ASSESSMENT
OF THE
"FLIGHT PLAN" FORECASTS
FOR
SEATTLE/TACOMA AND
REGIONAL AIRPORTS

TOGETHER WITH
REFLECTIONS ON
THE PROPER BASIS
FOR
AIRPORT PLANNING

Report prepared for the
Air Transportation Commission
State of Washington

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SUMMARY

Traditional master planning for airports, as indicated by the US Federal Aviation Administration, involves three major steps:

1. The preparation of a forecast of future traffic and the ability of the existing facilities to meet that forecast;
2. The evaluation of alternative plans for developing the airport system, as regards their suitability to meet the forecast conditions; and
3. The selection of the master plan.

The justification of the master plan thus clearly rests on the selection of the traffic forecast. A different forecast implies that a different master plan would be preferred. It is thus natural to ask, as the State of Washington has done in requesting this report, about the validity of the forecast.

Specifically, this report was commissioned by the Washington State Air Transportation Commission, an agency set up by the legislature to review and comment on aviation planning statewide. Their charge for this report was to assess the Flight Plan demand and capacity forecasts. In doing so, no attempt was made to analyze the planning process or recommendations of the Flight Plan.

The fact is that no single forecast of future airport needs can be relied on. For all practical purposes, "a forecast is always wrong". Future world and regional economic circumstances, airline policies and aeronautical technology inevitably turn out to be different than assumed. The fact that any single forecast is almost certainly wrong is fully demonstrated by experience nationally and regionally. A retrospective examination of forecasts for Seattle-Tacoma documents the difficulties in correctly anticipating growth that has occurred in this context.

The discrepancies to be expected between actual growth and that anticipated by any single forecast have been compounded by airline deregulation, which has led to great instability in the patterns of traffic. This phenomenon has been extensively documented nationally. The volatility of traffic in the Puget Sound area is evidenced by rapid changes in local traffic, such as the surge of commuter operations in the past few years.

The future capacity of the existing airport facilities is also uncertain. This is because the "capacity" of an airport is not only sensitive to the types of aircraft using the airport and their patterns of daily and seasonal variation, it is also sensitive to the level of inconvenience that is judged to be acceptable. The ability of a set of runways to handle traffic cannot be established on the basis of purely technical considerations.

Taking the inevitable unreliability of forecasts into account, the Flight Plan study correctly indicates that there is a real risk that the existing airfield facilities at Seattle-Tacoma International Airport will be inadequate. The need for additional capacity is not absolute since the forecasts cannot be certain. It is possible that further facilities might not be required. Conversely however, it cannot be demonstrated that no facilities are needed. The real risk that new airfield facilities are needed is inescapable.

The proper basis for airport planning is thus a broad range of forecasts, both of the level of traffic and of its range of requirements. These need to be matched with an equally realistic broad range of estimates of the capabilities of future airport facilities to serve traffic. As in any risky situation, the full range of possible scenarios has to be recognized.

For Seattle-Tacoma International and the regional airports, there appears to be a strong possibility both that there will be a real need to provide major new additions to airport capacity in the region, and alternatively that current facilities could be made to cope with future needs with only modest improvements. Specifically, the future traffic in the year 2010 might be estimated at 30 million plus or minus 10 million passengers a year. This implies a "capacity gap" of anywhere from 0 to 20 million passengers a year that might have to be provided for by additional runway capacity.

The proper approach to airport planning in the unavoidable context of risk is Dynamic Strategic Planning. The essential aspect of this approach is that it recognizes the uncertainties and attendant risks. It therefore builds flexibility into the plan, so that there are adequate responses to whatever develops. It thus provides insurance against these risks.

Dynamic Strategic Planning is dynamic in that it is responsive to changes in circumstances, and adjusts to them over time. It is strategic in that it takes a long term view of goals and criteria of performance. It is a planning process that extends and improves the existing approaches.

Dynamic Strategic Planning is analogous to playing chess (or any other board game). The planner:

1. Considers the range of possible events over the long term, (for example, the next 5 or more moves of the opponent);
2. Selects an initial good move, one that has the flexibility to respond appropriately to whatever may arise; and
3. Adjusts the plans continuously, in response to what actually happens.

As in playing chess, good planners do not commit to a long range master plan.

As applied to Seattle-Tacoma International and regional airports, Dynamic Strategic Planning would lead to:

1. The decision to take one or more steps now that would enable the region to proceed with the provision of eventual major additions to airport capacity, such steps might include the selection of a site for a second major airport, or the execution of an Environmental Impact Statement for a new runway for Seattle-Tacoma International Airport; and
2. The deferral of decisions about actually building new facilities, as well as what kind of major facilities to build, until the necessary preliminary work such as an Environmental Impact Statement has been done, and the needs for these facilities becomes more clear.

The recommended approach is a logical conclusion to the observation that forecasts are unreliable. The review did not however seek to determine whether past, present or contemplated planning and decision-making regarding the Puget Sound region are consistent with dynamic strategic planning, and no judgment is implied with respect to such activities or decisions.

1. INTRODUCTION

Proposals to build major new airport facilities, such as to lay down a two-mile long runway or to concentrate future traffic at a secondary airport, always are controversial. The history of airport planning is a continuing saga of public debates.

Major airport projects are inherently controversial for two reasons:

1. They are unique projects that shape the character of a region over generations -- unique in that, as distinct from highways or power plants, they are difficult to build incrementally, and impossible to scatter over a region; and
2. They must be based on forecasts which are inherently unreliable, because small differences in annual rates of growth compound into enormous differences over a generation.

Planning for major new airport facilities involves making life-long choices on the basis of information which is, however well thought out, unavoidably speculative. Choices about airport planning are always risky: it is possible to commit prematurely or unnecessarily to a project, as was done in building Montreal's Mirabel airport; it is also possible to defer modernization excessively, and drive away significant business and traffic, as some experts believe has happened at New York's Kennedy Airport.

What is then the proper basis for airport planning? What forecasts should be relied on? This is essentially the question that the State of Washington and the people of the Puget Sound Area have been grappling with as regards the future of Seattle-Tacoma International Airport.

