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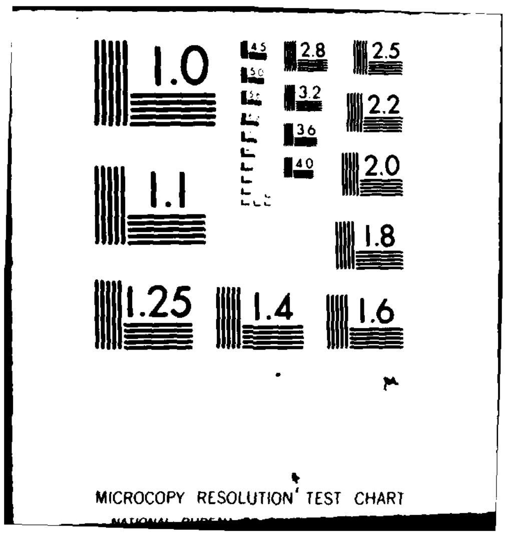
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DECEMBER 1975

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This report develops establishment criteria for Airport Surface Detection Equipment (ASDE-3) radar. ASDE's operational effectiveness must be considered primarily during periods of instrument flight rule (IFR) low visibility and during the busy hours after sunset when the visibility conditions are visual flight rule (VFR). Controllers rarely refer to ASDE during the daylight hours when the entire airport is visible, and most indicate this would be the case regardless of the type and quality of the equipment. However, during periods of reduced visibility ASDE can assist the controllers by providing increased safety in the movement of aircraft while also expediting departures. Arrival rate is also aided under the same circumstances by providing positive assurance of nonoccupancy of runways by ground vehicles as well as aircraft.

This analysis is the basis for the ASDE criteria that are published in Airway Planning Standard Number One. Based on a benefit versus cost analysis, the following establishment criteria have been developed:

1. The airport has a Category III runway; or

2. The airport has 180,000 or more annual itinerant operations, of which 100,000 or more are annual certificated route air carrier operations.



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Appendix B - Sample Ceiling-Visibility Data, Greater Pittsburgh Airport

Appendix C - Hourly Departure Rates (A/C, GA, and MIL)

## EXECUTIVE SUMMARY


This report develops establishment criteria for Airport Surface Detection Equipment (ASDE-3) radar. ASDE's operational effectiveness must be considered primarily during periods of instrument flight rule (IFR) low visibility and during the busy hours after sunset when the visibility conditions are visual flight rule (VFR). Controllers rarely refer to ASDE during the daylight hours when the entire airport is visible, and most indicate this would be the case regardless of the type and quality of the equipment. However, during periods of reduced visibility ASDE can assist the controllers by providing increased safety in the movement of aircraft while also expediting departures. Arrival rate is also aided under the same circumstances by providing positive assurance of nonoccupancy of runways by ground vehicles as well as aircraft.

This analysis is the basis for the ASDE criteria that are published in Airway Planning Standard Number One. Based on a benefit versus cost analysis, the following establishment criteria have been developed:

1. The airport has a Category III runway; or

2. The airport has 180,000 or more annual itinerant operations, of which 100,000 or more are annual certificated route air carrier operations.

Twenty-three airport locations meet these criteria now, and by FY-86 an additional 14 airport locations will be identified as ASDE candidates based on the Terminal Area Forecast, 1976-1986. Of the initial 23 ASDE candidates, 9 presently have ASDE-2 radar installed. The budget impact of the initial 23 ASDE facilities is estimated at $17.2 million.

A queuing or waiting-line model has been used to determine the improved efficiency in releasing departures with and without the aid of ASDE. The safety benefit was developed using the annual instrument operations at an airport as an indication of the level of activity during periods of reduced visibility.

## SECTION I - INTRODUCTION

Control of aircraft on approach and departure paths and on the surface of the airport is currently managed manually by controllers stationed in the cab of the airport control tower. Communications are by voice, and surveillance is mostly accomplished by visual observations and pilot reports. The only controller aids currently available are analog ground surveillance radars (ASDE-2) at nine airports, television cameras at a few airports to cover areas blocked from the controller's view by physical obstacles, and the Airport Surveillance Radar (ASR). The ASR generally covers the airspace within 1 to 60 miles of the airport, but only at a few airports does the coverage include the critical portion of the approach or departure path nearest the runway and no surveillance of the airport surface is provided. In good visibility conditions, the local controller monitors these regions visually; in poor visibility conditions, he must rely on pilot position reports as to aircraft position.

