
2013	$609	$716	$944	$609	$1,052	$1,237	$1,631	$1,052	$1,661	$1,952	$2,575	$1,661
2014	$655	$780	$1,038	$655	$1,127	$1,343	$1,787	$1,127	$1,782	$2,124	$2,825	$1,782
2015	$701	$846	$1,133	$1,133	$1,203	$1,450	$1,944	$1,944	$1,904	$2,296	$3,077	$3,077
2016	$748	$911	$1,229	$1,229	$1,278	$1,557	$2,100	$2,100	$2,026	$2,468	$3,329	$3,329
2017	$795	$977	$1,325	$1,325	$1,354	$1,664	$2,257	$2,257	$2,148	$2,641	$3,582	$3,582
2018	$842	$1,044	$1,422	$1,422	$1,429	$1,771	$2,413	$2,413	$2,271	$2,815	$3,835	$3,835
2019	$890	$1,110	$1,520	$1,520	$1,504	$1,878	$2,570	$2,570	$2,394	$2,988	$4,090	$4,090
2020	$937	$1,178	$1,618	$1,618	$1,580	$1,985	$2,726	$2,726	$2,517	$3,163	$4,344	$4,344

Table 11 presents the mean expected benefits in terms of their present-day value. As the Table shows, strategy C1 yields the highest present value of benefits from both the community and airline viewpoint ($4.6 billion and $1.7 billion respectively).

TABLE 11

Mean Projected Benefits in Present Value -- 1988-2020
(in Millions of Dollars)

	All Benefits	Aircraft Benefits
STRATEGY A	3,622	1,349
STRATEGY B	3,939	1,468
STRATEGY C1	4,619	1,725
STRATEGY C2	4,144	1,548

5.0 BENEFIT-COST ANALYSIS

The benefit-cost analysis considers both net worth and timing. In addition, this Section looks at key attributes of the best strategies emerging from the analysis, namely early obsolescence, the impact of peak spreading and distributional implications.

Net Worth

The net present value of the principal strategies are presented in Table 12 and in Figures 8 and 9. Table 12 confirms that all strategies are profoundly more economic than the base case. Strategy C1 has the highest net present value for the community as a whole ($3.7 billion) and, as shown in Figure 8, there is virtually no risk of the NPV falling even close to the zero mark. Strategy C1 achieves a greater NPV than a new airport-only plan, which has an estimated return of $3.3 billion if the airport is commissioned in 1999. It is noteworthy however that a new airport in 1999 achieves about the same return as two new runways at MSP while yielding greater long term flexibility and environmental benefits.

Strategy A emerges as slightly more advantageous for airlines operating at MSP than strategy C1. However, Figure 9 indicates little statistical difference between strategies A and C1 from the airline perspective. In either case, airlines can expect huge net savings in operating costs relative to their expenses under the base case.

Tables 13 and 14 report the estimated rates of return and benefit-cost ratios for each strategy. All rates of return are far in excess of the ten percent hurdle rate established for this study and the benefit-cost tests confirm that all strategies are socially worthwhile.

Timing

First-year benefit and pay-back tests, reported in Table 15, indicate that from the perspective of the community as a whole, capacity expansion is well overdue. The 75 percent first-year benefit from a new north-south runway means that the region would have reaped large economic gains had it build the facility five years ago.

From the airlines' perspective, the commissioning of a new airport in 2008 is somewhat premature; a one year delay would bring the first-year benefit to 10 percent, however, indicating that 2009-2010 is about the right time to commission the facility if current forecasts are borne out.

Detailed Analysis of Strategy C1

The construction of a new north-south runway in the mid-1990s and the commissioning of a new airport around 2009-2010 emerges with the highest net present value and thus deserves more detailed scrutiny.

Early Obsolescence. Does it make sense to open a new runway in 1997, only to close it ten years later, prior to end of its useful life? The analysis in Table 16 indicates that such a strategy is indeed economic since the north-south runway can be expected to pay for itself within 1.2 years from the community's perspective and

FIGURE 8

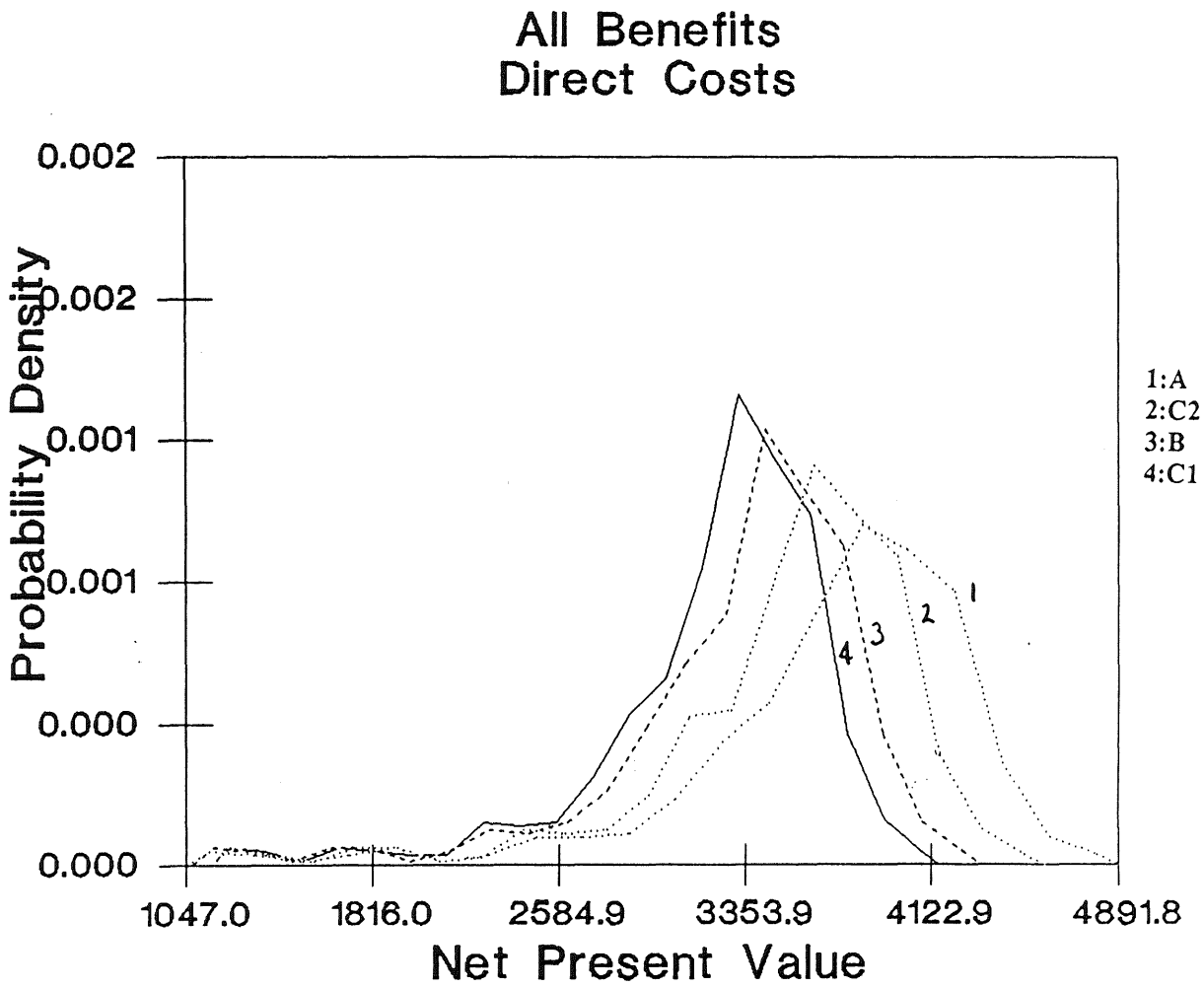

All Benefits
Direct Costs
0.002
0.002
0.001
0.001
0.000
0.000
Probability Density
1:A
2:C2
3:B
4:C1
1
2
3
4
1047.0
1816.0
2584.9
3353.9
4122.9
4891.8
Net Present Value

FIGURE 9

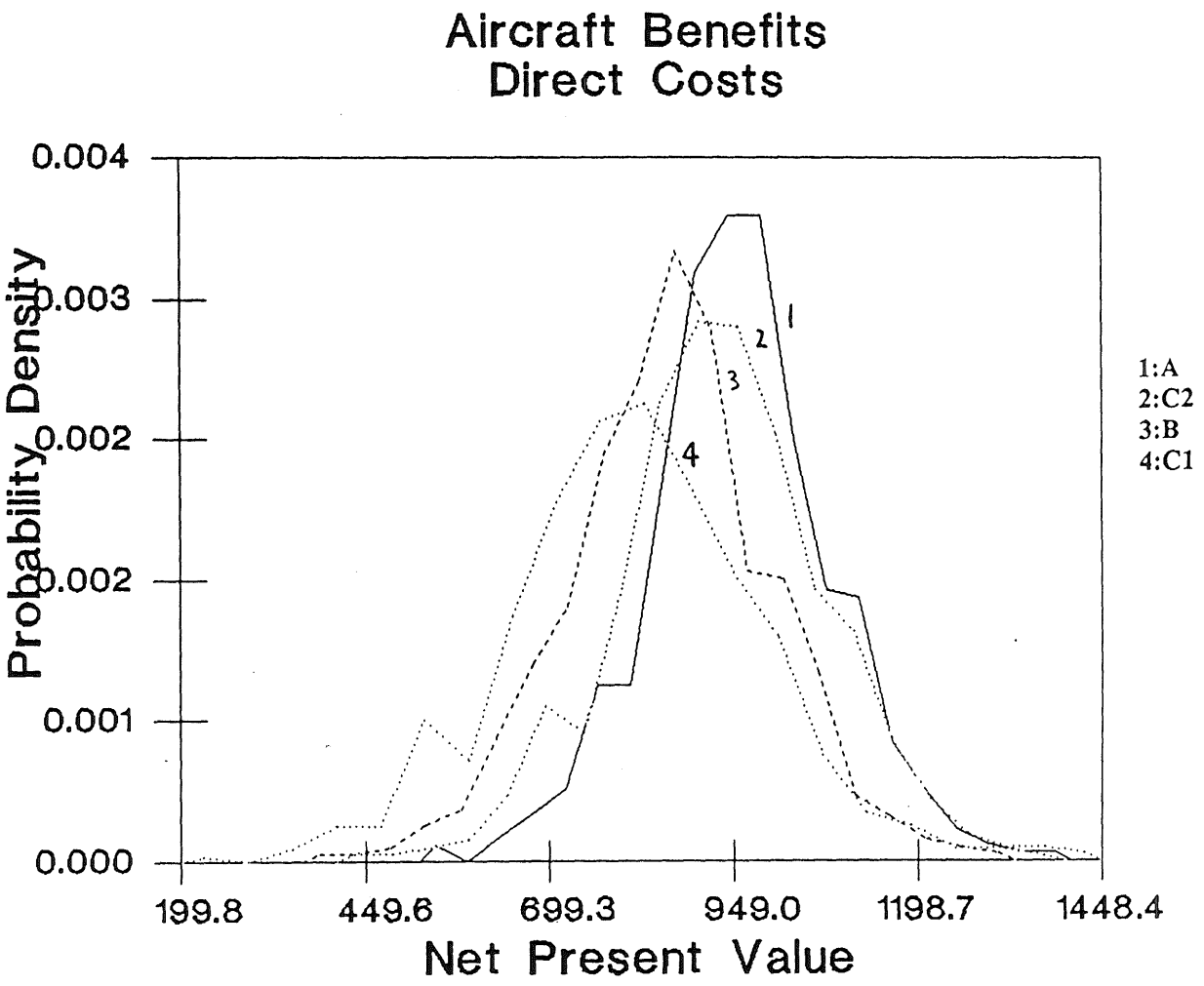

Aircraft Benefits
Direct Costs
Probability Density
0.004
0.003
0.002
0.002
0.001
0.000
199.8
449.6
699.3
949.0
1198.7
1448.4
Net Present Value
1
2
3
4
1:A
2:C2
3:B
4:C1

TABLE 12

RETURN ON INVESTMENT OF ALTERNATIVE STRATEGIES - NET PRESENT VALUE, 1988-2020
(in Millions of Dollars)

	DIRECT COSTS		DIRECT COSTS & SAFETY ZONES	
	All Benefits	Aircraft Benefits	All Benefits	Aircraft Benefits
STRATEGY A	3,229	956	2,708	431
STRATEGY B	3,332	861	2,808	337
STRATEGY C1	3,705	811	3,185	287
STRATEGY C2	3.527	931	3,008	407

1. The discount rate assumed is 8 1/4% plus 1 3/4% allowance for risk, for a total of 10%.

TABLE 15

RETURN ON INVESTMENT OF ALTERNATIVE STRATEGIES -- RATE OF RETURN, 1988-2020
(in Percent)

	DIRECT COSTS		DIRECT COSTS & SAFETY ZONES	
	All Benefits	Aircraft Benefits	All Benefits	Aircraft Benefits
STRATEGY A	47%	26%	26%	14%
STRATEGY B	46%	23%	25%	13%
STRATEGY C1	44%	21%	25%	12%
STRATEGY C2	47%	25%	26%	13%

RETURN ON INVESTMENT OF ALTERNATIVE STRATEGIES -- RATIO OF BENEFITS TO COST, 1988-2020

	DIRECT COSTS		DIRECT COSTS & SAFETY ZONES	
	All Benefits	Aircraft Benefits	All Benefits	Aircraft Benefits
STRATEGY A	9.3:1	3.5:1	4.0:1	1.5:1
STRATEGY B	6.5:1	2.4:1	3.5:1	1.3:1
STRATEGY C1	5.1:1	1.9:1	3.2:1	1.2:1
STRATEGY C2	6.8:1	2.5:1	3.7:1	1.4:1

TABLE 15

TIMING OF ALTERNATIVE STRATEGIES

	DIRECT COSTS				DIRECT COSTS & SAFETY ZONES			
	All Benefits		Aircraft Benefits		All Benefits		Aircraft Benefits	
	FYB (%)	PB (years)	FYB (%)	PB (years)	FYB (%)	PB (years)	FYB (%)	PB (years)
STRATEGY A	75	1.2	26	3.5	27	3.5	9.6	7.5
STRATEGY B [1]	14.3	3.5	4.9	5.5	--	--	--	--
STRATEGY C1 [2]	19.0	3.5	6.8	6.5	--	--	--	--
STRATEGY C2 [3]	80.2	1.2	62.9 [4]	3.0	--	--	--	--

1. Figures reflect the incremental return of the far parallel runway only.
2. Figures reflect the incremental return of the new airport only.
3. As footnote 2.
4. The FYB for new airport is 10% when new airport opens 2009. 2009 is thus the optimum year.

TABLE 16

IMPACT OF EARLY OBSCOLESCENCE -- RETURN ON INVESTMENT: NORTH SOUTH RUNWAY - 1997-2008 (in Millions of Dollars)

	DIRECT COSTS [1]		DIRECT COSTS & SAFETY ZONES [2]	
	All Benefits	Aircraft Benefits	All Benefits	Aircraft Benefits
NET PRESENT VALUE ($) [3]	1,685	372	1,184	(129)
FIRST-YEAR BENEFIT(%) [3]	75	26	27	9.6
PAY-BACK (YEARS) [4]	1.2	3.5	3.5	7.5

1. Includes no addition of wider safety zones to existing runways.
2. Includes addition of safety zones to existing runways.
3. Discount rate is 10 percent.
4. Includes interest costs incurred during construction period.

3.5 years from the perspective of the airlines. Even a sizeable recession, which could delay pay-back by up to five years, would not alter this conclusion.

Depeaking and Demand Management Efficiencies. A common source of error in benefit-cost studies is failure to allow for improvements in capacity utilization that are possible without major capacity expansion. In particular, airlines can be expected to do everything they can to resolve congestion-related problems by spreading peaks and adding larger planes. They are limited in the former by the need to maintain close connections (the raison d'etre of hub operations) and by practical constraints on fleet flexibility. The question considered here is whether sharp improvements in capacity utilization under the base case would dampen the economic need to expand capacity and build a new airport.

Tables 17 and 18 outline the depeaking scenarios considered in this study; their impacts, as simulated through PC-ADSIM, are reported in Tables 19, 20 and 21. The likelihood of much larger aircraft is already incorporated through the aircraft size probability distributions reported in the Aviation Forecasts Working Paper.

To assess the additional impact of depeaking on measures of net worth, the de-peaking-induced reductions in delay reported in the tables are incorporated into the base case and measures of net worth re-calculated accordingly for the alternative strategies; the results are reported in Table 22 and Figures 10 and 11. The results indicate that strategy C1 remains highly worthwhile from both the community and the airline perspective, with virtually no risk of economic failure.