This report addresses this issue of what constitutes the proper basis for airport planning. It specifically assesses the validity and reliability of the forecasts contained in the Flight Plan put forth by the Port of Seattle and the Puget Sound Regional Council.
Since the validity and reliability of any statement can only be properly judged in the context of what is usual and in comparison with what is possible, it is necessary to establish this context and to recognize the fundamental limits to forecasting. This is the role of the Sections 2 and 3 on the "Airport Planning Process" and the "Forecasting Process".

Sections 4 and 5 point out that forecasts of air traffic are all, taken as a whole, inaccurate. Not only are individual forecasts almost certainly wrong over the long term, but the traffic itself is highly volatile in the deregulated environment that prevails. In this context it would seem that the Flight Plan forecasts are as valid and reliable as any other professional forecast. On the other hand, it would seem equally probable that the actual future traffic may be quite different from that anticipated by the Flight Plan forecast.

The future capacity of the existing airport facilities is also uncertain, as discussed in Section 6. This is because the "capacity" of an airport is not only sensitive to the types of aircraft using the airport and their pattern of daily and seasonal variation, it is also sensitive to the level of inconvenience that is judged to be acceptable. The ability of a set of runways to handle traffic cannot be established on the basis of purely technical considerations.

The assessment of the Flight Plan forecasts is given in Section 7. The essential conclusion is that these projections are "reasonable but unreliable". They are reasonable in that they conform to the best professional standards and are as good as any prospective estimates for the next 20 to 30 years could expect to be. These forecasts are -- as any forecasts can be assumed to be -- unreliable in that the actual future may turn out to be quite different from what was projected.

The proper basis for planning new airport capacity, given the inevitable uncertainty about forecasts, is thus a range of forecasts for both traffic and capacity, as indicated in Section 8. These combine to define a range of possible "Capacity Gaps" that is, the risks that need to be considered by the planning process. These risks are unavoidable, whatever decisions are made.

The proper basis for airport planning is thus to recognize the inherent risk and uncertainty, and then to deal with them realistically. Section 9 presents the reasonable and common sense approach that involves two elements:

1. Insurance against the risks, obtained by securing options for particular facilities that might be needed; and
2, Flexibility in the planning, that permits the region to adjust its plans to suit the traffic as it develops.

These are the elements of Dynamic Strategic Planning, suggested as the proper basis for airport planning.

2. AIRPORT PLANNING PROCESS

Traditional Master Planning: The planning process for airports in the United States follows the guidelines of the US Federal Aviation Administration (the FAA), set forth in its Advisory Circular on "Airport Master Plans" (No.150/5070-6A). This advice is virtually mandatory, since airport authorities should follow it in order to get federal money for airport planning and construction.

This planning process involves three major kinds of steps:

1. The preparation of a forecast of future traffic and the ability of the existing facilities to meet that forecast;
2. The evaluation of alternative plans for developing the airport system, as regards their suitability to meet the forecast conditions; and
3. The selection of the master plan.

The justification of any master plan thus clearly rests on the selection of the traffic forecast. Indeed, all the results depend on this premise. The suitability of various alternatives obviously is tied to the level and type of traffic they are presumed to handle. Consequently, the airport plan that seems most suitable is also a consequence of whatever forecast has been taken as the basis for the planning process.

The traditional master planning focuses on a single forecast, rather than consider a range of possibilities. As the FAA Advisory Circular indicates:

> "Aviation demand Forecasts. Aeronautical demand, expressed in units necessary to determine the required capacity for airport facilities, is forecast for short, intermediate and long time frames..." (Chapter 2)

In practice, this guidance is generally interpreted to mean that a single forecast is prepared. Sometimes these predictions are placed within a band of overall uncertainty indicated by possible high and low forecasts for any specific year. These ranges do not normally represent different assumptions about the nature of the traffic, but only a degree of uncertainty in the timing of the anticipated need for new facilities.

This focus on timing of a particular kind of traffic -- and disregard for the range of possible types of traffic -- is brought out by the Advisory Circular:

> "Purpose of Forecasts. The purpose of aviation forecasts is to indicate the relative timing for airport investments... The idea is to forecast the different elements of aviation demand, compare that demand over time with the capacity of the airport's various facilities, and to identify the time when new or expanded airport facilities may be needed..." (Chapter 5, underlining added for emphasis)

The usual practice in airport master planning is thus to focus on a single forecast, accepting some variation in the timing of the needs. The Flight Plan forecasts must be appreciated in this context of what is normally expected.

The fact is, however, that there must be great uncertainty about the types of traffic that may occur, and thus about what should be done. It turns out that master plans are extremely poor guides to what actually gets built at an airport. They are inadequate not simply because their timing is off; they are poor guides because what actually gets built, corresponding to the traffic that occurs, is quite different from was anticipated. An exhaustive study comparing what was built to what was anticipated in master plans throughout New England, indicated that only 1/3 (!!) of the projects built were in the original master plans (For details, see Maldonado, 1990).

As suggested by the rest of this report, there should always be considerable doubt about what airline and airport traffic will be. Understanding this reality provides the proper basis for airport systems planning.

Application to Seattle/Tacoma: The Flight Plan study is the latest in a series of master planning exercises that have been conducted for the Seattle-Tacoma International Airport. They can each be presumed to have been conducted according to the guidelines of the US Federal Aviation Administration, according to the then prevailing version of the Advisory Circular on Master Planning.

The previous master plan for the Seattle-Tacoma International Airport is worth considering because appears to indicate quite clearly the limitations of the master planning process. Prepared in the early 1980's, it seems to have led to a substantially different view of the long-term aviation needs for Seattle-Tacoma International Airport.

Copies of the previous master plan were unfortunately not yet available for this report, but its major conclusions were outlined by experienced senior members of the Airport staff. In short, in the early 1980's, it reportedly seemed "inconceivable that Sea-Tac would ever run out of runway capacity", and thus "all the problems seemed to be with the capacity of the airport terminals". This perspective is almost diametrically opposite to that of the Flight Plan study, which focusses on the pressing needs for more runway capacity.

The story about the previous Master Plan for Seattle-Tacoma International Airport is a cautionary tale. It underlines the conclusion that master plans are poor guides to what actually gets built or is needed (see Maldonaldo, 1990). They are poor not just because they cannot accurately pinpoint the timing of any need, but because they may emphasize the wrong needs over the long term.