The principal problems for tower controllers have been determined to be accurate determination of aircraft position and, especially for the ground controller, the ability to retain a mental image of the changing traffic situation. These problems are aggravated by restricted visibility due to poor weather conditions; physical obstructions (such as large buildings); night operations; complex taxiway/runway configurations; the great distances from the control tower to the airfield extremities; and high traffic counts. These may lead to controller workload saturation, reduction in airport capacity, aircraft delays, and possibly unsafe operating conditions.

The first attempt to assist the tower controllers in obtaining positive aircraft location during periods of reduced visibility was the deployment of the Airport Surface Detection Equipment (ASDE-2) in the early 1960's. This ASDE-2 radar is still the primary low visibility aid for the controllers who are monitoring aircraft movement on the airport surface. There are 14 ASDE-2 radars in the FAA inventory, and 9 of these are currently commissioned at operational airports. ASDE-2 is a vacuum-tube design that suffers from a number of performance problems. The current ASDE-2 Mean Time Between Unscheduled Maintenance (MTBM) has been 180 hours, and it has very poor performance during periods of precipitation. This latter problem has significantly reduced the radar's operational usefulness. The ASDE-3 radar will be basically solid-state, which should improve reliability and the level of maintenance required. The antenna assembly will be substantially lighter in weight than the ASDE-2, promoting simpler and less costly tower-top installation.

However, it should be noted that a survey of 28 airports that are potential candidates for ASDE equipment indicated that approximately 68 percent of the cabs and 43 percent of the towers/terminal buildings appear to be structurally inadequate to support the ASDE antenna. In some cases very complicated and expensive structural strengthening modification may be necessary to the cabs and the support towers or buildings to support the ASDE antenna and its radome cover.

Examples of the controllers' displays are given in Figures 1 and 2 to illustrate the difference between existing airport surveillance equipment displays and that which will be available on future ASDE's. Elimination of the clutter gives a clear background and target presentation.

As the number of airports equipped to handle Category II (visibility as low as 1,200 feet runway visual range) operations increases from 33 to 59, and the number of Category IIIA (700 feet runway visual range) airports increases from 2 to 12, the need for the ASDE system to supplement the controller's visual surveillance of surface traffic will become more critical. At the larger airports, during both good and poor visibility conditions, ASDE can be used to help expedite peak-hour traffic.

This report includes an analysis of the air traffic control procedures for both the local and ground controller in the air traffic control tower. The analysis will determine in general where an ASDE facility would improve the safety and efficiency of airport operations. The bases for the analysis are the following four studies:

1. A Preliminary Requirements Analysis for Airport Surface Traffic Control, FAA, SRDS, Report No. FAA-RD-73-6, January 1973.