Finally, the question of demand management entails the critical issue of peak period pricing -- would airlines sharply curtail their use of peak landing slots if the long-run marginal cost additional capacity were reflected in landing fees. If so, the investments considered here would not be worthwhile in the sense that airlines are not actually willing to pay for them. The analysis indicates however that even sharp depeaking, within the limits imposed by hub operations, would not dampen delay by enough to off-set the need for new runways. This implies that if airlines wish to sustain the financial benefits of hub operations they will indeed be willing to pay such fees. Although we have not looked at the financial losses that would arise from de-hubbing the schedule versus the cost of peak-period fees, the fact that airport costs are less than six percent of total airline operating expenses indicates strongly that airlines would pay rather than shift radically into off-peak operations.

Distributional Implications of Strategy C1. The huge $3-4 billion net benefits generated under this strategy provide ample sums with which to compensate those affected by additional noise. Whether they are sufficient to compensate the losers and still leave the community and the airlines better off overall is explored in the Working Paper on Noise Analysis. That paper concludes that since the new airport will end noise problems in the MSP region (assuming an undeveloped site) by 2010, it would appear that the net benefits are indeed sufficient to achieve a social optimum prior to that date.

TABLE 17
DEPEAKING

MILD DEPEAKING is done for absolute peak hours only (the hour within each peak that contains the single most flights -- all other hours within the peak remain unchanged). In this form of depeaking, operations in these hours are distributed uniformly throughout the sixty minutes, eliminating any bunching or peaking within this time, yet no operation gets moved out of the hour for which it was originally scheduled. In our work for Minneapolis, this involved redistributing traffic within the hours of 8:00, 13:00, and 17:00. For example, in 1998 during the 17:00 peak, flights get moved by an average of 5.12 minutes from their originally scheduled time, with a standard deviation of 3.63 minutes.

SHARP DEPEAKING extends this smoothing to the entire peak period but does not force any flights outside of the peak period. In this case, hourly operations are made identical for all hours within the peak period. For example, in the case of the peak hours 7:00, 8:00, and 9:00, with hourly operations of 75, 96, and 84, respectively, hourly operations can be shifted out of the hour for which they were originally scheduled if necessary. Flights get moved by an average of 7.43 minutes from their originally scheduled time, with a standard deviation of 4.01 minutes.

TABLE 18

ALTERNATIVE DEPEAKING SCENARIOS

Depeaking Scenarios	Average Schedule Change (Minutes)	95% Statistical Range (Minutes)
Mild Depeaking	5.12	± 7.1[1]
Sharp Depeaking	7.43	±14.6[2]

1. There is a 95% chance that a given flight will be re-scheduled by 12.2 minutes either earlier or later than originally scheduled.

2. There is a 95% chance that given flight will be re-scheduled by 22 minutes either earlier or later than originally scheduled.

TABLE 19

SUMMARY OF TOTAL ANNUAL DELAYS AND AVERAGE DAILY DELAYS

CURRENT AIRPORT

	1988		2008	
SCHEDULE	TOTAL (HOURS)	AVERAGE (MINS.)	TOTAL (HOURS)	AVERAGE (MINS.)
NORMAL	75578	14.1	439731	50.5
MILD DEPEAKING	72416	13.5	431643	49.6
SHARP DEPEAKING	58526	10.9	438899	50.4

TABLE 20

SUMMARY OF ANNUAL DELAYS BY CATEGORY OF DELAY

CURRENT AIRPORT

SCHEDULE	TYPE	1988 TOTAL (HOURS)	1988 % OF TOTAL	2006 TOTAL (HOURS)	2006 % OF TOTAL
NORMAL	AIR DELAYS	28900	38.2%	133781	30.1%
	RUNWAY DELAYS	6717	8.9%	11886	2.7%
	TAXIWAY DELAYS	39931	52.8%	255170	58.1%
	OTHER DELAYS	0	0.0%	38591	8.8%
MILD DEPEAKING	AIR DELAYS	29087	40.2%	130958	30.3%
	RUNWAY DELAYS	6627	9.2%	11970	2.8%
	TAXIWAY DELAYS	36702	50.7%	249528	57.8%
	OTHER DELAYS	0	0.0%	39187	9.1%
SHARP DEPEAKING	AIR DELAYS	25009	42.7%	121353	28.3%
	RUNWAY DELAYS	6129	10.5%	11751	2.7%
	TAXIWAY DELAYS	27388	46.8%	267105	60.9%
	OTHER DELAYS	0	0.0%	35687	8.1%

TABLE 21

PERCENTAGE BELOW NORMAL SCHEDULE DELAYS

CURRENT AIRPORT

SCHEDULE	TYPE	1988	2008
MILD DEPEAKING	AIR DELAYS	0.6%	-2.1%
	RUNWAY DELAYS	-1.8%	0.7%
	TAXIWAY DELAYS	-8.1%	-2.3%
	OTHER DELAYS	NA	1.5%
SHARP DEPEAKING	AIR DELAYS	-13.5%	-7.0%
	RUNWAY DELAYS	-9.2%	-1.1%
	TAXIWAY DELAYS	-31.4%	4.6%
	OTHER DELAYS	NA	-7.5%

TABLE 22

COMPARISON OF NET PRESENT VALUE FOR STRATEGY A UNDER NORMAL AND DEPEAKED AIRLINE SCHEDULE 1988-2020 (in Millions of Dollars)

	DIRECT COSTS		DIRECT COSTS & SAFETY ZONES	
	All Benefits	Aircraft Benefits	All Benefits	Aircraft Benefits
STRATEGY A: NORMAL SCHEDULE	3,229	956	2,708	431
STRATEGY A: SHARPLY DEPEAKED SCHEDULE	3,073	899	2,551	375

FIGURE 10

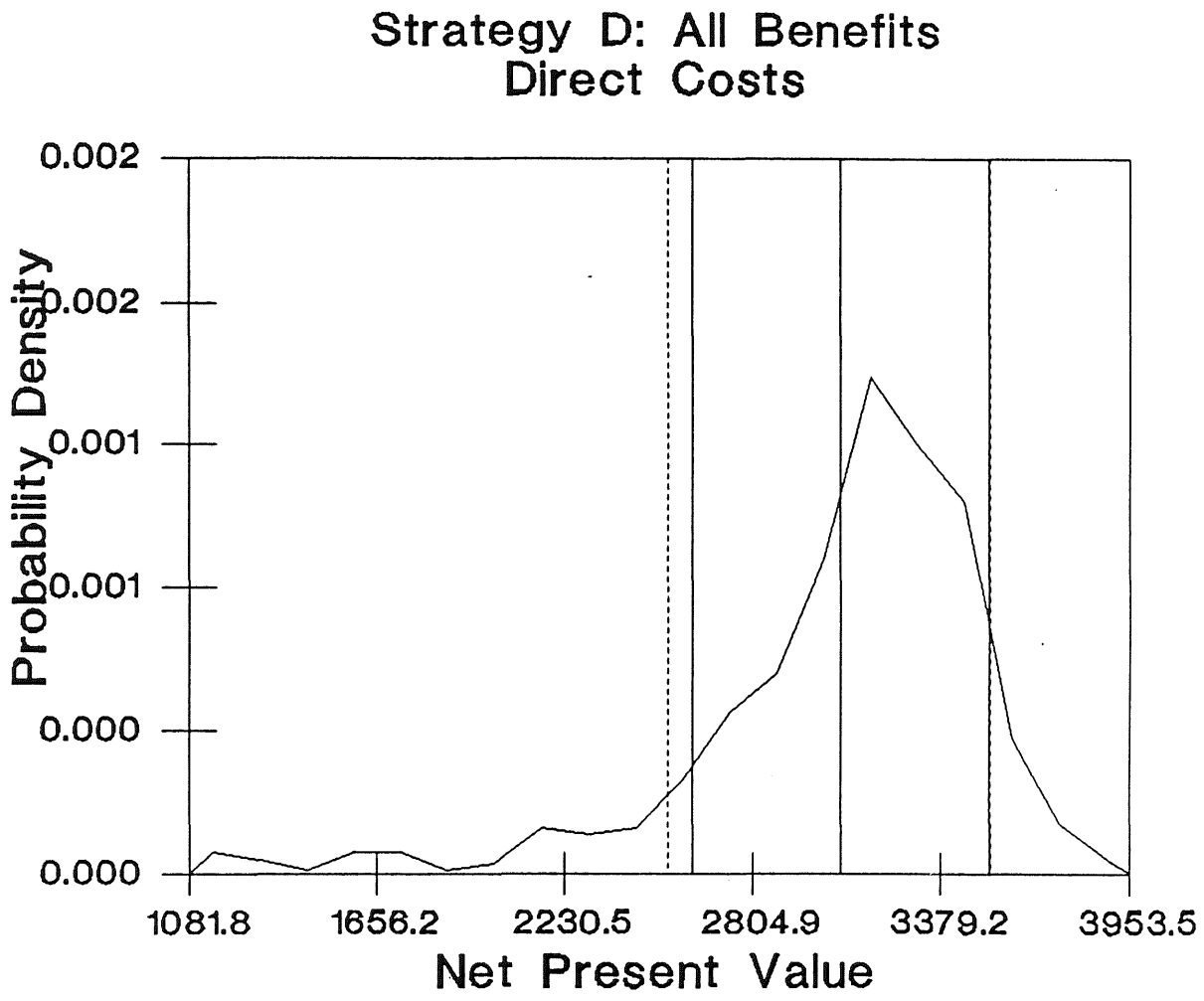
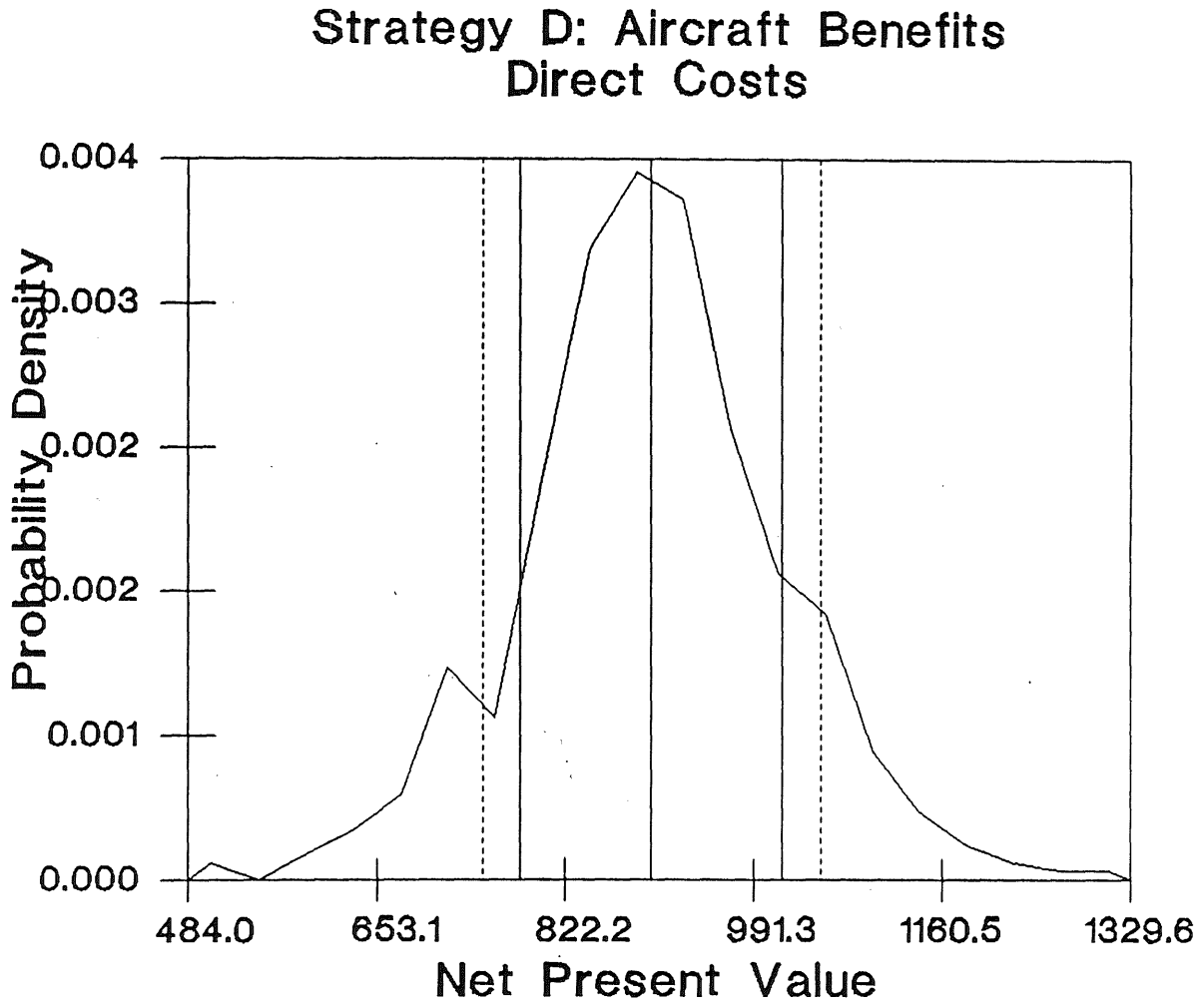

Strategy D: All Benefits
Direct Costs
0.002
0.002
0.001
0.001
0.000
0.000
Probability Density
1081.8
1656.2
2230.5
2804.9
3379.2
3953.5
Net Present Value

FIGURE 11


Strategy D: Aircraft Benefits
Direct Costs
Probability Density
0.004
0.003
0.002
0.002
0.001
0.000
484.0
653.1
822.2
991.3
1160.5
1329.6
Net Present Value

APPENDIX A

TABLE A1

	CURRENT AIRPORT	
YEAR	TOTAL CAPITAL IMPROVMENTS ($M)	TOTAL O&M ($M)
1988	$115.3	$53.7
1989	$68.5	$55.6
1990	$20.3	$56.1
1991	$7.5	$56.3
1992	$7.4	$56.5
1993	$14.3	$56.9
1994	$18.4	$57.4
1995	$13.6	$57.8
1996	$13.6	$58.1
1997	$13.6	$58.5
1998	$13.6	$58.9
1999	$14.4	$59.2
2000	$14.4	$59.6
2001	$14.4	$59.6
2002	$14.4	$60.0
2003	$14.4	$60.4
2004	$14.4	$60.8
2005	$14.4	$61.2
2006	$14.4	$61.6
2007	$9.5	$61.8
2008	$115.3	$61.8
2009	$68.5	$61.8
2010	$20.3	$61.8
2011	$7.5	$61.8
2012	$7.4	$61.8
2013	$14.3	$61.8
2014	$13.6	$61.8
2015	$13.6	$61.8
2016	$13.6	$61.8
2017	$13.6	$61.8
2018	$13.6	$61.8
2019	$13.6	$61.8
2020	$13.6	$61.8

TABLE A2

STRATEGY A

	PROPERTY ACQUISITION														
YEAR	NAT. GUARD	AIR FORCE	WEST RESID'L	OTHER	TOTAL LAND ACQ.	CLEAR ZONE (FAA)	SAFETY ZONE A	SAFETY ZONE B	TOTAL SAFETY ZONES	AIR FIELD DEV	TERM. FACIL.	DIRECT CAP. COSTS	INDIR. CAP. COSTS	ALL CAP. COSTS	INCREM OPER. COSTS
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	30	0	30	0	42.3	22.2	64.5	0	0	94.5	221.7	316.2	0.0
1994	0	0	10	0	10	0	84.6	44.4	129	0	48	187	443.4	630.4	0.0
1995	0	0	0	0	0	0	42.3	22.2	64.5	17.2	96	177.7	221.7	399.4	0.0
1996	0	0	0	0	0	0	0	0	0	17.2	48	65.2	0	65.2	0.0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9

TABLE A3

STRATEGY B

YEAR	PROPERTY ACQUISITION															
	NAT. GUARD	AIR FORCE	WEST RESID'L	OTHER	TOTAL LAND ACQ.	CLEAR ZONE (FAA)	SAFETY ZONE A	SAFETY ZONE B	TOTAL SAFETY ZONES	AIR FIELD DEV	TERM. FACIL.	HOV LANES	DIRECT CAP. COSTS	INDIR. CAP. COSTS	ALL CAP. COSTS	INCREM OPER. COSTS
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	30	0	30	0	42.3	22.2	64.5	0	0	0	94.5	221.7	316.2	0.0
1994	0	0	10	0	10	0	84.6	44.4	129	0	48	0	187	443.4	630.4	0.0
1995	0	0	0	0	0	0	42.3	22.2	64.5	17.2	96	0	177.7	221.7	399.4	0.0
1996	0	0	0	0	0	0	0	0	0	17.2	48	0	65.2	0	65.2	0.0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2003	185	128.3	0	75	388.3	56.3	65	62.3	127.3	0	0	0	0	0	0	22.9
2004	20.6	14.3	0	0	34.9	18.8	21.6	20.8	42.4	0	24	0	120.1	0	120.1	22.9
2005	0	0	0	0	0	0	0	0	0	14.5	48	9.2	71.7	0	71.7	22.9
2006	0	0	0	0	0	0	0	0	0	14.5	24	9.2	47.7	0	47.7	22.9
2007	0	0	0	0	0	0	0	0	0	0	0	9.2	9.2	0	9.2	22.9
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.3