The Flight Plan study itself was conducted jointly by the Puget Sound Regional Council and the Port of Seattle, the owner of the Seattle-Tacoma International Airport. This study was partially funded, according to the usual pattern, by the US Federal Aviation Administration, and it was coordinated with its airport planning staff and other aviation experts.

3. FORECASTING PROCESS

General Approach: A traffic forecast is an estimate, based on expectations about other factors, derived from assumptions. If the underlying assumptions are changed, even modestly, a completely different forecast may result. This sensitivity of forecasts to their premises, to judgments impossible to demonstrate conclusively, must be recognized from the start.

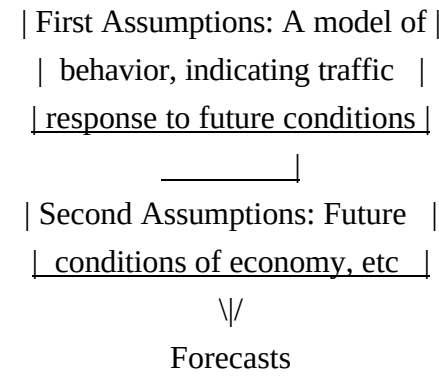
Professional forecasts of traffic are made through what can be seen as a three step process. (See Exhibit 1). The effort starts with some kind of mental image, or model, of how people respond to their environment: how potential passengers react to changes in income or fares, for example, or how airline companies will choose aircraft for their fleets.

Secondly, these initial assumptions, specific to the kind of traffic to be estimated, are coupled with larger assumptions about the overall context, for instance that the regional economy will continue to grow as it has in the past. These more general assumptions

provide the basis for estimating the future values of the range of factors that influence traffic, such as: the population of a region, its income, the price of fuel and cost of travel, the type of aircraft being used and so on.

Finally, the expectations about the factors influencing traffic are incorporated into the basic model to derive predictions. Assuming that one is working with the correct relations between traffic and fares (a controversial proposition), and further assuming that it is possible to estimate the price of travel twenty years hence (a most hazardous guess), an econometrician will be able to calculate the traffic over that period. In short, forecasts of traffic come from assumptions upon assumptions.

Exhibit 1: Forecasts are derived from assumptions upon assumptions:



Limits of Methods: The best theories and professional judgments are naturally used to arrive at the assumptions that must be made to produce a forecast. For example, both economic theory and common sense tell us that as the price of air travel falls, more people will fly; this feature will be part of any decent model.

Forecasters differ, however, about how to translate theory into the kinds of specific formulas they use. For instance, all will agree that the future price of air travel will affect the number of airline passengers, but there are many ways this phenomenon can be expressed mathematically. Price can be incorporated into formulas in real or nominal terms; as a total, an increment or a ratio; linearly or logarithmically; in dollars or utility -- the professional literature on forecasting includes all of these, and there is no consensus about which is best.

Furthermore, forecasters do not even agree on exactly which factors to include in any forecasting formula. There is no theory or analytic method which can define unambiguously what factors must be considered in general, or in any particular situation. The formulas used by different forecasters thus can differ considerably.

Forecasters all attempt to justify their own approach by demonstrating that their model, using the mathematical expressions they have chosen, accords with the experience represented by past data. Unfortunately, many different formulations -- and thus forecasts -- can always be found to match past data. This fact is easily demonstrated, either mathematically or by example. Exhibit 2 uses the recent experience for Boston to illustrate the point.

Looking backwards at past experience is in any case an incomplete basis for anticipating the future. The past may well be prologue, but the past does not define the future. Major events that were not part of past experience constantly occur to reshape the path of history. The War in the Gulf, a national recession, the reorganization of intercontinental air routes associated with the opening of Soviet airspace, the ups and downs of traffic associated with airline deregulation, the major investments by foreign airlines in Northwest and US Air, the prospect that transpacific fares might fall to the level of the transatlantic fares, are all current events that may make the patterns of air traffic at Seattle-Tacoma International Airport differ from historical trends.

Using a statistical model for defining the future has been compared to driving a car by looking in the rear view mirror. While focusing on past trends, it does not prepare us for the changes in direction, for the uncertainties that lie ahead.

Exhibit 2: Four major forecasts for airport passengers for Boston, whose formulas each agree almost perfectly with past data ($R^2 = 1.00$), produced entirely different predictions of passenger traffic for the year 2010.

Name of Model	Coefficient of Correlation (R^2)	Forecast Millions of Pass. Low	Medium	High	Average and Range

CHART	> 0.98	33.7	35.5	37.4		
LADS	> 0.98	46.3		56.6	69.2	45
LOGIC	> 0.98	35.8		40.1	43.6	plus or minus 30%
MASSPORT	> 0.98	39.9	47.3	56.4		

Source: de Neufville (1991).

4. INACCURACY OF FORECASTS

The fact is that no single forecast of future airport needs can be relied on. For all practical purposes, "a forecast is always wrong". Future world and regional economic circumstances, airline policies and aeronautical technology inevitably turn out to be different than assumed. Retrospective studies invariably show that the actual levels of traffic are significantly different than those forecast. As a rule of thumb, about half the forecasts are off by 20 percent or more after a mere 5 years.

The forecasts are wrong not only as to the level of the traffic but as to the type. This is a crucial observation because different types of traffic impose quite different demands upon an airport. Transfer passengers, for example, need to focus on a single airport and are unconcerned with airport access. Passengers originating in a metropolitan area can, however, be well served by two or more airports, and try to minimize trips to congested areas.

It thus really matters if 34 million passengers (as projected by KPMG Peat Marwick in 1990 for Seattle-Tacoma International Airport in the year 2010) are mostly transfer or locally originating passengers. The Flight Plan forecasts assume that the current percentage of connecting passengers will be the same 30% in the year 2010 as it is now. This may or may not be so, of course, it depends on airline decisions. This level of traffic is properly handled by a single airport if passengers mostly transfer between aircraft (as at

Atlanta), but more appropriately handled by several airports if the traffic mostly originates in the metropolitan area (as for Washington DC).

National Experience as regards levels: Numerous retrospective comparisons of forecasts with the actual traffic that subsequently occurred document the fact that forecasts are routinely inaccurate. As a practical matter for long-term planning we can assume that "a forecast is always wrong".