2. Preliminary Operational System Description, Airport Surface Traffic Control (Draft), FAA, TSC, March 1973.

3. Airport Surface Traffic Control Systems Deployment Analysis, FAA, SRDS, Report No. FAA-RD-74-6, January 1974.

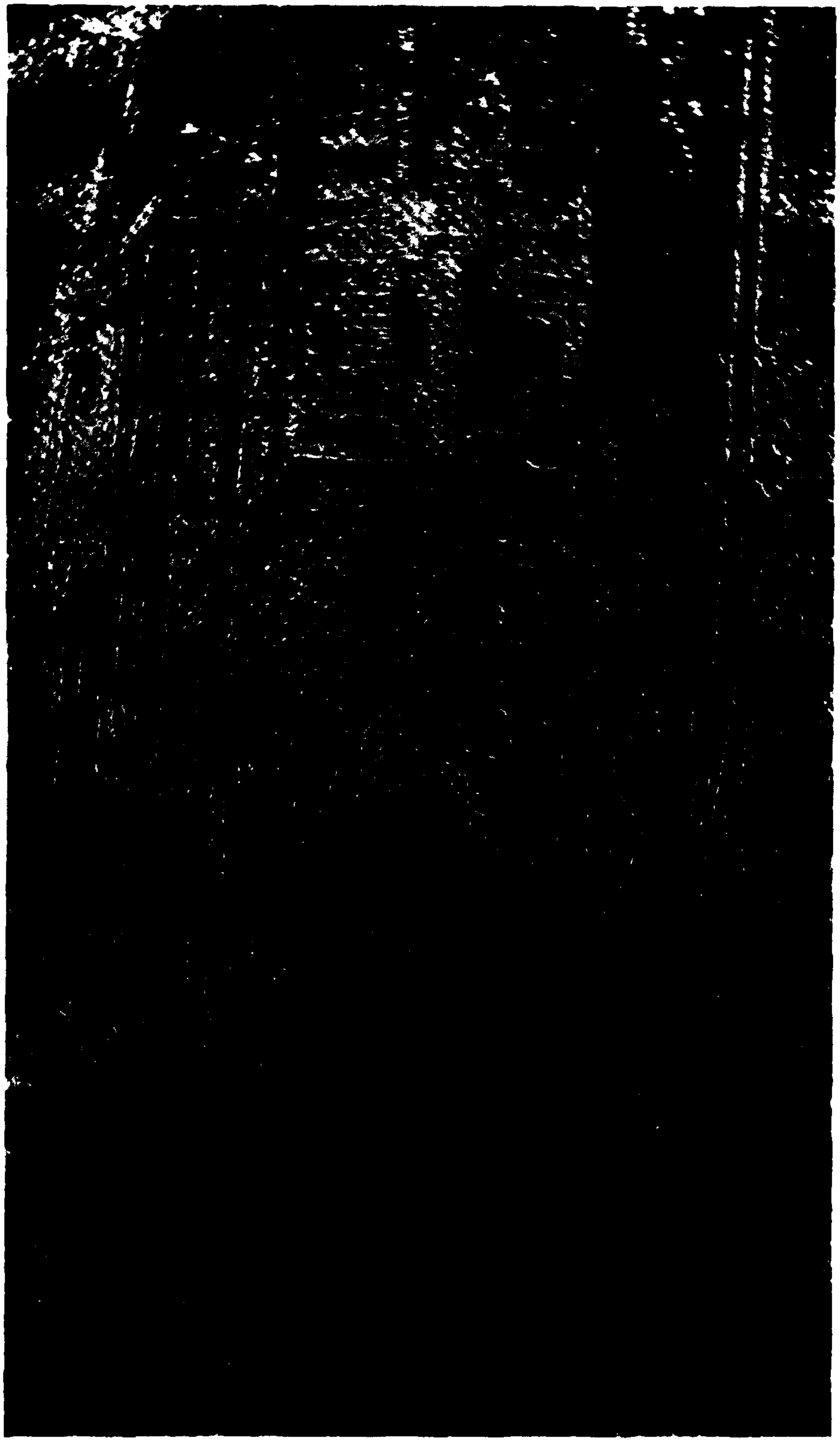


Figure 1. Existing Airport Surveillance Equipment
(Texas Instruments Company)