TABLE A4

STRATEGY C1

	PROPERTY ACQUISITION														
YEAR	NAT. GUARD	AIR FORCE	WEST RESID'L	OTHER	TOTAL LAND ACQ.	CLEAR ZONE (FAA)	SAFETY ZONE A	SAFETY ZONE B	TOTAL SAFETY ZONES	AIR FIELD DEV	TERM. FACIL.	DIRECT CAP. COSTS	INDIR. CAP. COSTS	ALL CAP. COSTS	INCREM OPER. COSTS
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	30	0	30	0	42.3	22.2	64.5	0	0	94.5	221.7	316.2	0.0
1994	0	0	10	0	10	0	84.6	44.4	129	0	48	187	443.4	630.4	0.0
1995	0	0	0	0	0	0	42.3	22.2	64.5	17.2	96	177.7	221.7	399.4	0.0
1996	0	0	0	0	24.5	0	0	0	0	17.2	48	89.7	0	89.7	0.0
1997	0	0	0	0	24.5	0	0	0	0	0	0	24.5	0	24.5	22.9
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2001	0	0	0	0	185.9	0	0	0	0	10	40	235.9	0	235.9	22.9
2002	0	0	0	0	185.9	0	0	0	0	30	75	290.9	0	290.9	22.9
2003	0	0	0	0	0	0	0	0	0	50	150	200	0	200	22.9
2004	0	0	0	0	0	0	0	0	0	13.8	100	113.8	0	113.8	22.9
2005	0	0	0	0	0	0	0	0	0	31.3	80.5	111.8	0	111.8	22.9
2006	0	0	0	0	0	0	0	0	0	60	70	130	0	130	22.9
2007	0	0	0	0	0	0	0	0	0	31.3	29.9	61.2	0	61.2	22.9
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1

TABLE A5

STRATEGY C2

	PROPERTY ACQUISITION														
YEAR	NAT. GUARD	AIR FORCE	WEST RESID'L	OTHER	TOTAL LAND ACQ.	CLEAR ZONE (FAA)	SAFETY ZONE A	SAFETY ZONE B	TOTAL SAFETY ZONES	AIR FIELD DEV	TERM. FACIL.	DIRECT CAP. COSTS	INDIR. CAP. COSTS	ALL CAP. COSTS	INCREM OPER. COSTS
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
1993	0	0	30	0	30	0	42.3	22.2	64.5	0	0	94.5	221.7	316.2	0.0
1994	0	0	10	0	10	0	84.6	44.4	129	0	48	187	443.4	630.4	0.0
1995	0	0	0	0	0	0	42.3	22.2	64.5	17.2	96	177.7	221.7	399.4	0.0
1996	0	0	0	0	0	0	0	0	0	17.2	48	65.2	0	65.2	0.0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2003	0	0	0	0	24.5	0	0	0	0	0	0	24.5	0	24.5	22.9
2004	0	0	0	0	24.5	0	0	0	0	0	0	24.5	0	24.5	22.9
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.9
2008	0	0	0	0	185.9	0	0	0	0	10	40	235.9	0	235.9	22.9
2009	0	0	0	0	185.9	0	0	0	0	30	75	290.9	0	290.9	22.9
2010	0	0	0	0	0	0	0	0	0	50	150	200	0	200	22.9
2011	0	0	0	0	0	0	0	0	0	13.8	100	113.8	0	113.8	22.9
2012	0	0	0	0	0	0	0	0	0	31.3	80.5	111.8	0	111.8	22.9
2013	0	0	0	0	0	0	0	0	0	60	70	130	0	130	22.9
2014	0	0	0	0	0	0	0	0	0	31.3	29.9	61.2	0	61.2	22.9
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211.1

APPENDIX B

TABLE B1

MSP DELAY SUMMARIES

	AIRCRAFT DELAY IN HOURS PER YEAR				AIRCRAFT DELAY SAVINGS				
YEAR	CURRENT AIRPORT *	STATEGY A	STATEGY B	STATEGY C1	OPTION A	OPTION B	OPTION C1	OPTION C2	OPTION C3
1988	75577	75577	75577	75577	0	0	0	0	0
1989	89705	89705	89705	89705	0	0	0	0	0
1990	103833	103833	103833	103833	0	0	0	0	0
1991	117961	117961	117961	117961	0	0	0	0	0
1992	132089	132089	132089	132089	0	0	0	0	0
1993	146218	146218	146218	146218	0	0	0	0	0
1994	160346	160346	160346	160346	0	0	0	0	0
1995	174474	174474	174474	174474	0	0	0	0	0
1996	188602	188602	188602	188602	0	0	0	0	0
1997	202730	57008	57008	57008	145722	145722	145722	145722	0
1998	216858	61591	61591	61591	155267	155267	155267	155267	0
1999	239145	66174	66174	66174	172971	172971	172971	172971	227188
2000	261433	70757	70757	70757	190676	190676	190676	190676	248361
2001	283720	75340	75340	75340	208380	208380	208380	208380	269534
2002	306007	79923	79923	79923	226085	226085	226085	226085	290707
2003	328295	84506	84506	84506	243789	243789	243789	243789	311880
2004	350582	89088	89088	89088	261493	261493	261493	261493	333053
2005	372869	93671	93671	93671	279198	279198	279198	279198	354226
2006	395156	98254	98254	98254	296902	296902	296902	296902	375399
2007	417444	102837	102837	102837	314607	314607	314607	314607	396572
2008	439731	107420	93875	21987	332311	345856	417744	332311	417744
2009	520899	151428	122586	26045	369471	398513	494854	369471	494854
2010	602068	195436	150897	30103	406632	451171	571964	406632	571964
2011	683236	239444	179408	34162	443792	503829	649074	443792	649074
2012	764405	283452	207918	38220	480953	556486	726184	480953	726184
2013	845573	327460	236429	42279	518113	609144	803294	518113	803294
2014	926742	371468	264940	46337	555273	661802	880405	555273	880405
2015	1007910	415476	293450	50396	592434	714460	957515	957515	957515
2016	1089078	459484	321961	54454	629594	767117	1034625	1034625	1034625
2017	1170247	503492	350472	58512	666755	819775	1111735	1111735	1111735
2018	1251415	547500	378983	62571	703915	872433	1188845	1188845	1188845
2019	1332584	591508	407493	66629	741076	925090	1265955	1265955	1265955
2020	1413752	635516	436004	70688	778236	977748	1343065	1343065	1343065

* INCLUDES CURRENT CAPITAL IMPROVEMENTS PROGRAM

TABLE B2

AVERAGE DELAY PER OPERATION

YEAR	CURRENT ARRT *	OPTION A	OPTION B	OPTION C1
1988	14.10	14.10	14.10	14.10
1989	16.15	16.15	16.15	16.15
1990	18.07	18.07	18.07	18.07
1991	19.85	19.85	19.85	19.85
1992	21.53	21.53	21.53	21.53
1993	23.10	23.10	23.10	23.10
1994	24.58	24.58	24.58	24.58
1995	25.98	25.98	25.98	25.98
1996	27.29	27.29	27.29	27.29
1997	28.54	8.02	8.02	8.02
1998	29.72	8.44	8.44	8.44
1999	32.14	8.89	8.89	8.89
2000	34.48	9.33	9.33	9.33
2001	36.73	9.75	9.75	9.75
2002	38.89	10.16	10.16	10.16
2003	40.99	10.55	10.55	10.55
2004	43.00	10.93	10.93	10.93
2005	44.95	11.29	11.29	11.29
2006	46.83	11.64	11.64	11.64
2007	48.65	11.99	11.99	11.99
2008	50.41	12.32	10.76	2.52
2009	57.95	16.85	13.62	2.90
2010	65.06	21.12	16.31	3.25
2011	71.77	25.15	18.85	3.59
2012	78.11	28.97	21.25	3.91
2013	84.12	32.58	23.52	4.21
2014	89.82	36.00	25.68	4.49
2015	95.24	39.26	27.73	4.76
2016	100.38	42.35	29.68	5.02
2017	105.29	45.30	31.53	5.26
2018	109.96	48.11	33.30	5.50
2019	114.42	50.79	34.99	5.72
2020	118.68	53.35	36.60	5.93

APPENDIX C

EXAMPLE OF ADSIM OUTPUT

88BCEV

AVERAGE FLOW RATES

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	AVERAGE TRAVEL TIMES FIX TO THRESH	THRESH TO GATE	GATE TO ROLL
100	3.0	.0	.0	.0	.0	.0	3.0	3.0	.0	.0	1.0	.0	.0	.0	.0	1.0	2.0	-1.0	10.13	.87	.03
100- 200	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.0	1.0	.0	.0	.0	.0	2.0	1.0	.0	.00	.00	.03
200- 300	1.7	.0	.0	.0	.0	.0	1.7	1.7	.0	1.0	1.0	.0	.0	.0	.0	2.0	2.0	.0	10.00	.89	.03
300- 400	1.3	2.0	.0	.0	.0	.0	3.3	3.3	.0	1.0	2.0	.0	.0	.0	.0	3.0	3.0	.0	10.00	.91	.03
400- 500	2.0	.0	.0	.0	.0	.0	2.0	2.0	.0	2.0	2.0	.0	.0	.0	.0	4.0	4.0	.0	10.36	.87	.03
500- 600	1.7	4.0	.0	.0	.0	.0	5.7	6.3	-.7	3.0	2.7	.0	.0	.0	.0	5.7	6.0	-.3	10.09	.86	.03
600- 700	8.0	7.7	.0	.0	.0	.0	15.7	15.7	-.7	10.0	4.3	.0	.0	.0	.0	14.3	19.0	-5.0	10.27	.92	.39
700- 800	23.7	15.7	.0	.0	.0	.0	39.3	41.0	-2.3	19.0	11.0	.0	.0	.0	.0	30.0	32.0	-7.0	11.56	.91	2.56
800- 900	38.3	12.3	.0	.0	.0	.0	50.7	54.7	-6.3	18.0	6.7	.0	.0	.0	.0	24.7	41.0	-23.3	19.89	.90	13.41
900-1000	14.3	9.0	.0	.0	.0	.0	23.3	17.7	-.7	41.7	31.3	.0	.0	.0	.0	73.0	58.0	-8.3	15.41	.91	11.90
1000-1100	14.0	3.7	.0	.0	.0	.0	17.7	18.3	-1.3	20.3	5.0	.0	.0	.0	.0	25.3	20.0	-3.0	10.31	.93	22.64
1100-1200	37.7	14.0	.0	.0	.0	.0	51.7	54.3	-4.0	14.0	12.3	.0	.0	.0	.0	26.3	39.0	-15.7	18.21	.90	2.65
1200-1300	32.7	23.0	.0	.0	.0	.0	55.7	52.3	-.7	22.7	12.7	.0	.0	.0	.0	35.3	36.0	-16.3	13.81	.91	19.62
1300-1400	22.0	9.7	.0	.0	.0	.0	31.7	31.3	-.3	35.7	11.0	.0	.0	.0	.0	46.7	56.0	-25.7	10.73	.92	14.02
1400-1500	14.0	7.0	.0	.0	.0	.0	21.0	20.7	.0	41.7	16.0	.0	.0	.0	.0	57.7	40.0	-8.0	10.32	.89	27.37
1500-1600	15.0	7.0	.0	.0	.0	.0	22.0	22.7	-.7	16.0	8.7	.0	.0	.0	.0	24.7	19.0	-2.3	10.68	.87	16.90
1600-1700	33.0	24.7	.0	.0	.0	.0	57.7	69.7	-12.7	13.7	7.3	.0	.0	.0	.0	21.0	24.0	-5.3	14.73	.94	2.30
1700-1800	28.3	12.3	.0	.0	.0	.0	40.7	36.3	-8.3	27.3	10.0	.0	.0	.0	.0	37.3	55.0	-23.0	15.83	.92	7.20
1800-1900	37.0	10.3	.0	.0	.0	.0	47.3	39.7	-.7	19.3	11.0	.0	.0	.0	.0	30.3	44.0	-36.7	24.02	.92	17.70
1900-2000	17.3	13.3	.0	.0	.0	.0	30.7	30.3	-.3	41.0	17.7	.0	.0	.0	.0	58.7	33.0	-11.0	10.63	.91	28.62

AVERAGE DELAYS

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI IN	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI OUT	RWY CNG	GRAND TOTAL AVERAGE DELAYS ARR DELAY	DEP DELAY
100	.1	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0
100- 200	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
200- 300	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
300- 400	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
400- 500	.4	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.4	.0
500- 600	.0	.1	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0
600- 700	.2	.3	.0	.0	.0	.0	.3	.0	.0	.5	.1	.0	.0	.0	.0	.4	.0	.0	.0	.3	.4
700- 800	1.7	1.3	.0	.0	.0	.0	1.6	.0	.0	2.3	1.2	.0	.0	.0	.0	1.9	.0	.6	.0	1.6	2.5
800- 900	13.0	.3	.0	.0	.0	.0	9.9	.0	.0	6.6	.4	.0	.0	.0	.0	4.9	.0	8.5	.0	9.9	13.4
900-1000	8.5	.3	.0	.0	.0	.0	5.4	.0	.0	2.9	1.3	.0	.0	.0	.0	2.2	.0	9.7	.0	5.4	11.9
1000-1100	.4	.1	.0	.0	.0	.0	.3	.0	.0	1.6	.0	.0	.0	.0	.0	1.3	.0	21.3	.0	.3	22.6
1100-1200	11.1	.5	.0	.0	.0	.0	8.2	.0	.0	3.3	.5	.0	.0	.0	.0	2.0	.0	.6	.0	8.2	2.6
1200-1300	4.6	2.5	.0	.0	.0	.0	3.8	.0	.0	5.5	3.3	.0	.0	.0	.0	4.7	.0	14.9	.0	3.8	19.6
1300-1400	1.0	.2	.0	.0	.0	.0	.7	.0	.0	3.4	.5	.0	.0	.0	.0	2.7	.0	11.3	.0	.7	14.0
1400-1500	.4	.2	.0	.0	.0	.0	.3	.0	.0	2.8	.2	.0	.0	.0	.0	2.1	.0	25.3	.0	.3	27.3
1500-1600	.8	.3	.0	.0	.0	.0	.7	.0	.0	1.6	.2	.0	.0	.0	.0	1.1	.0	15.8	.0	.7	16.9
1600-1700	4.8	4.7	.0	.0	.0	.0	4.7	.0	.0	2.0	1.8	.0	.0	.0	.0	2.0	.0	.3	.0	4.7	2.3
1700-1800	7.1	2.8	.0	.0	.0	.0	5.8	.0	.0	4.5	1.2	.0	.0	.0	.0	3.6	.0	3.6	.0	5.8	7.2
1800-1900	17.9	.2	.0	.0	.0	.0	14.0	.0	.0	6.5	.5	.0	.0	.0	.0	4.3	.0	13.4	.0	14.0	17.7
1900-2000	.6	.7	.0	.0	.0	.0	.6	.0	.0	2.9	1.9	.0	.0	.0	.0	2.6	.0	26.0	.0	.6	28.6

CONTINUED

AVERAGE FLOW RATES

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	AVERAGE TRAVEL TIMES FIX TO THRESH	THRESH TO GATE	GATE TO ROLL
2000-2100	27.3	13.0	.0	.0	.0	.0	40.3	41.7	-1.7	20.3	4.3	.0	.0	.0	.0	24.7	18.0	-4.3	10.84	.92	46.46
2100-2200	11.7	7.0	.0	.0	.0	.0	18.7	17.0	.0	23.3	12.0	.0	.0	.0	.0	35.3	31.0	.0	10.59	.92	3.40
2200-2300	9.7	3.0	.0	.0	.0	.0	12.7	17.7	-.7	7.0	7.0	.0	.0	.0	.0	14.0	11.0	1.0	10.21	.91	21.71

88BCEV

AVERAGE DELAYS

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DEPARTURES RWY CRS	TAXI IN	RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI OUT	RWY CNG	GRAND TOTAL AVERAGE DELAYS ARR DELAY	DEP DELAY
2000-2100	1.1	.3	.0	.0	.0	.0	.8	.0	.0	2.8	.5	.0	.0	.0	.0	2.4	.0	44.1	.0	.8	46.4
2100-2200	.8	.1	.0	.0	.0	.0	.6	.0	.0	2.6	1.3	.0	.0	.0	.0	2.2	.0	1.2	.0	.6	3.4
2200-2300	.3	.0	.0	.0	.0	.0	.2	.0	.0	.3	.0	.0	.0	.0	.0	.2	.0	.0	.0	.2	.2
2300-2400	.0	.4	.0	.0	.0	.0	.1	.0	.0	.2	.0	.0	.0	.0	.0	.2	.0	.0	.0	.1	.2
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