The inaccuracy of aviation forecasts has been conclusively demonstrated by the US Office of Technology Assessment (1982) that conducted an exhaustive survey of the performance of the US Federal Aviation Administration over two decades. As the FAA each year prepares 5 year forecasts for a broad range of standard categories of aviation activities, their experience provides an excellent statistical sample of the accuracy to be expected from the Nation's principal source of aviation forecasts.

Exhibit 3 documents the discrepancies between forecasts and reality for 8 categories of national aviation activity over 18 years. As can be seen, forecasts are typically off by over 10% -- after only 5 years! Less than a third of the forecasts were under 10%. These "better" forecasts were counterbalanced by the third of the forecasts that were wrong by more than 25% in a mere 5 years.

The discrepancies occur in patterns. For some years they are consistently low (negative errors in Exhibit 3), for other years they are consistently high. Exhibit 4 illustrates this with a graph of some of these data. What happens of course is that the forecasters aim too low in periods of low growth in traffic, and too high in periods of rapid expansion. As expressed at the end of the previous section, forecasting is similar to driving a car by looking in the rear view mirror: extrapolations of recent experience fail to call the turns of traffic.

This analysis of the FAA data is just one of a series of reports that document the inaccuracy of aviation forecasts. A previous study of earlier FAA data, for example, indicated that about half the forecasts of passenger traffic were consistently in error by more than 20%. (see de Neufville, 1976).

The forecasts are more inaccurate for longer terms, as one should expect. A recent examination of forecasts prepared by aviation consultants over the last 20 years for New

England shows that the average error in the forecasts grew by about 25% every 5 years. Exhibit 5 gives the details.

The inability to forecast accurately is a worldwide phenomenon, of course. By way of example, Exhibit 6 presents the series of major forecasts commissioned or executed by the Australian Government for the major Australian airport, Sydney. As can be seen, only one of the three forecasts correctly predicted the traffic a decade ahead. The other two forecasts were each off, up and down, by about a factor of two!

The tendency to give ranges of uncertainty that are far too narrow is evident in Exhibit 6. The forecasts suggest a margin of error of plus or minus 10 to 15%. The more likely error after ten years or more is closer to plus or minus 50%, as discussed above, and in fact was about plus or minus about 100% for two of the three forecasts.

The pretentious precision commonly associated with traffic forecasts is also illustrated by Exhibit 6. As typical, the forecasts are stated to within three and even four decimal places. Yet experience documents that we are fortunate to forecast actual traffic within 25%, and can only hope to be accurate within one or at most two decimal places!

National Experience as regards type of traffic: Many examples illustrate the difficulty of predicting the mix of traffic at an airport. These become most evident when airport facilities have to be refashioned to cope with the needs of a completely different kind of traffic than that anticipated.

Dallas/Forth Worth airport is a prime example of a failure to anticipate the mix of traffic. This airport was designed for high volumes of local traffic: it was built with a series of "gate-arrival" terminals that were to permit passengers to drive to their gates and get to their aircraft by a short walk. In fact the vast majority of the traffic through the Dallas/Forth Worth airport is transfer traffic connecting between planes. Because the terminal buildings only have aircraft on one side of them, they are twice as long as they need to be, and the terminals are quite inappropriate to the traffic.

Exhibit 5: Forecasts become more unreliable as the planning horizon increases, as indicated by Master Plans for the New England Region of the FAA.

Planning Horizon (years)	Average Error (percent)	Range of Errors (percent)
Five	23	64 to 196
Ten	41	58 to 240
Fifteen	78	66 to 310

Source: Maldonaldo (1990)

Exhibit 6: Examples of erroneous international forecasts:
The estimates of international passengers for Sydney, Australia.

Forecast Agency	Date of Forecast	Millions of Passengers for the year 1980	1985	1990
1974 Morgan R Travers	3.77	7.40	9.80	
MANS Study	1978	2.98 to 3.46	3.87 to 4.34	4.71 to 5.51
Dept. of Aviation	1983		2.674 to 3.047	2.762 to 3.751
Actual Traffic	1989			5.34 plus transit

Source: Kinhill Engineers (1985)

The shift in the mix of traffic for Dallas/Forth Worth, from predominately local to predominantly transfer traffic was totally unanticipated by the forecasts. This error was, unfortunately, literally cast into concrete. Such errors need not occur, and would not have occurred at Dallas/Forth Worth if the planners had appreciated the potential inaccuracy of the forecasts.

Another example of the difficulties of forecasting traffic mix -- out of many that might be possible -- involves international traffic for Boston's Logan Airport. Based upon forecasts, its International Terminal was built around 20 years ago. As these forecasts were quite wrong, the terminal was practically empty for many years. In a way this was fortunate, as this empty terminal then provided space for the new domestic shuttle services due to unanticipated deregulation -- although quite awkwardly. Later on, Northwest decided to shift most of its transatlantic services away from New York to Boston, and established a transfer hub at the International terminal. This facility is now jammed with a mixture of international and domestic passengers, performing functions, and serving traffic at a level quite unforeseen by the forecasts of 20 years earlier.

Washington Experience as regards levels and type of traffic: The national experience with regard to the inaccuracy of forecasts is replicated for the state of Washington and for Seattle-Tacoma International Airport. Many local forecasts are in fact really extensions of the national forecasts. For example, the "Demand Forecast Analysis" prepared in June 1992 for the Washington State Air Transportation Commission is based on FAA forecasts (see TRA Consulting, 1992).

Local forecasts are generally much more inaccurate than national forecasts. This is because national figures on traffic aggregate and thus balance out the extreme variations of local figures, thereby minimizing variations. The principle is the same as that of mutual funds, whose performance is more steady than individual stocks.

The relative inaccuracy of forecasts for Seattle-Tacoma International Airport is shown by Exhibits 7 and 8, mirroring at the local level Exhibits 3 and 4 for the national level.

Exhibits 7A and 7B give the relative accuracy of the 6 and 12 year forecasts prepared by the Federal Aviation Administration for the Seattle-tacoma International Airport, for those available in the libraries. Note that, in this sample, the 6 year forecasts are off by 11% on average. The 12 year forecasts are off by 21%, almost exactly twice as much. For comparison, note that the 1990 FAA forecast for Seattle-tacoma predicted 8.75 million enplanements for 1991, that is nearly 10% more than actually occurred 2 years later!