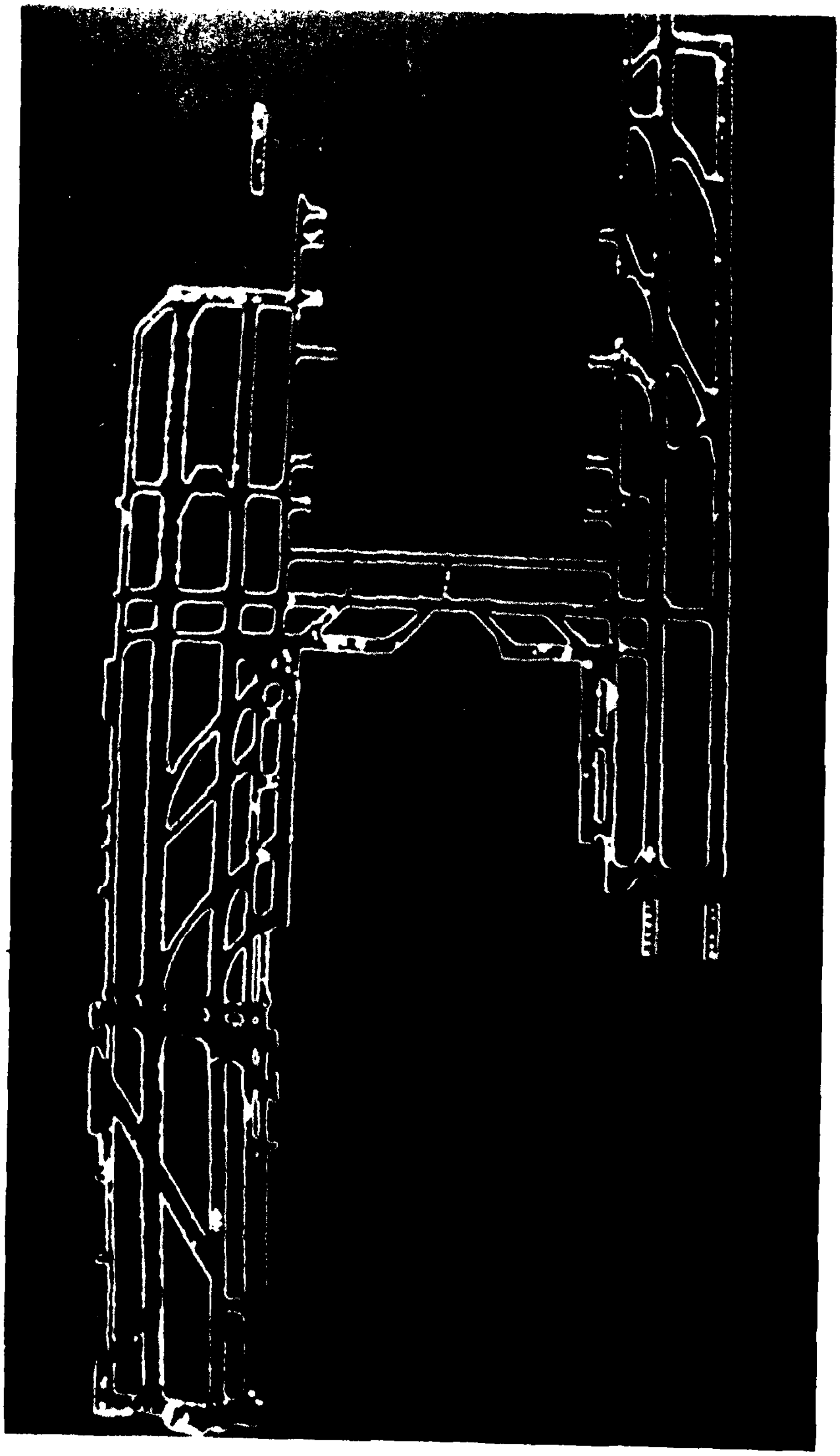


Figure 2. Future ASDE

4. Operations Analysis of Airport Surface Traffic Control (ASTC) System at O'Hare International Airport (Working Paper), Volumes I and II, DOT, TSC, November 1974.

A review of these four studies indicates that an ASDE's value can be assessed for its present and potential contribution to:

1. Safety

2. Operational considerations, i.e., expediting aircraft flow

The following two sections of this report discuss these aspects of the value of ASDE.

## SECTION II - SAFETY BENEFITS

The prime safety factor during restricted visibility conditions is the lack of positive surveillance. For example, in the case of the July 31, 1973, Boston-Logan accident, the use of ASDE may have permitted the local controller to make an instant determination that the aircraft had crashed short of the runway. Also, the use of ASDE would have permitted the local controller to determine that the aircraft had not reached its assigned runway and then could have immediately started some action to determine the aircraft's location. Even though this crash was considered nonsurvivable, the availability of ASDE could have reduced the 8-minute time interval that occurred from the time of the crash until crash/rescue action was initiated.

In an accident at Chicao O'Hare on December 20, 1972, a Convair 880 aircraft taxied without clearance across an active runway and was struck by a departing DC-9. This accident might have been prevented if the local and ground controllers had had ASDE that presented an adequate display for determining aircraft location on the airport surface. Chicago O'Hare had ASDE-2 when this accident occurred, but its performance at times is less than satisfactory. The proposed ASDE-3 will provide the controllers with an improved presentation of aircraft locations. With this improved equipment, the ground controller might not have misunderstood where the taxiing aircraft was and the local controller might have noticed the aircraft crossing the runway.