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TIME	ARRIVALS FLOW RATE	AIR DELAY	TAXI-IN DELAY	RWY-XNG DELAY	DEPARTURES FLOW RATE	RUNWAY DELAY	TAXI-OUT DELAY	RWY-XNG DELAY	ENRTE GTE-HLD	GTE-HLD RWY-CNG	TOTAL GROUND DELAYS	ARRIVAL AIR	TRAVEL TIMES ARRIVAL GROUND	DEPARTURE GROUND	TOTAL
0- 100	3.0	.4	.0	.0	1.0	.0	.0	.0	.0	.0	.0	30.4	2.6	.0	33.0
100- 200	.0	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1
200- 300	1.7	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	16.7	1.5	.1	18.2
300- 400	3.3	.0	.0	.0	3.0	.0	.0	.0	.0	.0	.0	33.3	3.0	.1	36.4
400- 500	2.0	.7	.0	.0	4.0	.0	.0	.0	.0	.0	.0	20.7	1.7	.1	22.6
500- 600	5.7	.6	.0	.0	5.7	.0	.0	.0	.0	.0	.0	57.2	4.9	.2	62.2
600- 700	15.7	4.3	.0	.0	14.3	5.1	.0	.0	.0	.0	5.1	160.9	14.4	5.6	180.9
700- 800	39.3	61.7	.0	.0	30.0	57.9	18.5	.0	.0	.0	76.5	454.7	35.9	76.8	567.4
800- 900	50.7	503.4	.0	.0	24.7	118.5	210.7	.0	.0	.0	329.1	1007.9	45.4	330.7	1384.0
900-1000	23.3	126.9	.0	.0	73.0	161.8	704.7	.0	.0	.0	866.6	359.6	21.2	868.8	1249.5
1000-1100	17.7	5.8	.0	.0	25.3	33.4	553.8	.0	.0	.0	587.2	182.2	16.4	573.7	772.3
1100-1200	51.7	424.9	.0	.0	26.3	53.1	15.4	.0	.0	.0	68.5	941.1	46.4	69.8	1057.2
1200-1300	55.7	213.1	.0	.0	35.3	163.2	524.8	.0	.0	.0	688.0	768.9	50.6	693.2	1512.7
1300-1400	31.7	23.2	.0	.0	46.7	125.4	525.7	.0	.0	.0	651.1	339.9	29.2	654.5	1023.6
1400-1500	21.0	6.8	.0	.0	57.7	119.5	1455.2	.0	.0	.0	1574.7	216.8	18.8	1578.4	1814.0
1500-1600	22.0	14.9	.0	.0	24.7	29.4	492.2	.0	.0	.0	521.6	235.0	19.2	416.9	671.1
1600-1700	57.7	270.5	.0	.0	21.0	42.4	5.9	.0	.0	.0	48.3	849.3	54.0	48.3	951.6
1700-1800	40.7	239.9	.0	.0	37.3	134.8	133.3	.0	.0	.0	268.2	643.9	37.2	268.7	949.9
1800-1900	47.3	663.2	.0	.0	30.3	130.5	409.4	.0	.0	.0	539.9	1136.9	43.5	536.9	1717.4
1900-2000	30.7	19.5	.0	.0	58.7	151.6	1520.5	.0	.0	.0	1672.1	325.9	28.0	1679.1	2033.0
2000-2100	40.3	33.8	.0	.0	24.7	59.1	1091.0	.0	.0	.0	1150.1	437.3	37.0	1146.1	1620.4
2100-2200	18.7	10.5	.0	.0	35.3	77.8	41.3	.0	.0	.0	119.1	197.6	17.2	120.2	335.1
2200-2300	12.7	2.7	.0	.0	10.0	1.8	.0	.0	.0	.0	1.8	129.3	11.5	2.1	142.8
2300-2400	5.7	1.0	.0	.0	3.0	.6	.0	.0	.0	.0	.6	57.5	5.0	.7	63.3
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	598.0	2627.9	.0	.0	596.0	1466.0	7702.5	.0	.0	.0	9168.5	8603.1	544.7	9071.1	18218.9

88BCEV2

AVERAGE FLOW RATES

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	AVERAGE TRAVEL TIMES FIX TO THRESH	THRESH TO GATE	GATE TO ROLL
0- 100	3.0	.0	.0	.0	.0	.0	3.0	3.0	.0	.0	1.0	.0	.0	.0	.0	1.0	2.0	-1.0	10.01	.93	.03
100- 200	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.0	1.0	.0	.0	.0	.0	2.0	1.0	.0	.00	.00	.03
200- 300	1.3	.0	.0	.0	.0	.0	1.3	1.3	.0	1.0	1.0	.0	.0	.0	.0	2.0	2.0	.0	10.00	.92	.03
300- 400	.7	2.0	.0	.0	.0	.0	2.7	3.0	-.3	1.0	2.0	.0	.0	.0	.0	3.0	3.0	.0	10.03	.89	.03
400- 500	3.0	.3	.0	.0	.0	.0	3.3	3.0	.0	2.0	2.0	.0	.0	.0	.0	4.0	4.0	.0	10.02	.85	.25
500- 600	1.3	4.3	.0	.0	.0	.0	5.7	6.0	-.3	3.0	2.7	.0	.0	.0	.0	5.7	6.0	-.3	10.00	.85	.06
600- 700	9.3	7.0	.0	.0	.0	.0	16.3	17.0	-1.0	10.0	4.3	.0	.0	.0	.0	14.3	19.0	-5.0	10.13	.93	.36
700- 800	22.7	15.3	.0	.0	.0	.0	38.0	37.7	-.7	18.3	11.0	.0	.0	.0	.0	29.3	32.0	-7.7	11.83	.90	2.60
800- 900	37.7	12.7	.0	.0	.0	.0	50.3	55.7	-6.0	19.7	7.0	.0	.0	.0	.0	26.7	41.0	-21.0	19.38	.90	12.19
900-1000	14.7	8.0	.0	.0	.0	.0	22.7	18.0	-1.3	43.3	31.0	.0	.0	.0	.0	74.3	58.0	-5.7	16.41	.91	11.48
1000-1100	15.0	4.7	.0	.0	.0	.0	19.7	20.0	-1.7	17.7	5.0	.0	.0	.0	.0	22.7	20.0	-3.0	10.49	.90	21.67
1100-1200	37.0	14.0	.0	.0	.0	.0	51.0	52.3	-3.0	12.7	12.7	.0	.0	.0	.0	25.3	39.0	-16.7	18.72	.91	1.81
1200-1300	32.7	22.7	.0	.0	.0	.0	55.3	52.3	.0	26.0	12.3	.0	.0	.0	.0	38.3	36.0	-14.3	15.29	.90	16.10
-1400	22.7	10.3	.0	.0	.0	.0	33.0	33.0	.0	36.7	11.0	.0	.0	.0	.0	47.7	56.0	-22.7	10.60	.90	12.67
1400-1500	14.0	6.7	.0	.0	.0	.0	20.7	20.7	.0	41.7	16.0	.0	.0	.0	.0	57.7	40.0	-5.0	10.30	.88	24.24
15 .600	15.0	7.7	.0	.0	.0	.0	22.7	23.0	-.3	13.0	9.0	.0	.0	.0	.0	22.0	19.0	-2.0	10.51	.89	9.40
1600-1700	30.0	24.0	.0	.0	.0	.0	54.0	66.7	-13.0	15.7	7.0	.0	.0	.0	.0	22.7	24.0	-3.3	14.41	.92	2.12
1700-1800	31.0	13.0	.0	.0	.0	.0	44.0	37.3	-6.3	24.3	10.0	.0	.0	.0	.0	34.3	55.0	-24.0	17.44	.94	5.91
1800-1900	36.0	9.0	.0	.0	.0	.0	45.0	40.3	-1.7	22.3	11.0	.0	.0	.0	.0	33.3	44.0	-34.7	25.74	.93	19.22
1900-2000	17.7	14.0	.0	.0	.0	.0	31.7	31.0	-1.0	39.7	17.3	.0	.0	.0	.0	57.0	33.0	-19.7	10.81	.90	31.17

AVERAGE DELAYS

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI IN	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI OUT	FWY ENG	GRAND TOTAL AVERAGE DELAYS ARR DELAY	DEP DELAY
0- 100	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
100- 200	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
200- 300	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
300- 400	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0	.0	.0
400- 500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0	.2	.0	.0	.0	.0	.2
500- 600	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	0	.0	.0
600- 700	.0	.2	.0	.0	.0	.0	.1	.0	.0	.4	.2	.0	.0	.0	.0	.3	.0	.0	.0	.1	.3
700- 800	1.9	1.9	.0	.0	.0	.0	1.9	.0	.0	1.8	2.2	.0	.0	.0	.0	1.9	.0	.6	.0	1.8	3.6
800- 900	12.3	.6	.0	.0	.0	.0	9.4	.0	.0	5.8	.2	.0	.0	.0	.0	4.3	.0	7.9	.0	9.4	12.2
900-1000	9.7	.4	.0	.0	.0	.0	6.4	.0	.0	2.9	1.2	.0	.0	.0	.0	2.2	.0	9.3	.0	6.4	11.4
1000-1100	.6	.1	.0	.0	.0	.0	.5	.0	.0	1.4	.1	.0	.0	.0	.0	1.1	.0	20.5	.0	.5	21.6
1100-1200	11.8	.6	.0	.0	.0	.0	8.7	.0	.0	2.6	.6	.0	.0	.0	.0	1.5	.0	.2	.0	8.7	1.3
1200-1300	6.5	3.6	.0	.0	.0	.0	5.3	.0	.0	5.0	3.3	.0	.0	.0	.0	4.4	.0	13.7	.0	5.3	18.1
-1400	.7	.3	.0	.0	.0	.0	.5	.0	.0	3.2	.5	.0	.0	.0	.0	2.5	.0	10.1	.0	.6	12.6
1400-1500	.3	.2	.0	.0	.0	.0	.3	.0	.0	2.8	.3	.0	.0	.0	.0	2.1	.0	22.1	.0	.3	24.2
150 00	.6	.3	.0	.0	.0	.0	.5	.0	.0	1.2	.4	.0	.0	.0	.0	.9	.0	8.5	.0	.5	9.4
1600-1700	6.0	2.6	.0	.0	.0	.0	4.4	.0	.0	2.3	1.0	.0	.0	.0	.0	1.9	.0	.2	.0	4.4	2.1
1700-1800	9.5	2.1	.0	.0	.0	.0	7.1	.0	.0	4.4	1.2	.0	.0	.0	.0	3.5	.0	2.4	.0	7.4	5.9
1800-1900	17.1	.4	.0	.0	.0	.0	13.7	.0	.0	5.7	.4	.0	.0	.0	.0	3.9	.0	15.3	.0	13.7	19.2
1900-2000	1.9	.5	.0	.0	.0	.0	.9	.0	.0	3.0	2.2	.0	.0	.0	.0	2.7	.0	28.4	.0	.9	31.1

MINNEAPOLIS-ST.PAUL AIRPORT - BASE CASE, 1988, EAST FLOW, VFR - RUN 2

AVERAGE FLOW RATES

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	AVERAGE TRAVEL TIMES FIX TO THRESH	THRESH TO GATE	GATE TO ROLL
2000-2100	26.3	12.7	.0	.0	.0	.0	39.0	39.7	-1.7	21.3	4.7	.0	.0	.0	.0	26.0	18.0	-2.7	10.62	.89	62.10
2100-2200	13.0	7.7	.0	.0	.0	.0	20.7	19.7	-.7	21.7	12.0	.0	.0	.0	.0	33.7	31.0	.0	10.57	.91	2.34
2200-2300	8.7	3.3	.0	.0	.0	.0	12.0	11.3	.0	7.0	3.0	.0	.0	.0	.0	10.0	11.0	-2.0	10.45	.87	.25
2300-2400	4.3	1.7	.0	.0	.0	.0	6.0	6.0	.0	3.0	.0	.0	.0	.0	.0	3.0	2.0	.0	10.10	.91	.14
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.00	.00	.00

AVERAGE DELAYS

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI IN	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI OUT	RWY CNG	GRAND TOTAL AVERAGE DELAYS ARR DELAY	DEP DELAY
2000-2100	.7	.5	.0	.0	.0	.0	.6	.0	.0	2.9	.3	.0	.0	.0	.0	2.4	.0	29.6	.0	.6	32.1
2100-2200	.8	.1	.0	.0	.0	.0	.6	.0	.0	1.8	1.2	.0	.0	.0	.0	1.6	.0	.7	.0	.6	2.3
2200-2300	.6	.2	.0	.0	.0	.0	.4	.0	.0	.3	.0	.0	.0	.0	.0	.2	.0	.0	.0	.4	.2
2300-2400	.1	.0	.0	.0	.0	.0	.1	.0	.0	.1	.0	.0	.0	.0	.0	.1	.0	.0	.0	.1	.1
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

TIME	ARRIVALS FLOW RATE	AIR DELAY	TAXI-IN DELAY	RWY-XNG DELAY	DEPARTURES FLOW RATE	RUNWAY DELAY	TAXI-OUT DELAY	RWY-XNG DELAY	ENRTE GTE-HLD	TOTAL GTE-HLD RWY-CNG	GROUND DELAYS	TRAVEL TIMES ARRIVAL AIR	ARRIVAL GROUND	DEPARTURE GROUND	TOTAL
0- 100	3.0	.0	.0	.0	1.0	.0	.0	.0	.0	.0	.0	30.0	2.5	.0	32.6
100- 200	.0	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1
200- 300	1.3	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	13.3	1.2	.1	14.6
300- 400	2.7	.1	.0	.0	3.0	.0	.0	.0	.0	.0	.0	26.8	2.4	.1	29.2
400- 500	3.3	.1	.0	.0	4.0	.9	.0	.0	.0	.0	.9	33.4	2.8	1.0	37.2
500- 600	5.7	.0	.0	.0	5.7	.1	.0	.0	.0	.0	.2	56.7	4.8	.3	61.8
600- 700	16.3	2.2	.0	.0	14.3	4.6	.0	.0	.0	.0	4.6	165.5	15.2	5.1	185.8
700- 800	38.0	69.5	.0	.0	29.3	56.3	19.1	.0	.0	.0	75.4	449.4	34.3	76.1	559.9
800- 900	50.3	471.9	.0	.0	26.7	113.9	210.9	.0	.0	.0	324.8	975.3	45.2	325.0	1345.5
900-1000	22.7	146.3	.0	.0	74.3	162.3	693.3	.0	.0	.0	855.6	372.0	20.6	853.3	1245.8
1000-1100	19.7	9.4	.0	.0	22.7	26.1	475.9	.0	.0	.0	502.0	206.2	17.8	491.2	715.2
1100-1200	51.0	444.2	.0	.0	25.3	41.0	4.8	.0	.0	.0	45.7	954.7	46.2	46.0	1046.9
1200-1300	55.3	293.7	.0	.0	38.3	167.3	530.4	.0	.0	.0	697.7	845.8	50.0	693.9	1589.7
1300-1400	33.0	19.9	.0	.0	47.7	122.8	477.2	.0	.0	.0	599.9	349.8	29.8	603.8	983.4
1400-1500	20.7	6.1	.0	.0	57.7	121.6	1281.4	.0	.0	.0	1403.0	212.8	18.1	1397.8	1628.7
1500-1600	22.7	11.8	.0	.0	22.0	18.9	221.1	.0	.0	.0	240.0	238.3	20.2	206.9	465.4
1600-1700	54.0	238.4	.0	.0	22.7	43.4	3.8	.0	.0	.0	47.2	778.3	49.6	47.9	875.9
1700-1800	44.0	326.9	.0	.0	34.3	119.0	83.4	.0	.0	.0	202.4	767.4	41.4	202.9	1011.7
1800-1900	45.0	619.2	.0	.0	33.3	129.5	509.7	.0	.0	.0	639.3	1068.3	42.0	641.1	1751.5
1900-2000	31.7	27.4	.0	.0	57.0	156.2	1616.4	.0	.0	.0	1772.5	343.9	28.5	1776.6	2149.0
2000-2100	39.0	24.4	.0	.0	26.0	63.5	766.7	.0	.0	.0	830.2	414.3	34.8	834.5	1283.7
2100-2200	20.7	12.0	.0	.0	33.7	53.4	24.3	.0	.0	.0	77.7	218.5	18.8	78.8	316.0
2200-2300	12.0	5.4	.0	.0	10.0	2.2	.0	.0	.0	.0	2.2	125.4	10.5	2.5	138.4
2300-2400	6.0	.6	.0	.0	3.0	.3	.0	.0	.0	.0	.3	60.6	5.5	.4	66.5
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	598.0	2729.5	.0	.0	596.0	1403.6	6918.2	.0	.0	.0	8321.8	8706.7	542.2	8285.4	17534.3