Exhibit 8 plots the various recent forecasts against the actual traffic at Seattle-Tacoma International Airport. It is an updated copy of the an exhibit prepared by P & D Technologies and others in 1988. The forecasts for the master plan of the early 1980's,

lower than most of those shown, unfortunately were not available. Exhibit 8 reinforces the observation, clearly indicated in the national forecasts of the US Federal Aviation Administration, that forecasts are low after periods of low growth, and high after periods of high growth.

The inaccuracy of the forecasts about the mix of traffic is very great indeed. Predictions about the mix are in fact predictions about the components of the total traffic. As indicated above, the errors associated with the parts are usually greater than those of the whole. The recent growth in commuter traffic at Seattle-Tacoma International Airport, tripling in about five years, illustrates the phenomenon. This was seemingly totally unexpected.

Exhibit 7A. Relative Accuracy of 6 year Federal Aviation Administration Terminal Area Forecasts for Seattle-Tacoma International Airport.

Forecast for Year	Millions of Enplanements Forecast	Actual	Percent Difference
1978	3.65	4.60	22
1983	4.77	5.07	6
1984	5.71	5.24	9
1985	6.46	6.82	7
Average 6 year Percent Difference			11

Exhibit 7B. Relative Accuracy of 12 year Federal Aviation Administration Terminal Area Forecasts for Seattle-Tacoma International Airport.

Forecast for Year	Millions of Enplanements Forecast	Actual	Percent Difference
1986	4.52	6.82	34
1988	6.18	7.25	14
1991	9.31	8.05	16
Average 12 year Percent Difference			21

Note: These data represent all the Terminal Area Forecasts now available in the MIT library system. Terminal Area Forecasts were not available from the Seattle District Office of the Federal Aviation Administration, which reports that they throw out their old copies as they are out of date.

5. VOLATILITY OF TRAFFIC

Volatility of traffic is a measure of its variability around a long-term trend. This concept provides a useful means to estimate the reliability of long-term forecasts. When traffic variability is low, it is easier to extrapolate a trend. When traffic variability is high, the existence or probability of large variations in traffic make any extrapolations of trends or forecasts quite unreliable.

Volatility is similar to the concept of standard deviation in statistics, but is more appropriate for traffic for both practical and theoretical reasons. Mathematically, the volatility of traffic is the average of the absolute values of the percent differences between yearly data, and the existing long term trend. (Details are provided in de Neufville and Barber, 1991).

National Experience: Airport traffic is now quite volatile. Substantial changes in the level of traffic are common, both at large and small airports. Exhibit 9 illustrates the phenomenon. Sometimes the traffic shoots up, sometimes it collapses.

Traffic doubled in two years at Raleigh-Durham when American Airlines chose the airport as a hub in its network. Traffic grew by a factor of three at New York/Newark as successive airlines (such as Peoples Express) built it up over only about 5 years to become about the busiest airport in the New York area, serving 21 million instead of 7 million passengers a year. Over the last couple of years, traffic has surged at Washington/Dulles, as United Airlines has built up its East Coast hub there.

Traffic at Chicago/O'Hare collapsed by around 25% when American Airlines moved its center of operations to Dallas/Fort Worth. A comparable decrease at New York/Newark was associated with the bankruptcy of Peoples Express. Similar losses have occurred at Kansas City (when TWA relocated to St.Louis), at Baltimore (following US Air's

acquisition and reorganization of Piedmont), at Denver (due to the bankruptcies of Frontier, Peoples Express and Continental Airlines).

Airport traffic is now especially volatile because of airline deregulation. The managers of airlines can now change their routes, their fares and their hubs on short notice. They have been doing so regularly and frequently. Most recently, for example, US Air dropped Columbus as a hub, Northwest has created an international/domestic hub at Boston, Eastern has collapsed leaving one quarter of the facilities at Atlanta empty. Meanwhile, price wars have created surges in traffic on certain routes.

There is every reason to expect airport traffic to continue to be highly volatile. Massive changes in airline patterns are highly probable in the next decade. The future of TWA is unclear. British Airways seems to be buying into US Air and may be reorienting its traffic. The new Denver airport is coming on stream and might become a principal hub for transpacific traffic for the Mid-Western United States, to the detriment of traffic at Seattle-Tacoma. Deregulation of air travel in Canada and an expanded "open skies" policy between Canada and the United States, might bring passengers back to Canada and away from border airports such as Bellingham and the Seattle-Tacoma International Airport.

Washington Experience: For the Puget Sound region, at least two events illustrate the volatility of air traffic due to deregulation. The most evident, perhaps, is the surge of commuter traffic at Seattle-Tacoma airport between 1986 and 1990. (See the Airport Activity Report - 1990 of the Seattle-Tacoma International Airport). Over only four years, the number of commuter operations tripled, to over 150,000 landings and take-offs a year. As of 1990, there was almost one commuter landing for every landing by a major carrier. As of 1991, however, "commuter operations' double digit growth rates in recent years ended abruptly" (Seattle-Tacoma International Airport draft Airport Activity Report - 1991).

This bubble in commuter operations could persist for a long time. It could also, as a result of short-term boardroom decisions, burst quite quickly. If commuter traffic at Seattle-Tacoma reverted to the pattern and level prevailing 5 or 6 years ago, there might -- for that reason alone -- be no net increase in the number of aircraft operations at Seattle-Tacoma between now and the end of the century.

The relative surge of travel by Canadians through border airports, through Bellingham for example, may also be wiped out by further developments in the North American Free Trade Agreement, or by greater airline deregulation in Canada. According to some Canadian sources, much of the growth in this area has been at the expense of Vancouver. It is not unreasonable to imagine that the tables might eventually be turned, and that the relatively uncongested airport at Vancouver, equipped with its prospective new runway, would attract a fair portion of the hubbing traffic that now passes through Seattle-Tacoma International Airport.

In short, we may expect that air traffic through Seattle-Tacoma will continue to be volatile. Significant shifts in the number of passengers and of operations might easily occur, thus disrupting established trends. This is all the more reason to expect that any forecast made now is quite likely to be wrong by the year 2000 and beyond.