DEPEAKING

88BCEVD

AVERAGE FLOW RATES

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	AVERAGE TRAVEL TIMES FIX TO THRESH	THRESH TO GATE	GATE TO ROLL
100	3.0	.0	.0	.0	.0	.0	3.0	3.0	.0	.0	1.0	.0	.0	.0	.0	1.0	2.0	-1.0	10.13	.87	.03
200	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.0	1.0	.0	.0	.0	.0	2.0	1.0	.0	.00	.00	.03
200- 300	1.7	.0	.0	.0	.0	.0	1.7	1.7	.0	1.0	1.0	.0	.0	.0	.0	2.0	2.0	.0	10.00	.89	.03
300- 400	1.3	2.0	.0	.0	.0	.0	3.3	3.3	.0	1.0	2.0	.0	.0	.0	.0	3.0	3.0	.0	10.00	.91	.03
400- 500	2.0	.0	.0	.0	.0	.0	2.0	2.0	.0	2.0	2.0	.0	.0	.0	.0	4.0	4.0	.0	10.36	.87	.03
500- 600	1.7	4.0	.0	.0	.0	.0	5.7	6.3	-.7	3.0	2.7	.0	.0	.0	.0	5.7	6.0	-.3	10.09	.86	.03
600- 700	8.0	7.7	.0	.0	.0	.0	15.7	15.7	-.7	10.0	4.3	.0	.0	.0	.0	14.3	19.0	-5.0	10.27	.92	.39
700- 800	23.3	15.7	.0	.0	.0	.0	39.0	40.7	-2.3	19.3	11.0	.0	.0	.0	.0	30.3	29.0	-3.7	11.55	.91	2.54
800- 900	36.0	12.0	.0	.0	.0	.0	48.0	54.3	-8.7	21.3	6.3	.0	.0	.0	.0	27.7	44.0	-20.0	16.51	.91	10.44
900-1000	17.0	9.3	.0	.0	.0	.0	26.3	18.3	-.7	40.3	31.7	.0	.0	.0	.0	72.0	58.0	-6.0	16.42	.90	11.77
1000-1100	13.7	3.7	.0	.0	.0	.0	17.3	18.3	-1.7	18.0	5.0	.0	.0	.0	.0	23.0	20.0	-3.0	10.34	.88	9.63
1100-1200	37.0	14.0	.0	.0	.0	.0	51.0	54.3	-5.0	13.3	12.3	.0	.0	.0	.0	25.7	39.0	-16.3	18.87	.90	1.64
1200-1300	33.7	22.3	.0	.0	.0	.0	56.0	51.0	.0	23.3	12.7	.0	.0	.0	.0	36.0	27.0	-7.3	15.17	.92	18.95
1300-1400	21.0	10.3	.0	.0	.0	.0	31.3	31.7	-.3	35.0	11.0	.0	.0	.0	.0	46.0	65.0	-26.3	10.76	.90	10.20
1400-1500	15.0	7.0	.0	.0	.0	.0	22.0	21.7	.0	41.7	16.0	.0	.0	.0	.0	57.7	40.0	-8.7	10.50	.88	20.92
1500-1600	15.0	7.0	.0	.0	.0	.0	22.0	22.7	-.7	16.7	9.0	.0	.0	.0	.0	25.7	19.0	-2.0	10.60	.89	19.99
1600-1700	33.3	24.0	.0	.0	.0	.0	57.3	69.3	-12.7	13.7	7.0	.0	.0	.0	.0	20.7	22.0	-3.3	14.94	.94	2.38
1700-1800	31.0	13.3	.0	.0	.0	.0	44.3	37.3	-5.7	25.7	10.0	.0	.0	.0	.0	35.7	57.0	-24.7	16.25	.93	7.87
1800-1900	34.3	10.0	.0	.0	.0	.0	44.3	39.0	-.3	24.0	10.7	.0	.0	.0	.0	34.7	44.0	-34.0	21.24	.92	20.80
1900-2000	17.0	13.3	.0	.0	.0	.0	30.3	30.3	-.3	41.0	18.0	.0	.0	.0	.0	59.0	33.0	-8.0	10.55	.90	28.18

AVERAGE DELAYS

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI IN	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI OUT	RWY CNG	GRAND TOTAL AVERAGE DELAYS ARR DELAY	DEP DELAY
100	.1	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0
200	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
200- 300	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
300- 400	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
400- 500	.4	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.4	.0
500- 600	.0	.1	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0
600- 700	.2	.3	.0	.0	.0	.0	.3	.0	.0	.5	.1	.0	.0	.0	.0	.4	.0	.0	.0	.3	.4
700- 800	1.7	1.3	.0	.0	.0	.0	1.6	.0	.0	2.3	1.2	.0	.0	.0	.0	1.9	.0	.6	.0	1.6	2.5
800- 900	8.6	.2	.0	.0	.0	.0	6.5	.0	.0	5.3	.5	.0	.0	.0	.0	4.1	.0	6.3	.0	6.5	10.4
900-1000	9.8	.3	.0	.0	.0	.0	6.4	.0	.0	3.1	1.3	.0	.0	.0	.0	2.3	.0	9.5	.0	6.4	11.7
1000-1100	.4	.1	.0	.0	.0	.0	.3	.0	.0	1.3	.0	.0	.0	.0	.0	1.0	.0	8.6	.0	.3	9.6
1100-1200	12.1	.5	.0	.0	.0	.0	8.9	.0	.0	2.6	.3	.0	.0	.0	.0	1.5	.0	.1	.0	8.9	1.6
1200-1300	6.7	2.7	.0	.0	.0	.0	5.2	.0	.0	5.5	3.7	.0	.0	.0	.0	4.8	.0	14.1	.0	5.2	18.9
1300-1400	.9	.4	.0	.0	.0	.0	.8	.0	.0	3.3	.3	.0	.0	.0	.0	2.6	.0	7.6	.0	.8	10.2
1400-1500	.6	.3	.0	.0	.0	.0	.5	.0	.0	2.9	.2	.0	.0	.0	.0	2.1	.0	18.8	.0	.5	20.9
1500-1600	.7	.3	.0	.0	.0	.0	.6	.0	.0	1.5	.2	.0	.0	.0	.0	1.1	.0	18.9	.0	.6	20.0
1600-1700	4.7	5.4	.0	.0	.0	.0	4.9	.0	.0	2.7	1.1	.0	.0	.0	.0	2.2	.0	.2	.0	4.9	2.4
1700-1800	7.1	4.0	.0	.0	.0	.0	6.3	.0	.0	4.7	.4	.0	.0	.0	.0	3.4	.0	4.4	.0	6.3	7.8
1800-1900	14.5	.2	.0	.0	.0	.0	11.2	.0	.0	5.2	.4	.0	.0	.0	.0	3.8	.0	17.0	.0	11.2	20.8
1900-2000	.4	.7	.0	.0	.0	.0	.5	.0	.0	2.9	2.0	.0	.0	.0	.0	2.6	.0	25.6	.0	.5	28.2

CONTINUED

AVERAGE FLOW RATES

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	DE-MAND	DIF	AVERAGE TRAVEL TIMES FIX TO THRESH	THRESH TO GATE	GATE TO ROLL
2000-2100	27.0	13.0	.0	.0	.0	.0	40.0	41.7	-2.0	18.7	4.3	.0	.0	.0	.0	23.0	18.0	-3.0	10.92	.92	41.74
2100-2200	12.0	7.0	.0	.0	.0	.0	19.0	17.0	.0	22.0	12.0	.0	.0	.0	.0	34.0	31.0	.0	10.56	.91	2.80
2200-2300	9.7	3.3	.0	.0	.0	.0	13.0	13.3	-.3	7.0	3.0	.0	.0	.0	.0	10.0	11.0	-1.0	10.26	.88	.31

AVERAGE DELAYS

TIME	ARRIVALS RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI IN	DEPARTURES RWY 11R	RWY 11L	RWY 4	RWY	RWY	RWY	TOT	RWY CRS	TAXI OUT	RWY CNG	GRAND TOTAL AVERAGE DELAYS ARR DELAY	DEP DELAY
2000-2100	1.2	.4	.0	.0	.0	.0	.9	.0	.0	2.6	.5	.0	.0	.0	.0	2.2	.0	39.5	.0	.9	41.7
2100-2200	.8	.1	.0	.0	.0	.0	.6	.0	.0	2.0	1.4	.0	.0	.0	.0	1.8	.0	.9	.0	.6	2.8
2200-2300	.3	.2	.0	.0	.0	.0	.3	.0	.0	.4	.0	.0	.0	.0	.0	.3	.0	.0	.0	.3	.3
2300-2400	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2	.0	.0	.0	.0	.0	.2	.0	.0	.0	.0	.2
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

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TIME	ARRIVALS FLOW RATE	AIR DELAY	TAXI-IN DELAY	RWY-XNG DELAY	DEPARTURES FLOW RATE	RUNWAY DELAY	TAXI-OUT DELAY	RWY-XNG DELAY	ENRTE GTE-HLD	TOTAL GTE-HLD RWY-CNG	GROUND DELAYS	ARRIVAL AIR	TRAVEL TIMES ARRIVAL GROUND	DEPARTURE GROUND	TOTAL
0- 100	3.0	.4	.0	.0	1.0	.0	.0	.0	.0	.0	.0	30.4	2.6	.0	33.0
100- 200	.0	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	.0	.1	.1	.1
200- 300	1.7	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	16.7	1.5	.1	18.2
300- 400	3.3	.0	.0	.0	3.0	.0	.0	.0	.0	.0	.0	33.3	3.0	.1	36.4
400- 500	2.0	.7	.0	.0	4.0	.0	.0	.0	.0	.0	.0	20.7	1.7	.1	22.6
500- 600	5.7	.6	.0	.0	5.7	.0	.0	.0	.0	.0	.0	57.2	4.9	.2	62.2
600- 700	15.7	4.3	.0	.0	14.3	5.1	.0	.0	.0	.0	5.1	160.9	14.4	5.6	180.9
700- 800	39.0	60.6	.0	.0	30.3	58.3	18.5	.0	.0	.0	76.8	450.5	35.6	77.1	563.2
800- 900	48.0	312.2	.0	.0	27.7	112.2	166.9	.0	.0	.0	279.1	792.6	43.5	288.8	1124.9
900-1000	26.3	171.0	.0	.0	72.0	163.8	680.3	.0	.0	.0	844.1	432.5	23.6	847.6	1303.6
1000-1100	17.3	6.2	.0	.0	23.0	25.5	218.1	.0	.0	.0	243.6	179.2	15.2	221.4	415.9
1100-1200	51.0	452.0	.0	.0	25.7	39.3	2.0	.0	.0	.0	41.3	962.6	46.0	42.1	1050.7
1200-1300	56.0	291.7	.0	.0	36.0	170.0	504.5	.0	.0	.0	674.4	849.6	51.4	682.0	1583.1
1300-1400	31.3	23.8	.0	.0	46.0	119.8	345.8	.0	.0	.0	465.6	337.1	28.1	469.3	834.5
1400-1500	22.0	11.0	.0	.0	57.7	121.8	1086.1	.0	.0	.0	1207.9	230.9	19.4	1206.6	1456.9
1500-1600	22.0	12.8	.0	.0	25.7	28.6	557.6	.0	.0	.0	586.3	233.1	19.6	513.1	765.8
1600-1700	57.3	281.7	.0	.0	20.7	44.7	4.0	.0	.0	.0	48.6	856.4	53.6	49.3	959.2
1700-1800	44.3	277.3	.0	.0	35.7	122.2	158.4	.0	.0	.0	280.6	720.6	41.2	280.9	1042.6
1800-1900	44.3	499.3	.0	.0	34.7	130.2	591.0	.0	.0	.0	721.3	941.8	40.9	720.9	1703.7
1900-2000	30.3	16.7	.0	.0	59.0	152.6	1508.5	.0	.0	.0	1661.1	319.9	27.3	1662.6	2009.9
2000-2100	40.0	36.4	.0	.0	23.0	52.0	948.2	.0	.0	.0	1000.2	436.7	36.9	960.0	1433.5
2100-2200	19.0	10.3	.0	.0	34.0	61.8	32.2	.0	.0	.0	94.0	200.7	17.3	95.1	313.0
2200-2300	13.0	3.4	.0	.0	10.0	2.8	.0	.0	.0	.0	2.8	133.4	11.5	3.1	148.0
2300-2400	5.3	.0	.0	.0	3.0	.5	.0	.0	.0	.0	.5	53.3	5.1	.6	59.0
2400-2500	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	598.0	2472.4	.0	.0	596.0	1411.3	6822.0	.0	.0	.0	8233.3	8450.2	544.2	8126.6	17121.1

THE METROPOLITAN COUNCIL OF THE TWIN CITIES

MSP AIRPORT ADEQUACY STUDY

PROGRESS REPORT ON MSP ADEQUACY STUDY

Forecast and Capacity Results: A First Look

April 21, 1988

Prepared By:



APOGEE RESEARCH
Thompson-Hickling
CH2M HILL
Enviroscience

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SNAP SHOT

FORECAST NUMBERS

Total Enplanements		Peak Hour Operation Demand (80% Chance of Meeting)	
1986	8,300,000		
1998	12,700,000	1998	132
2003	14,000,000	2003	148
2008	15,300,000	2008	158
2018	19,800,000	2018	210

CAPACITY ENHANCEMENT OPTIONS

Peak Hour Operational Maximum Capacity (VFR)

Base Case	103
Enhanced "A"	125
Enhanced "B"	150
Ultimate "A"	189

SUMMARY

FORECAST RESULTS

- Examined 20 Key Variables Over 30 Years
- Two Thirds Chance Traffic Will Increase by 50 Percent in 10 Years (From 8 Million Enplanements to 12 Million)
- One Third Chance Traffic Will Double (To 16 Million Enplanements in 20 Years
  - 84 Percent Chance of Doubling in 30 Years

CAPACITY

- Examined 15 Options
- New North-South Runway is Promising Near-Term Option
- Possible Room for Two New Runways
  - But Significant Noise and land Use Impacts
  - Construction Costs
- FAA Rule Changes to Allow Independent Runways Could Add 30 % But Very Unlikely Before Turn of Century -- If Then
- Air Traffic Control Changes Could Add 10 to 20 Percent by Early in Next Century
- Demand Management Could Offset Several Years of Growth
  - But Economic and Political Problems

COMBINATION OF SUPPLY AND DEMAND

- Severe Shortage of Capacity Under Base Case
- Shortfall Under Most Options Within 20 Years

TO ASSURE 80 PERCENT CHANCE OF MEETING DEMAND:

- Need 90 Percent Increase in Capacity Within 20 Years
- Need 150 Percent Increase in Capacity Within 30 Years

POLICY IMPLICATIONS

- Major Capital Investments Required
- Need to Make Key Decisions Soon
- Meeting Demand in 20 Years Requires:
  - Two New Runways -- "Ultimate A"
  - Demand Management
  - Relocation of Some Land Uses
- 30 Year Demand Exceeds Likely Capacity
- Face Likelihood of Diverting Traffic to Other Cities

OVERVIEW OF PROCESS

- RISK ASSESSMENT APPROACH
  - Turn Uncertainty into Strength
  - Probabilities Versus Point Estimates
  - Encourages Sensitivity Analysis
  - Monte Carlo Simulation

- EXPERT PANELS REVIEW INPUTS
  - Help Identify Key Variables
  - Analysis and Expertise
  - Forecast Panel:
    - local and national economists
    - aviation experts
    - industry specialists
  - Capacity Panel:
    - local and national airport engineers
    - air traffic control experts
    - Federal Aviation Administration
    - Airline Industry
  - Task Force Members on Panels.