6. UNCERTAINTY ABOUT CAPACITY

A fuzzy concept: The first thing anyone should know about airport capacity is that it is a nebulous concept, whose meaning itself is inherently uncertain.

The concept of the "capacity" of an airport facility is quite unlike the concept of the physical capacity of a container. A quart bottle for example will hold a quart, and will overflow if anyone attempts to pour more into it. This is not the case for airports: airports routinely operate far above their rated capacity. Boston's Logan Airport for instance now serves around 400,000 operations a year with virtually the same facilities that were rated at a capacity of around 250,000 operations a year about 15 years ago.

The concept of the capacity of an airport is rather like the concept of the capacity of a city bus. A bus will ordinarily have a rated capacity of so many riders seated and standing. At rush hour, this capacity may frequently be exceeded by half again as many riders. Naturally, the crowded bus is unpleasant, and riders would generally prefer to have more seats. But the crucial observation is that the physical capacity of the bus, as for an airport facility, is a most imprecise concept.

The capacity of an airport represents an arbitrary level of convenience and comfort. Just as the capacity of a bus allows for a limited numbers of standees and inconvenience, the

capacity of a system of airport runways represents a specific level of average delay. In practice, capacity has been defined by an average delay of about 4 minutes per aircraft.
The connection between airport capacity and delays incurred at the airport, which used to be quite direct, has recently become quite tenuous. Modern air traffic control systems connect the delays at one airport with the delays at the others and, in fact, shift the delays between airports. It used to be that aircraft would arrive somewhere and then wait in a local holding pattern, experiencing a delay that was directly associated with an airport. Now however, air traffic controllers may hold aircraft at other airports to reduce total delays (this is called "flow control") and normally slow aircraft down as they fly between cities so that these now almost never wait in holding patterns. Furthermore, the airlines adjust their schedules to reflect these series of delays (the published travel times between Boston and Washington DC have increased by about 20 minutes over the last 20 years, for example), so that passengers themselves may not even sense any delay at all.

The current system of air traffic control thus makes it difficult to define exactly how new airfield capacity at an airport will reduce delays at that airport. To the extent that delays are due to other cities and other parts of the air transportation system, additional runway capacity would only lead to limited improvements.

In conclusion, although the rated capacity of an airport is a perfectly reasonable benchmark, it is in no way absolute. A region may choose to have its airports operate above capacity, and accept the inconvenience this represents to travellers. A region may alternatively choose to provide high quality service with the intent of making itself attractive to businesses and airlines.

Assessment Factors: The calculation of the rated capacity of an airport involves all kinds of factors that go beyond the physical nature of the facility, of the system of runways and taxiways for example. The capacity depends most importantly on the mix of the types of aircraft, and on the pattern of airport operations throughout the year. It is therefore not possible to look at the facilities and define the rated capacity.

The calculated capacity of a system of runways thus depends upon speculative assumptions. Who knows what the future proportion of commuter traffic will be at the airport, especially when that traffic has been proven to be quite volatile, as at Seattle-Tacoma International Airport? (See discussion in the section on volatility of traffic.) Who

knows whether the distribution of traffic throughout the year will become more or less seasonal?

Capacity depends on the mix of aircraft because different sizes of aircraft must be separated by different distances on landing and take-off. (This is a safety measure, principally to limit wake turbulence to the following aircraft.) Lighter aircraft can be closer together, for example, so that general aviation airports such as Boeing Field have very high capacities. The precise capacity for a runway thus depends upon detailed assumptions regarding both the percent of commuter aircraft operating in the stream of heavier aircraft and the way they will be sequenced.

Capacity also depends on the seasonality of the traffic. As a practical matter, the capacity of a system of runways is first calculated for the busiest period and then estimated for the year using some assumption about the relative distribution of traffic over the year expected at that airport. For identical runways, an airport whose traffic is concentrated in a few months will thus have a rated capacity far less than an airport whose traffic is spread evenly throughout the year.

Capacity depends strongly on the weather. The number of landings and takeoffs that can be done in clear weather, under "visual flight rules" (VFR), is greater than the number that can be done under the variety of bad weather and other conditions requiring "instrument flight rules" (IFR). Operationally, the capacity of an airport which has significant periods of bad weather, as Seattle-Tacoma does, will not be determined by the fair weather maxima, but by the mix and duration of the IFR conditions.

All estimates of airport capacity must therefore be assumed to be uncertain, because of their sensitivity to the changes in the mix and patterns of traffic. This fact reinforces the uncertainties about the level and type of need for future airport expansion. The needs may be greater or less than anticipated, depending on what patterns eventually prevail.

Application to Seattle/Tacoma: With some adjustments, the Flight Plan study largely assumed that the current patterns of use would extend indefinitely into the future. Although this seems like a reasonable first approximation, this approach has some limits.

The Flight Plan study did foresee a decrease in the percent of commuter operations at Seattle-Tacoma International Airport, from the current 43% to about half that by the year 2020. This decrease over about 30 years, to the share that existed just 6 years ago in

1986, is relatively slow. The Flight Plan study essentially assumed that the demand for landings and take-offs would not be managed dramatically. It was not thought reasonable or probable that the large number of smaller aircraft, operated by the commuter airlines, would be forced out, either by high prices or excessive congestion (as has been done at New York/Laguardia or at London/Gatwick, for example). This premise leads to estimates of the demand for airport operations which some might well think too high, especially since commuter traffic at Seattle-Tacoma International Airport represents 43% of the total, a remarkably high figure for a busy airport.

On the other hand, the Flight Plan study assumes that the fraction of International Traffic will stay about the same, and the Flight Plan is thus on this account relatively conservative about the future need for capacity. This is so because the intercontinental traffic is generally constrained to operate over fairly narrow windows of time in a day, periods that are mutually convenient to passengers at both the arrival and departure airports. (Flights from Japan now usually arrive at Seattle-Tacoma in the late morning, for example). Greater than average increases in this traffic thus accentuate the peaks of traffic and thus increase the need for capacity. Specifically, for example, a doubling of the level of international operations, from around 5% to 10% -- which might appear insignificant overall, might in fact be crucial because this increase would be concentrated around the peak 11 am period which defines the capacity of the airport (Seattle-Tacoma International Airport, Airport Activity Reports, 1991 and 1992).