- LINK WITH MAC MASTER PLAN
  - Avoid Expert Versus Expert Battles
  - Use of Plan Results as Inputs
  - MAC Staff and Consultants as Panel Members

- POLICY-ORIENTED STRUCTURE

- FOCUS ON ECONOMIC AND ENVIRONMENTAL IMPACTS

FORECAST APPROACH

TYPES OF VARIABLES -- 20 Key Assumptions
- Socio-Economic (Population, Jobs, Elasticities)
- Industry (Aircraft Size, Prices)
- Peaking and Hubbing

LOGIC STRUCTURE
- Parallel to Master Plan
- Econometric and Accounting Links
- Separate Estimates for:
  - Air Carriers
  - Regional Carriers
  - International
  - General Aviation

OUTPUT MEASURES
- Originations
- Enplanements
- Operations
- Peak-Hour Operations

THREE FORECASTS
- Base Case
- Reduced Hub
  - Slower Growth in Aircraft Size
  - Slower Growth in Regional
  - Less Hubbing
- Super Hub

FORECAST RESULTS

CONSISTENT WITH MASTER PLAN

LIKELIHOOD OF 50 PERCENT INCREASE IN ENPLANEMENTS:

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

LIKELIHOOD OF 100 PERCENT INCREASE IN ENPLANEMENTS:

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

LEVEL OF SERVICE CONCEPT

Capacity Needed to Ensure 80 % Chance of Meeting Demand

Base Case

Five Years	119 Operations
Ten Years	132 Operations
Fifteen Years	148 Operations
Twenty Years	158 Operations
Thirty Years	210 Operations

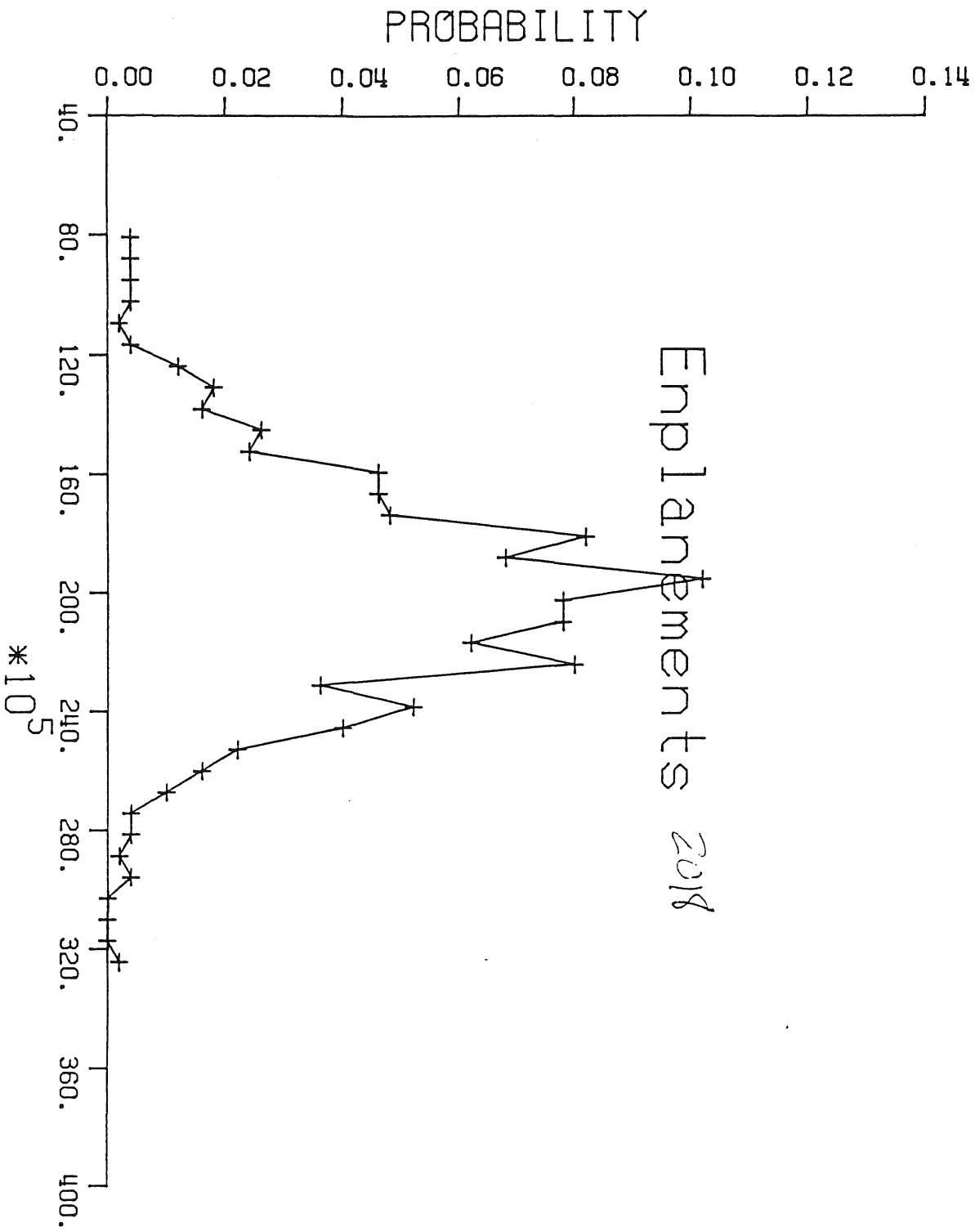
Reduced Hub

Ten Years	128 Operations
Fifteen Years	142 Operations
Twenty Years	149 Operations
Thirty Years	195 Operations

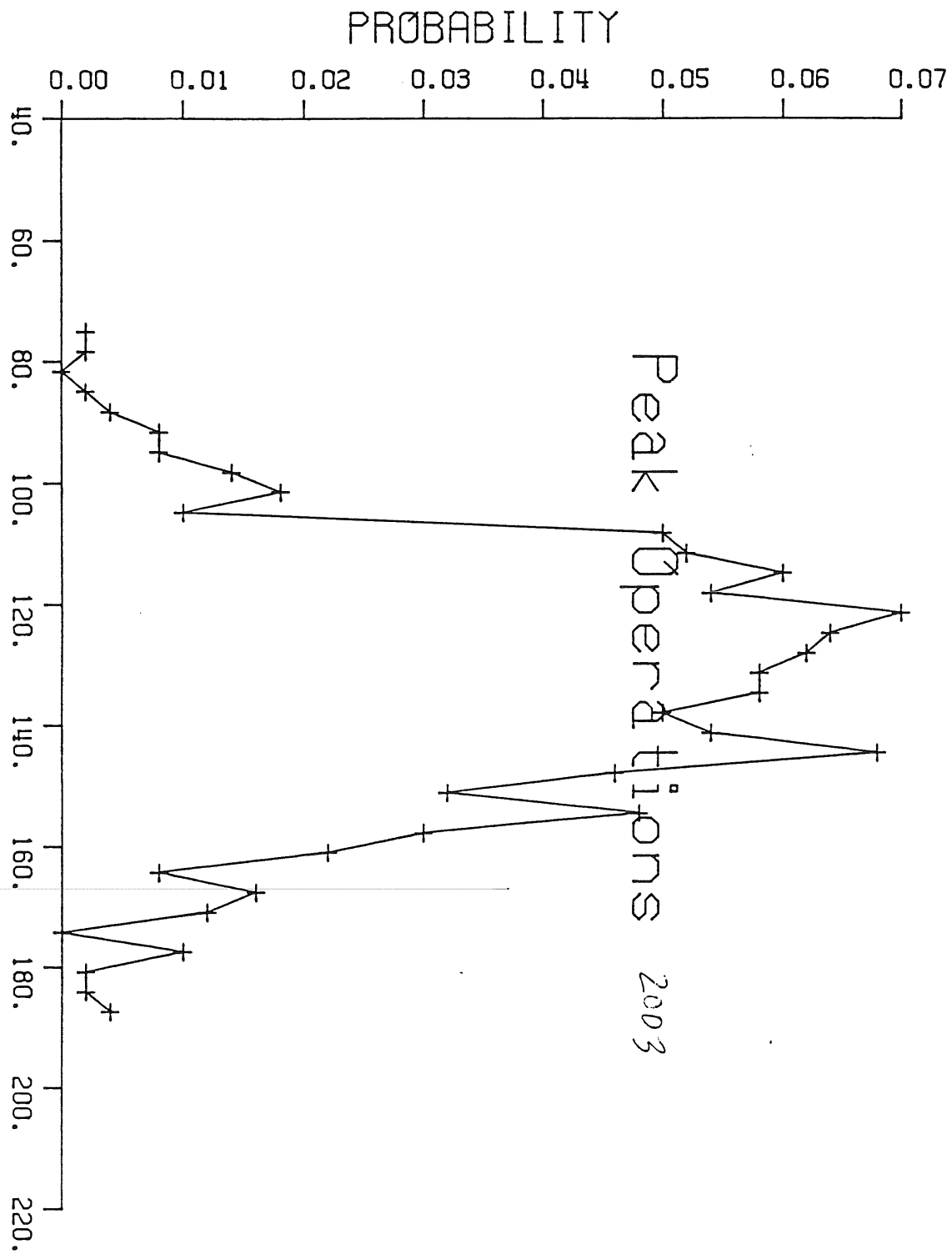
Super Hub

Ten Years	173 Operations
Fifteen Years	191 Operations
Twenty Years	200 Operations
Thirty Years	260 Operations

NOTE: Current VFR Capacity = 103



Enplanements 2018


PROBABILITY
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
40.
60.
80.
100.
120.
140.
160.
180.
200.
220.
Peak Operations 2003

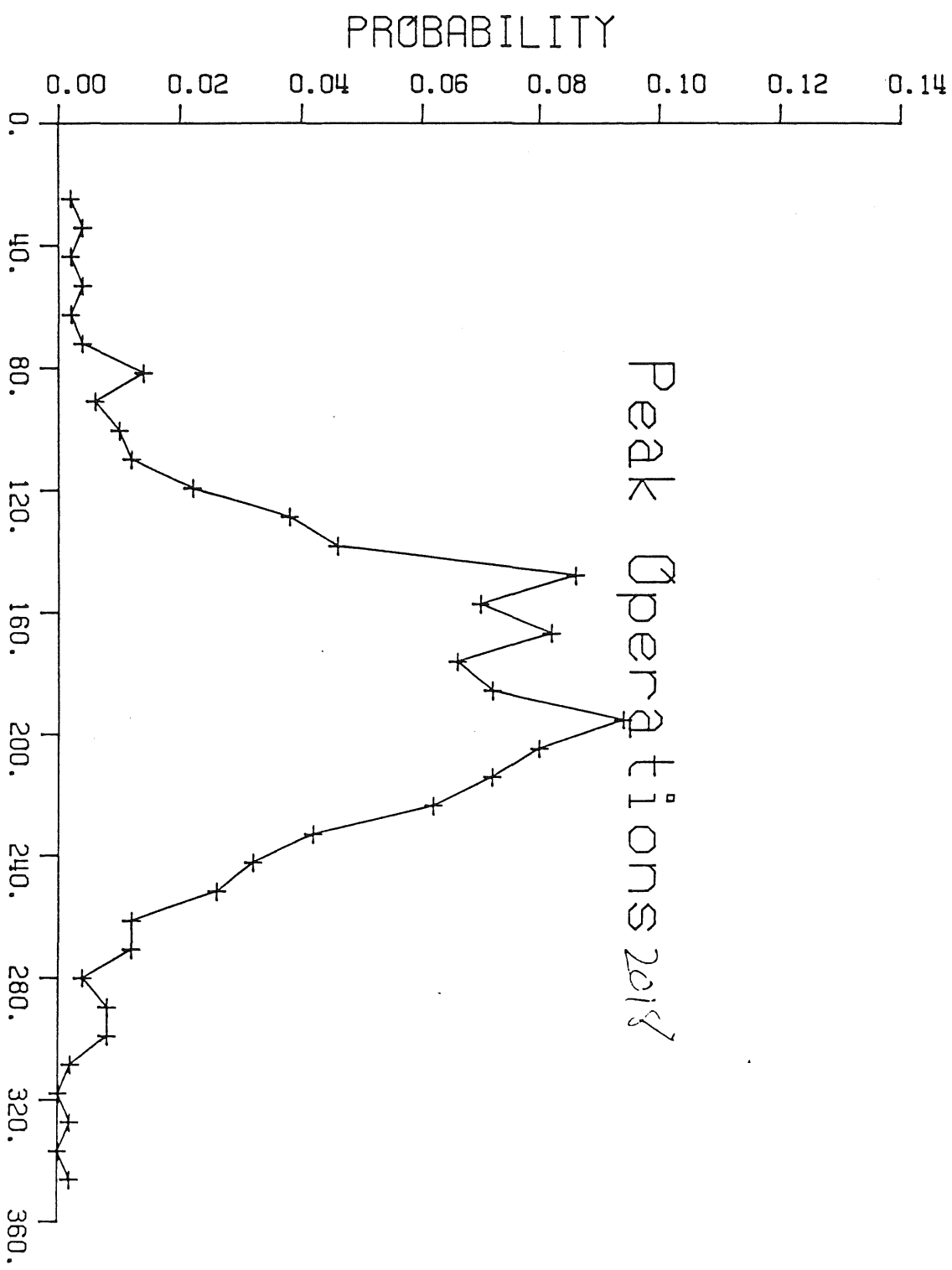

PROBABILITY
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.
40.
80.
120.
160.
200.
240.
280.
320.
360.
Peak Operations 2017

TABLE .: PROBABILITY (IN PERCENT) THAT MSP DOMESTIC REGIONAL AND INTERNATIONAL ENPLANEMENTS WILL EXCEED NUMBER SHOWN AT LEFT

Millions of Enplanements	1993	1998	2003	2008	2018
8.0	99.6	99.8	99.9	99.9	99.9
8.8	99.0	99.4	99.6	99.5	99.2
9.6	94.0	98.2	99.2	99.2	99.0
10.4	77.8	94.5	97.0	98.0	98.3
11.2	36.8	84.0	92.4	95.0	97.9
12.0	10.2	69.0	86.2	92.6	97.0
12.8	1.8	39.0	72.0	84.4	94.8
13.6		18.0	55.6	73.2	93.5
14.4		7.0	34.8	62.0	90.6
15.2		3.8	20.0	45.0	88.2
16.0		0.8	9.0	34.0	83.6
16.8			5.2	21.8	78.0
17.6			2.0	13.8	70.0
18.4			1.4	8.2	62.0
Mean (Millions)	11.0	12.6	14.0	15.3	19.8
Standard Deviation (Millions)	0.85	1.3	1.77	2.28	3.66

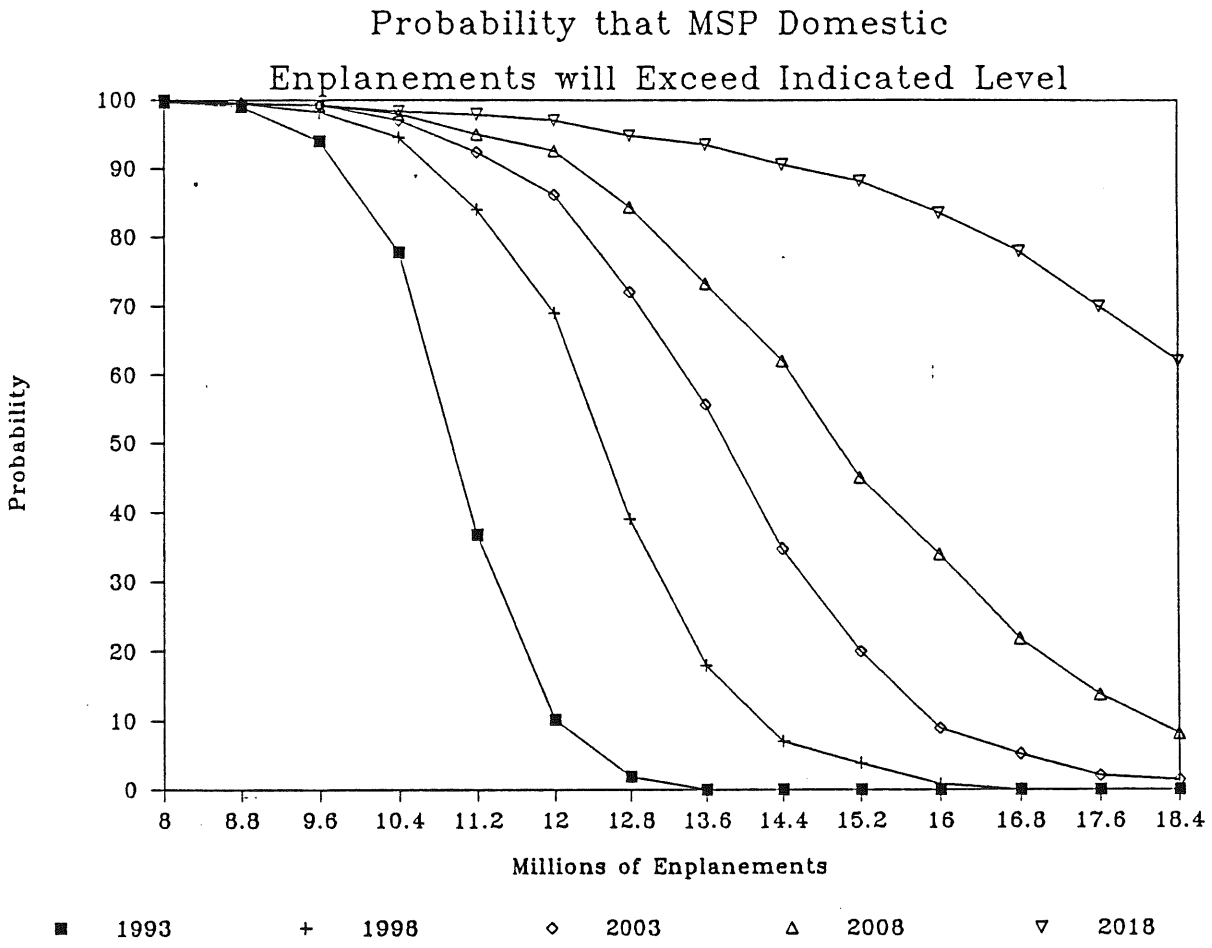
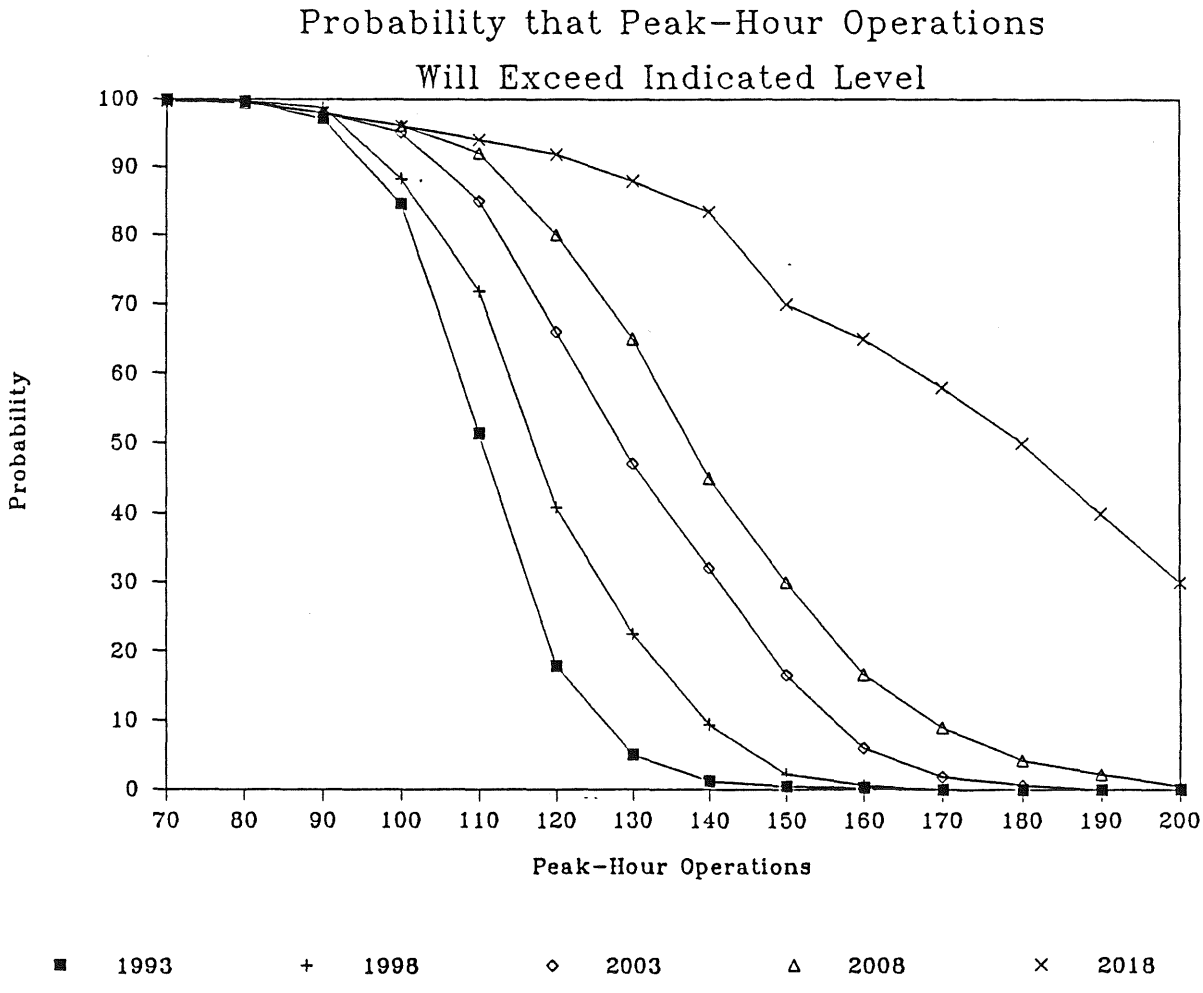

Probability that MSP Domestic
Enplanements will Exceed Indicated Level
Probability
100
90
80
70
60
50
40
30
20
10
0
8
8.8
9.6
10.4
11.2
12
12.8
13.6
14.4
15.2
16
16.8
17.6
18.4
Millions of Enplanements
1993
1998
2003
2008
2018

TABLE .: PROBABILITY (IN PERCENT) THAT PEAK-HOUR DOMESTIC AND REGIONAL OPERATIONS AT MSP WILL EXCEED NUMBER SHOWN AT LEFT

Peak-Hour Operations	1993	1998	2003	2008	2018
70	99.9	99.9	99.9	99.6	98.2
80	99.6	99.8	99.6	99.4	96.8
90	97.0	98.8	98.0	98.0	96.2
100	84.6	88.2	95.0	96.0	95.2
110	51.4	71.8	85.0	92.0	94.0
120	17.8	40.8	66.0	80.0	91.8
130	5.0	22.5	47.0	65.0	88.0
140	1.2	9.4	32.0	45.0	83.4
150	0.4	2.2	16.5	30.0	70.0
160	0.2	0.6	6.0	16.6	65.0
170			1.8	9.0	58.0
180			0.6	4.2	50.0
190				2.2	40.0
200				0.4	30.0
Mean Operations	112	120	132	142	183
Standard Deviation Operations	12	15	19	23	47


Probability that Peak-Hour Operations
Will Exceed Indicated Level
Probability
100
90
80
70
60
50
40
30
20
10
0
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Peak-Hour Operations
1993
1998
2003
2008
2018

CAPACITY OPTIONS

MEASURES

AIRCRAFT OPERATIONS: Airfield and Taxiways
ENPLANEMENTS: Terminal
ORIGINATIONS: Ground Access

OPERATIONS AS CRITICAL DECISION FACTOR FOR LONG-TERM ADEQUACY

- o TERMINAL AND GROUND ACCESS NOT LIMITED BY SPACE
  - Appears Solvable
  - Need Money
- o AIRFIELD CAPACITY
  - VFR: Visual Flight Rules -- Most Common
  - IFR: Instrument Flight Rules -- 9 % of Time
  - Modified VFR -- 30 Percent of Time
  - Noise Rules -- Reduce Capacity
    Preferential Runway System
    Noise Budget

KEY POLICY OPTIONS

- o ADD RUNWAYS/TAXIWAYS
- o IMPROVE AIRSPACE
- o DEMAND MANAGEMENT -- Constrains Demand
- o INCREASED CONGESTION/DELAYS
  - Diverted Traffic
  - Lower Level of Service
  - Reduced Use of Airport

ADD RUNWAYS

EXAMINED NINE OPTIONS: Focus on Four

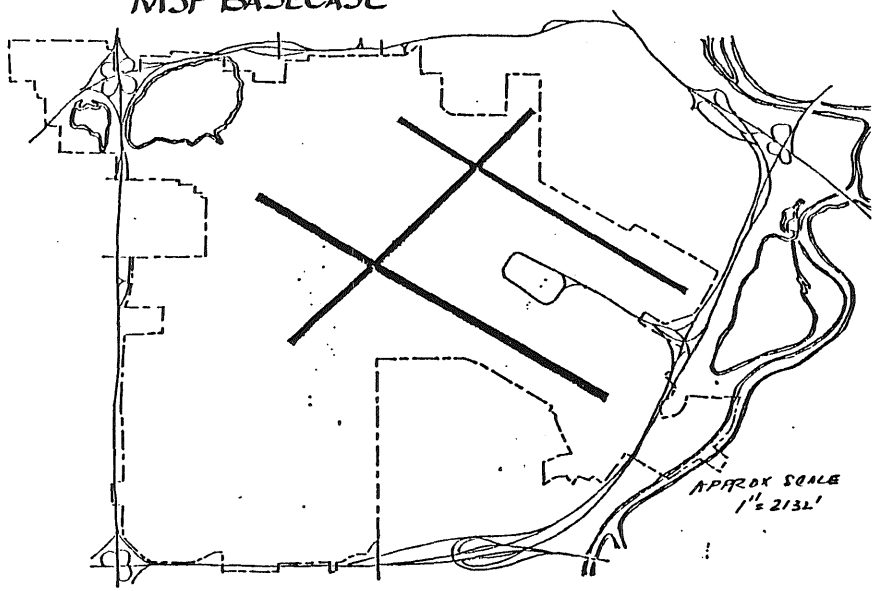
- Base Case

- Enhanced "A"
  Extend 4-22
  "Far" Parallel

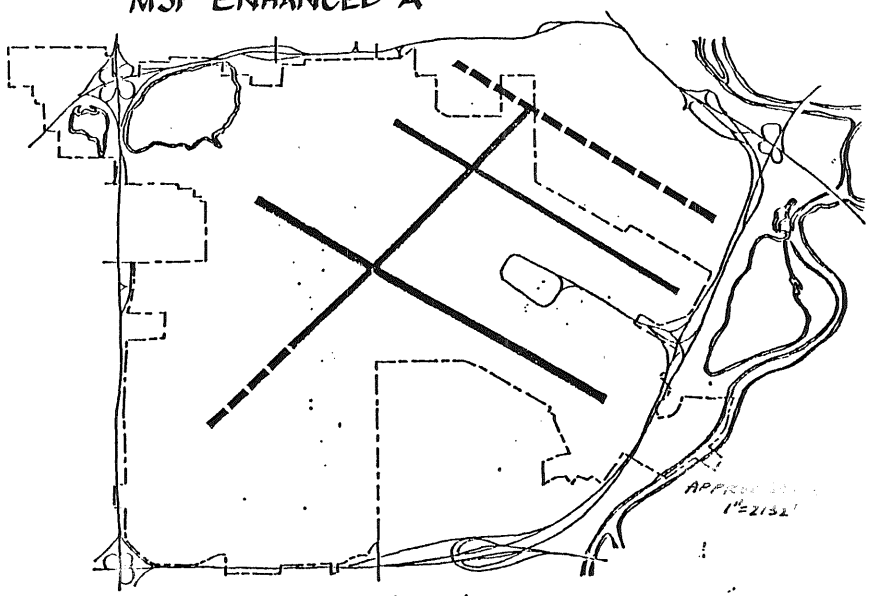
- Enhanced "B"
  Extend 4-22
  New North-South
  "Close" Parallel