The Flight Plan study has possibly underestimated the need for capacity insofar as there is indeed a strong possibility that transpacific traffic will increase dramatically over the next generation. Seattle faces large reservoirs of increasingly wealthy people in Japan, Korea and Taiwan, who have many reasons to travel away from their congested countries. Japanese, for example, already come to the Pacific Northwest for education (they operate a college at Spokane), for medical care (Portland seems to be a favorite), as well as for vacations. Furthermore, the transpacific air fares are likely to drop since they are quite high compared to fares in North America and across the Atlantic. In short, it is conceivable that Seattle-Tacoma could experience a real boom in transpacific travel. This occurred in Australia, in Sydney in particular, in the last five years.

7. ASSESSMENT OF FLIGHT PLAN FORECASTS

The Assumptions: The Flight Plan basically assumes continued growth for the region along the general pattern of the last decades. This seems like a reasonable interpretation of the long term trends and the prevailing political will of the region. In this regard the Flight Plan might be considerably optimistic.

Put another way, the Flight Plan is not pessimistic about the future of the region's leading industries such as aviation manufacturing, port facilities, lumber operations or the development of computer software -- any of which are vulnerable to competition from outside that region.

Moreover, the Flight Plan does not assume that the region wishes to restrict the level of growth (as distinct from managing the growth). It does not presume that there is any regional will to discourage or prevent immigration to the area, or to limit tourism or other forms of economic growth.

On the other hand, the Flight Plan study is not necessarily over optimistic. It is conservative about the growth in transpacific travel, for example. It is thus, as indicated in the previous section, also conservative about an important aspect of the need for airfield capacity. In general, the Flight Plan study is based on middle-of-the road assumptions that in the aggregate are more likely to be correct than any other single set of assumptions.

Validity of Data: The data used in the analysis appears to be reliable and complete. Other studies might emphasize different factors, but they are not therefore distinctly better.

The figures open to question are the estimates of capacity that result from the analysis. This is primarily because the notion of capacity is inherently nebulous. Additionally, as discussed in the section on capacity, it is increasingly difficult to determine to what degree capacity improvements at particular airports are effective at improving capacity for the airlines, since improvements at one bottleneck may simply displace the perceived lack of capacity to other bottlenecks in the system, for instance at other airports.

Validity of Methodology: The overall methodology used by the Flight Plan study is fairly standard. It is thus subject to all the kinds of limitations suggested in Sections 2 to 5 of this report.

The specific model used by the Flight Plan attempts to predict the future number of passengers is based on assumptions about future levels of population, income per person, and airline fares. Comparable models in other studies have included factors such as "disposable income per person" (which correlates with the desire to travel for vacations), "national income" (which might represent the capability of other people to visit the region), and "competition" (from Vancouver, for instance). Yet forecasts based on more or other factors are not necessarily more accurate, as experience shows.

Technically, almost all the factors one might assume to be important elements in explaining growth in air travel are highly correlated -- causally or by chance -- with each other, and so inherently represent each other. They all tend to grow exponentially over time. This is an important reason that many quite different models correlate so well with a same set of historical data, as Exhibit 2 suggests.

The most fundamental flaw of the methodology used in the Flight Plan study, perhaps, is that of all econometric forecasts: it relies heavily on recent events as a guide to the future, driving as it were by looking in the rear view mirror. Since the most recent years have witnessed relatively high rates of growth in air traffic (see Exhibit 8), there can be a reasonable presumption that the Flight Plan forecast might be on the high side.

Reliability of Analysis: The forecast of the Flight Plan study has been generated by standard procedures using reasonable assumptions. There is thus good reason to suppose that it is as unreliable as the similar forecasts that have preceded it, as discussed in the Sections 4 and 5. Many local factors influence the prospective reliability of the forecasts, some to increase it, some to decrease it as compared to the overall national experience. On balance, the forecasts are quite probably off by plus or minus 25% over the next twenty years or so, if not by much more.

The high (now 43%) percent of commuter traffic at Seattle-Tacoma International Airport increases the likely unreliability of the Flight Plan forecasts. This is because short distance traffic is especially sensitive to changes in price. (If the air fares to Portland or Bellingham are too high, one can go by land, an unlikely alternative for passengers to Chicago or Tokyo). Rapid swings in the levels of air traffic in the Northeast Corridor between Boston, New York and Washington have demonstrated this phenomenon conclusively.

On the other hand, the fact that the traffic at Seattle-Tacoma International Airport largely originates in the area means that it is less volatile, as compared to an airport with a high level of transfer passengers. On this account, the forecasts might be more reliable than the national average.

The fact that about one quarter of the traffic through Seattle-Tacoma is serviced by Alaska Airlines and its affiliates might however be a cause for concern. Although this group has been profitable, smaller regional airlines seem to be disappearing in the current period of consolidation of airlines into megacarriers.

8. PROPER BASIS FOR PLANNING

The proper basis for planning is reality. As regards forecasts, the realistic assessment is that no single forecast for the long term can be assumed to be correct. The fact is that, based on experience, any long term forecast has a good chance of being wrong by anywhere from 25% to 50%.

The search for a better single forecast is quixotic. Any thoughtful person can criticize a particular forecast, especially after it has been published and more recent data have already revealed some discrepancies between a forecast and reality. But the ability to point out deficiencies in another forecast does not give anyone the capacity to produce a better forecast: any proposal for an improved forecast is certain to have its own deficiencies which will soon be revealed by events.

The proper basis for airport planning is thus a broad range of forecasts, both of the level of traffic and of its range of requirements. These need to be matched with an equally realistic broad range of estimates of the capabilities of future airport facilities to serve traffic.

Traffic Ranges: As in any risky situation, the full range of possible scenarios has to be recognized. For Seattle-Tacoma International and the regional airports, there appears to be a strong possibility both that there will be a real need to provide major new additions to

airport capacity in the region, and alternatively that it is conceivable that current facilities could cope with future needs with only modest improvements.

Seattle and the Pacific Northwest is an attractive area, conveniently located on the shortest routes from North America to the growing industrial and population centers in Japan, Korea and China, as well as the rest of the Pacific rim. In this light, the growth in total passengers from the 16 plus million in 1990 to 34 million in 2010 anticipated in the Flight Plan Forecast appears quite reasonable: the implicit average annual rate of growth is about 3.5%, generally low by historical standards.