- Ultimate "A"
  Extend 4-22
  New North-South
  "Far" Parallel

MSP BASECASE

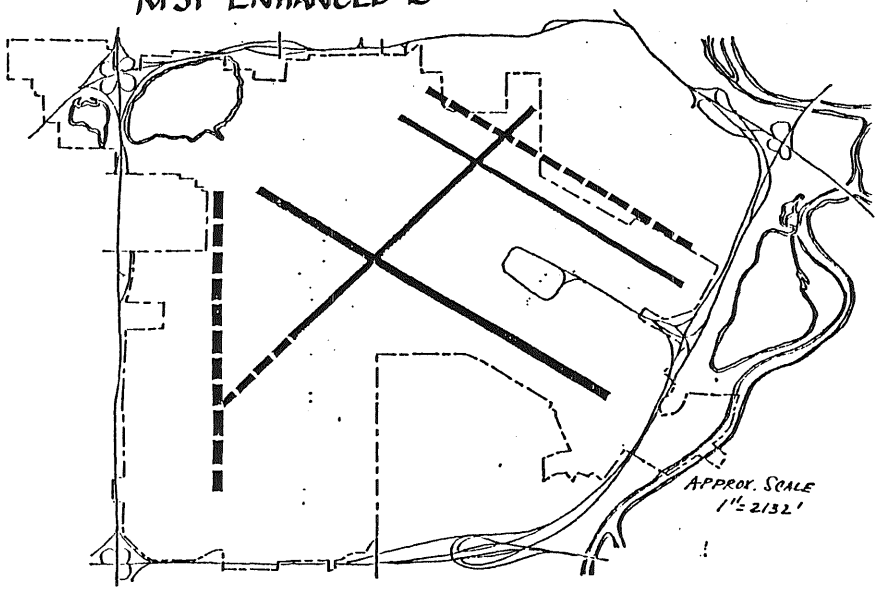


MSP ENHANCED A



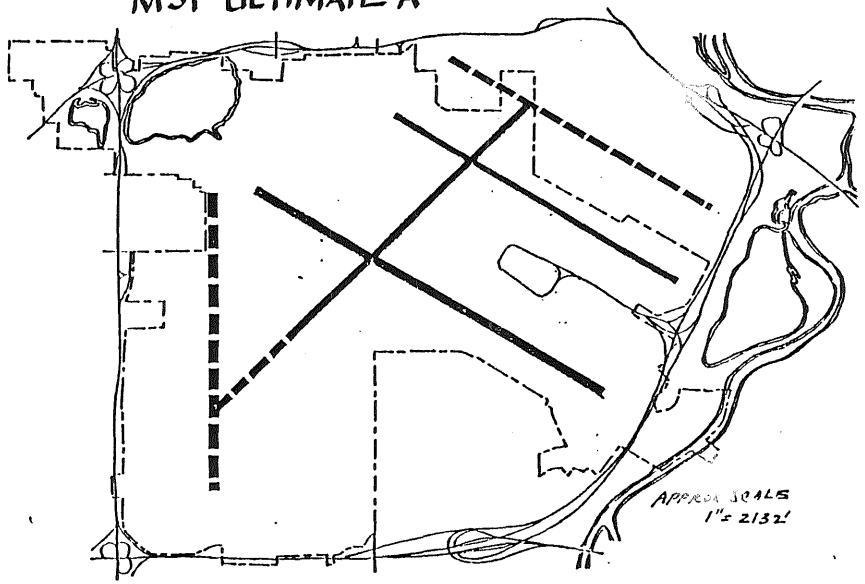
RUNWAYS APPROXIMATE LOCATION

MSP ENHANCED B

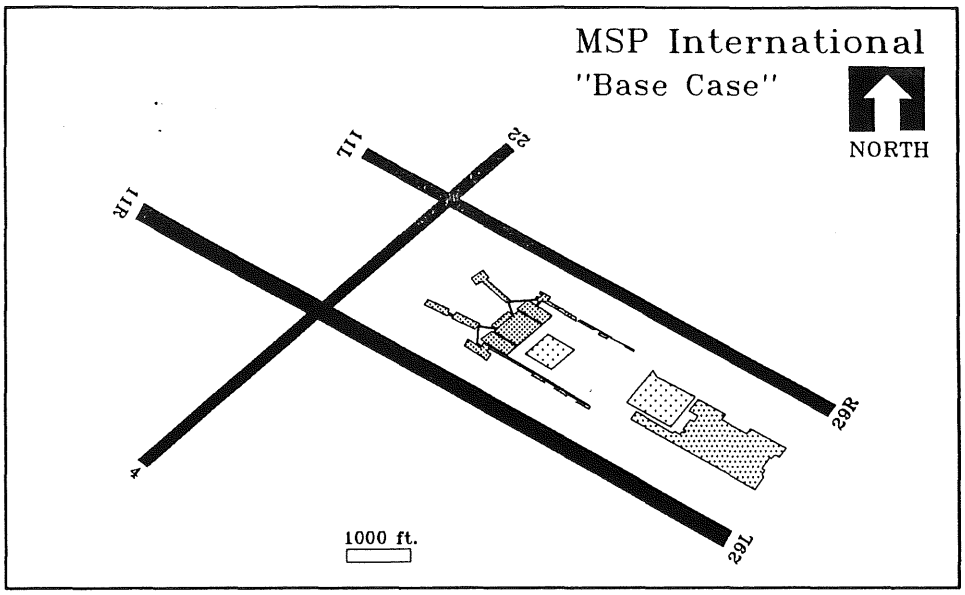


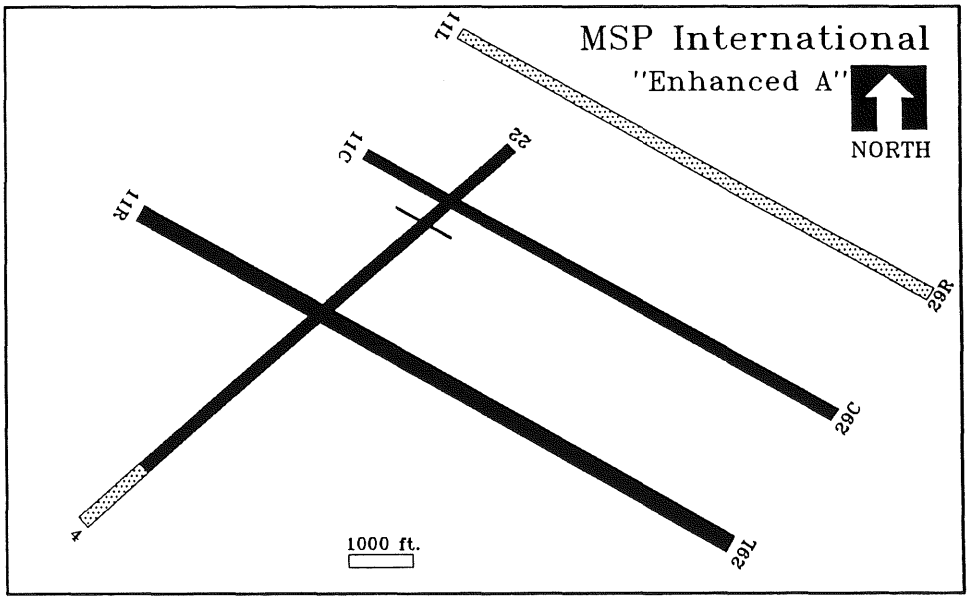
RUNWAYS APPROXIMATE LOCATION

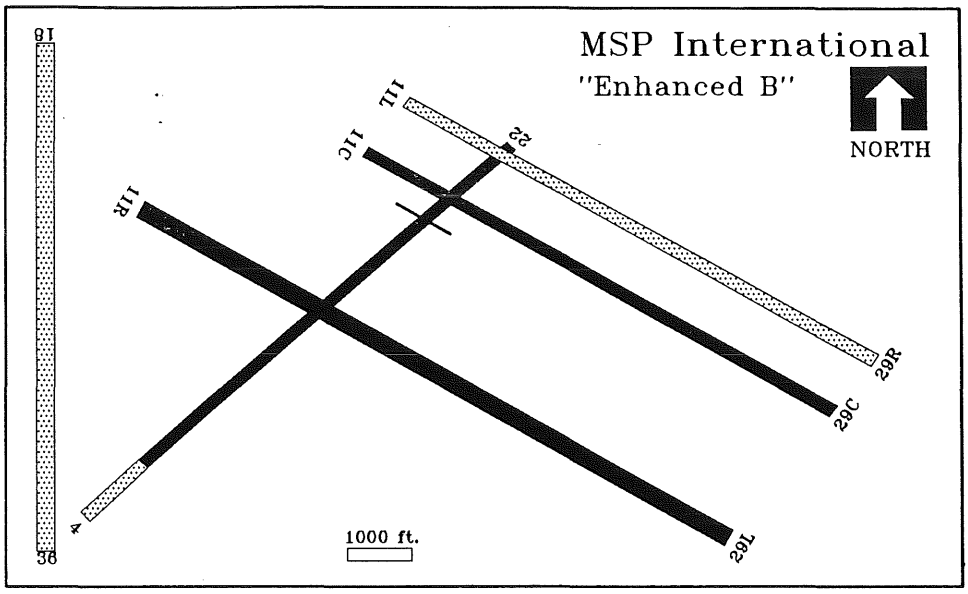
MSP ULTIMATE A

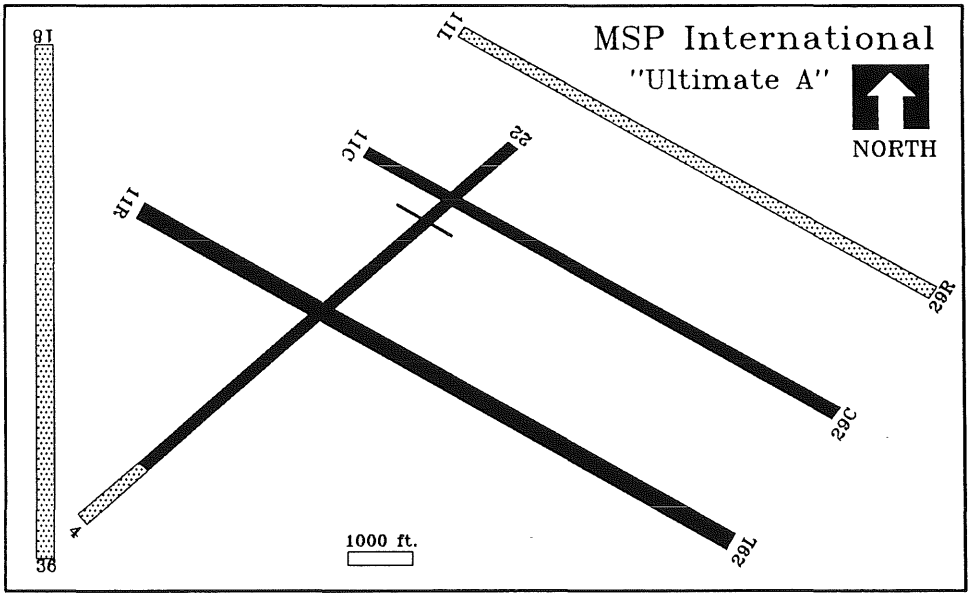


RUNWAYS APPROXIMATE LOCATION


MSP International
"Base Case"
NORTH
11L
22
11R
29R
4
29L
1000 ft.


MSP International
"Enhanced A"
NORTH
11L
11C
22
11R
29R
29C
4
29L
1000 ft.


MSP International
"Enhanced B"
NORTH
1000 ft.
11L
11C
11R
22
29R
29C
29L
4
36
18

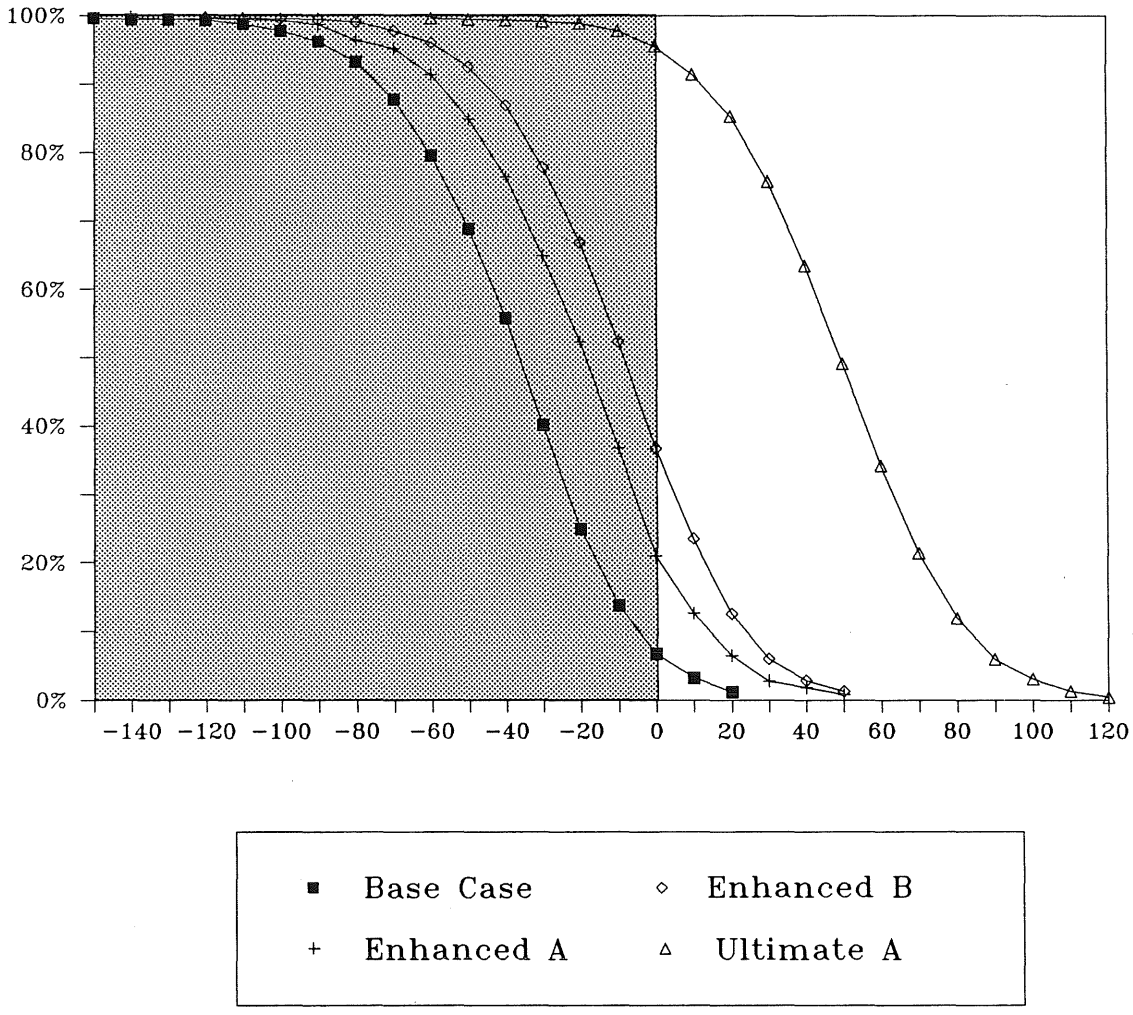

MSP International
"Ultimate A"
NORTH
1000 ft.
11L
11C
11R
22
29R
29C
29L
4
36
18

COSTS
- Construction
- Indirect
  - Noise
  - Changed Land Use
    - State Park
    - Air Force/National Guard
    - Residential Neighborhood

Estimated Capacity in Operations Per Hour
(1998)

	IFR	VFR
Base Case	85	103
Enhanced "A"	105	125
Enhanced "B"	135	150
Ultimate "A"	177	189

Net IFR Capacity
Under Different Development Scenarios
(2008)



IMPROVED AIR TRAFFIC CONTROL

KEY VARIABLES

- o When will changes be available?
- o Potential Level of Improvements
- o Actual Use: Learning Curve

INDEPENDENT PARALLEL APPROACHES

- o Reduce Separation from 4300 feet to 3400 feet
- o Very Unlikely Before Turn of Century -- if then
- o 30 to 40 Percent Increase in Capacity
  (20 to 30 operations per hour)

TERMINAL ATC AUTOMATION

- o Reduced Aircraft Separation
- o Late in 1990s
- o 10 Percent Improvement

MICROWAVE LANDING SYSTEM

- o Angled Approaches
- o Late 1990s
- o 5 to 10 Percent Improvement

LONG-TERM POTENTIAL FOR IFR TO APPROACH VFR

DEMAND MANAGEMENT

MOVE GENERAL AVIATION
- Assumed in MAC Forecast
  - GA Drops to 3 Percent in 20 Years
- Economic Effects for Business Community
- Increased Traffic at Relievers
- Political/Legal Problems

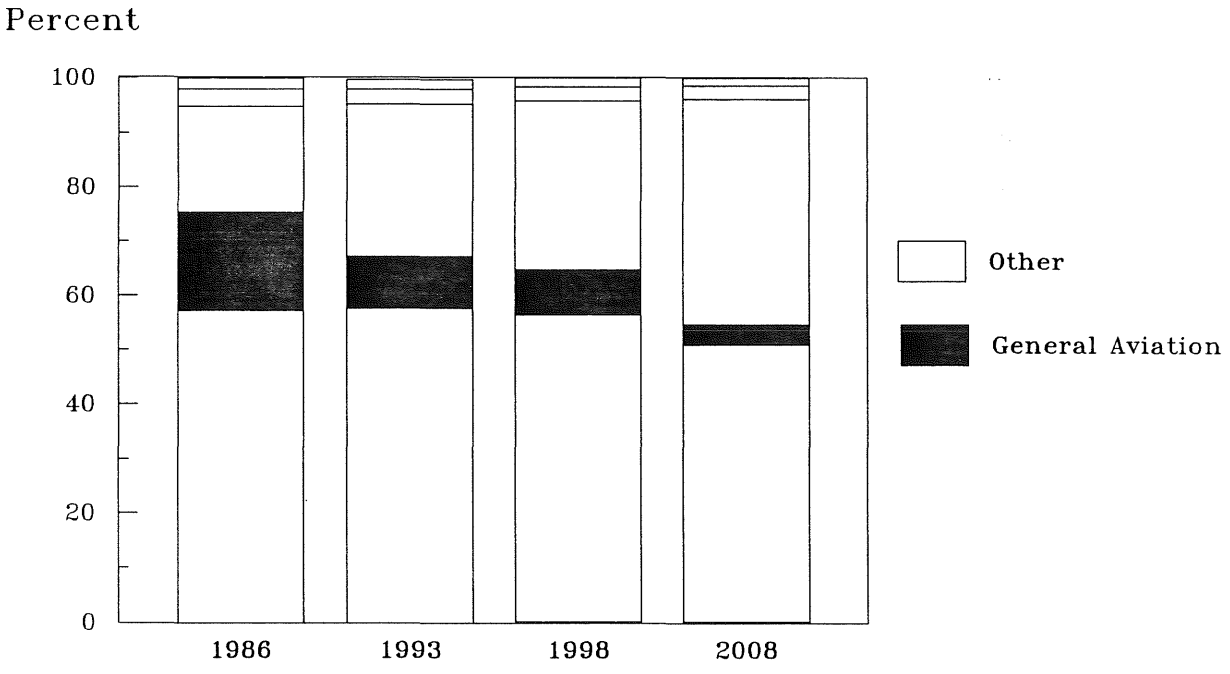
MOVE REGIONAL CARRIERS
- Regional Economic Impact
- Traffic Likely to Disappear Rather Than Move to Relievers
- Affect on Northwest Hubbing

SHIFT TO OFF-PEAK
- Growth of Hub Means Limited Off-Peak Times
- Hard to Shift Commercial Carriers

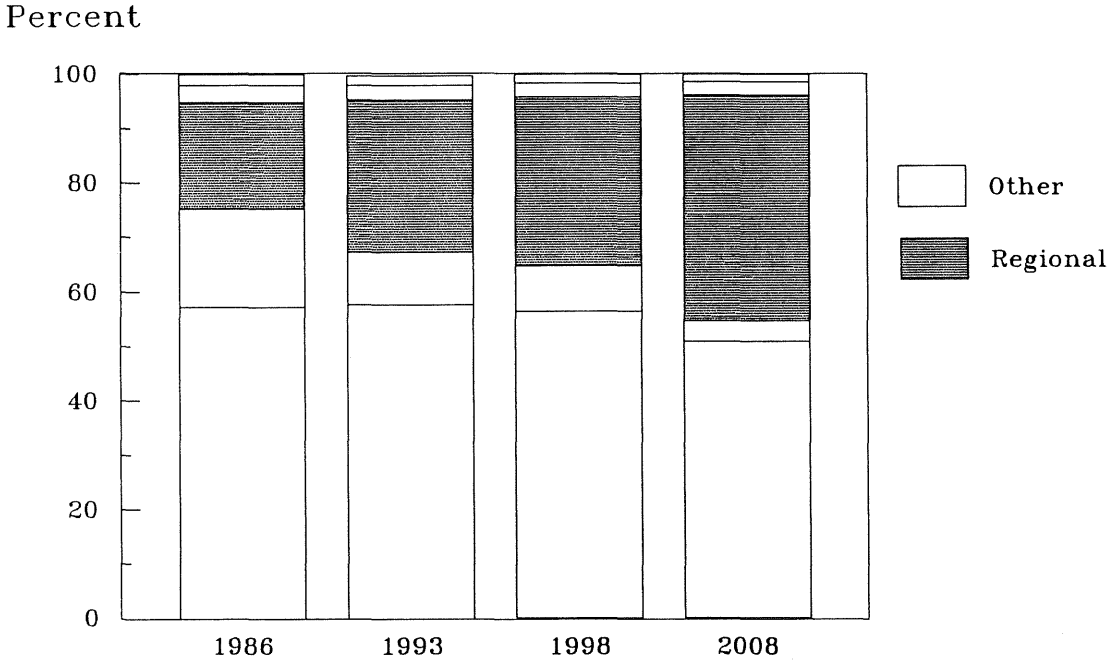
REDUCED TRAFFIC

- Hubbing Moves Elsewhere
- Reduced Number of Flights
- Reduced Economic Benefits for
  - Region
  - Business Community
- Reduced Noise Impacts

Forecast Share of Operations at MSP: General Aviation Versus All Others



Forecast Share of Operations at MSP:
Regional Carriers Versus All Others



POLICY IMPLICATIONS

- SEVERE SHORTAGE OF CAPACITY UNDER BASE CASE
- SHORTFALL WITHIN 20 YEARS UNDER MOST OPTIONS
- CAN MEET 20-YEAR DEMAND; BUT ONLY WITH:
  - ULTIMATE "A" OPTION
    - Land Use Implications
    - Noise Impacts
    - Construction Cost
  - DEMAND MANAGEMENT
    - Economic Impacts
    - Political/Legal Problems
- THIRTY YEAR DEMAND EXCEEDS LIKELY MAX CAPACITY

BALANCE OF WORK

- ECONOMIC IMPLICATIONS OF CAPACITY OPTIONS
  - Delays
  - Higher Fares
  - Lost Jobs: Multiplier
- ENVIRONMENTAL
  - Reduced Noise
  - Land Use
- OTHER FACTORS
  - Image of Region
  - Economic Development Potential
- FINANCIAL OPTIONS
  - Expansion of Current Site
  - New Airport

HE 9797.5 .U52 T9 1988b v.3
Is the airport adequate?

HE 9797.5 .U52 T9 1988b v.3
Is the airport adequate?

DATE	ISSUED TO
[illegible]	[illegible]
JAN 22 '92	
3-4-92	
4-15-92	

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