The Puget Sound region on the other hand faces competition as a commercial and touristic hub from Vancouver and Canada. It will also face competition as an aviation hub from many airports, such as the new airport in Denver. Furthermore, its industrial base in aviation faces an uncertain future against strong foreign competition. While the notion is perhaps heretical, it is possible that the area could suffer a severe economic setback -- as has happened not that many years ago. In this case, a total traffic through the area of around 25 million passengers in the year 2010, comparable to what now exists in Boston, might be more realistic.

The range of passenger traffic that might occur is thus easily between 25 and 35 million in the year 2010. By historical standards this is a narrow range for a 20 year projection. It might be more realistic to suggest that the range of risk to be anticipated by the airport planners should be 30 plus or minus 10 million annual passengers in the year 2010.

Capacity Ranges: The current capacity of Seattle-Tacoma International Airport has been estimated by P & D Aviation (1991d) as 380,000 landings and take-offs a year. This calculation assumes the current mix of aircraft, and distribution of traffic throughout the day. Because the future conditions of these key parameters cannot be known, the current estimates of capacity are not definitive.

Perhaps the key assumption concerns the number of small, commuter aircraft. Depending on how exactly they are sequenced into the stream of larger aircraft, they can alter the capacity of the runways significantly. To the extent that these aircraft can be separated from the stream of heavier aircraft, meaningful increases in the capacity to serve more passengers can be anticipated. This can be done both by serving the smaller aircraft from their own runway, and by reducing the total number of smaller aircraft using the airport

(through the establishment of airport charges that would discourage these users). In any case, it is possible to imagine that incremental measures, short of a major new runway or major new airport, could provide additional capacity to serve more passengers.

Management of the commuter traffic could certainly increase the number of passengers that might use Seattle-Tacoma International Airport. As documented by P & D Technologies (1988, page 3-24) the average number of seats per aircraft fell from over 160 in 1980 to less than 120 in 1990. This drop of over 25% in the ability to carry passengers per aircraft was associated, of course, with the three-fold increase in the number of commuter operations in the last several years.

If the percentage of commuter operations were reduced, it would be possible to increase the ability of Seattle-Tacoma International Airport to handle passengers. This certainly has been the strategy employed at other busy airports, such as New York/Kennedy, Boston/Logan, London/Heathrow and London/Gatwick for example. The success of these procedures is illustrated by the fact that London/Gatwick, which has a lot of poor weather, and must accommodate the bulk of its traffic in the summer months, still manages to serve 20 million passengers a year off of one runway.

The capacity of the existing runway system at Seattle-Tacoma International Airport to serve passengers clearly ranges upwards from what now prevails. It is entirely possible that as many as 20 to 25 million passengers a year could be served without a new runway for heavy, airline aircraft. The situation would then be comparable to New York/Laguardia (which most travellers agree is quite congested indeed).

Range of "Capacity Gap": The "capacity gap" is the difference between the future demand for service and the ability of the airport to provide this service. It is what the planners need to envisage in preparing their plans.

For Seattle-Tacoma International Airport, the "capacity gap" is thus somewhere between: **zero** (if traf

about 20 million passengers (if growth continues and no great gains in runway capacity are practical).

The State of Washington thus faces a significant risk. The region might manage to get by with only modest adjustments. But it is almost certain that something needs to be done

over the next 20 years. What needs to be done, and when this should be done is unavoidably unclear.

9. DYNAMIC STRATEGIC PLANNING

The essence of the airport planning process is that it must deal with risk. There are virtually no major decisions whose results can be anticipated precisely. In choosing between alternative major airport projects, one is essentially choosing between two portfolios of risk.

The alternatives generally fall into one of two categories. The planners can either:

1. Do the necessary to avoid the risk of poor service (this is the safe choice from the aviation point of view, but may be economically and environmentally difficult), or
2. Avoid commitments and hope the problem will go away (which saves money and effort in the short run, but runs the risk of real great difficulties in the long run).

The common sense approach to risky choices, which we all generally apply in our day-to-day life, is to:

1. Prepare to do the necessary, but
2. Defer commitments until they are clearly quite necessary.

Dynamic Strategic Planning embodies this approach. The essential aspect of this process is that it recognizes the uncertainties and attendant risks. It therefore builds flexibility into the plan, so that there are adequate responses to whatever develops. It thus provides insurance against these risks.

The Process: Dynamic Strategic Planning is dynamic in that it responsive to changes in circumstances, and adjusts to them over time. It is strategic in that it takes a long term view of goals and criteria of performance. It is a planning process that extends and improves the existing approaches.

Dynamic Strategic Planning is an extension of the method known as "decision analysis". The central idea of both is to evaluate the available choices of sequences of development choices over time, under the range of possible levels of growth of demands and of

performance. (see de Neufville, 1990, for the methodology, and Maldonaldo, 1990, for the application to airport planning).

The analysis leads to a strategy of development, whose evolution over time depends upon future conditions. Instead of a master plan that indicates that we should inevitably do this, that and the other in a fixed pattern, the strategic plan suggests a first step, and indicates which second (and later) steps are best for different future conditions.

Dynamic Strategic Planning is analogous to playing chess (or any other board game). A chess master:

1. Considers the range of possible events over the long term, (for example. the next 5 or more moves of the opponent);
2. Selects an initial good move, one that has the flexibility to respond appropriately to whatever may arise; and
3. Adjusts the plans continuously, in response to what actually happens.

As in playing chess, good planners do not commit to a long range master plan.

The best first steps are those that provide flexibility and insurance. Planners need flexibility so that they can react easily to new conditions. The public needs the insurance so that it is protected against undesirable outcomes.

Application to Washington State: As applied to Seattle-Tacoma International and regional airports, Dynamic Strategic Planning would lead to:

1. The decision to take one or more steps now that would enable the region to proceed with the provision of eventual major additions to airport capacity, such steps might include the selection of a site for a second major airport, or the execution of an Environmental Impact Statement for a new runway for Seattle-Tacoma International Airport; and
2. The deferral of decisions about actually building new facilities, as well as what kind of major facilities to build, until the necessary preliminary work such as an Environmental Impact statement has been done, and the needs for these facilities becomes more clear.

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