Controllers have reported very few possible saves due to the loss of ASDE, but there can be no doubt that the potential for accidents exists. Pilot reports of possible accident situations on the airport surface are also rare; and with the present use of ASDE, it is not possible to assess the actual contribution of ASDE to safety. However, the use of ASDE is considered to contribute significantly to safe aircraft operations. The following are examples of the use of ASDE by controllers on a continuing basis during periods of restricted visibility:

1. Insure that a departing aircraft cleared into position for takeoff is lining up on the proper runway of two close parallel runways when an arriving aircraft is on final approach for landing on the adjacent runway.

2. Insure that taxiing aircraft are not inadvertently entering an active runway during fog conditions when the pilot may not be able to see adequately to determine that he is holding clear of a runway.

3. Assist the ground controller in providing separation, preventing collisions, and expediting movement of aircraft and ground vehicles on the airport surface when dense fog prevents controller, pilots, or vehicle operators from seeing other ground traffic on the airport.

4. Determine that runways are clear of other aircraft, ground vehicles, or other obstructions prior to clearing a departing aircraft for takeoff or an arriving aircraft to land.

5. ASDE is used at night to determine positions of aircraft where the distance to the end of the runway and the flat viewing angle from the tower cab do not allow the controller to visually determine relative positions of aircraft awaiting takeoff.

Whatever contribution to safety ASDE makes now, there is no doubt that it will increase with the passage of time. For, as various means are developed for decreasing operating minimums, the number of aircraft moving on the surface during periods of poor visibility will increase. Since pilot and controller vision decreases with the reduction in minimums, this will proportionately increase the potential for collisions with objects other than aircraft and more than proportionately increase the potential for aircraft collisions. Taller, newly constructed towers accentuate the value of ASDE. Due to this increased height, visibility from the tower cab can be obscured while the airport is still operational (i.e., Boston-Logan, Kennedy International, Kansas City).

As so little data is available on accidents that can be identified specifically as being preventable by the use of ASDE, the method developed to quantify safety benefits is an estimate based on a premise of risk reduction. These benefits are estimated as follows: A review of the type of aircraft operating at Chicago O'Hare during November 1974 indicates that over 50 percent of all aircraft operating at that airport are Boeing 727 (33.6 percent) and Douglas DC-9 (20.2 percent). This is then used as a base to estimate that this type of aircraft is that most likely to be involved in an accident on an airport surface. The 1974 costs of these aircraft taken from AVMARK, INC., which is a worldwide aviation market service, is $7.75 million for a B727-200 and $5.5 million for a DC-9. The average cost of these aircraft is $6.625 million. We assume that during the 15-year life of the ASDE one accident, causing only 50 percent damage to the aircraft and no loss of life, will be prevented through the use of ASDE. This then provides the following safety benefit:

| | |
|---|---|
| Average value B727 and DC-9 | $6.625 million |
| 50% damage to value of one aircraft | $3.3125 million |
| This damage dispersed over the 15-year life of ASDE | $220,800 per year |

In order to equate this to the probability of a similar accident occurring at any other airport, the instrument operations at the candidate airport are compared to the instrument operations at O'Hare. For example in FY-74, Greater Pittsburgh Airport had 280,495 total instrument operations, which is 41.1 percent of the base of Chicago O'Hare (682,320 total instrument operations). An annual safety benefit of $90,749 ($220,800 x 0.411 = $90,749) is thus estimated for Greater Pittsburgh. Since no injury benefits are considered, the safety benefit to that extent is underestimated.

## SECTION III - OPERATING CONSIDERATIONS

### Utilization Period

ASDE's operational effectiveness must be considered primarily during periods of extreme low visibility and during the busy hours after sunset when the visibility conditions are VFR. Controllers rarely refer to ASDE during the daylight hours when the entire airport is visible, and most indicate this would be the case regardless of the type and quality of the equipment. To illustrate the periods during which ASDE is considered to provide assistance to the controllers, the following diagram (Figure 3) was developed.

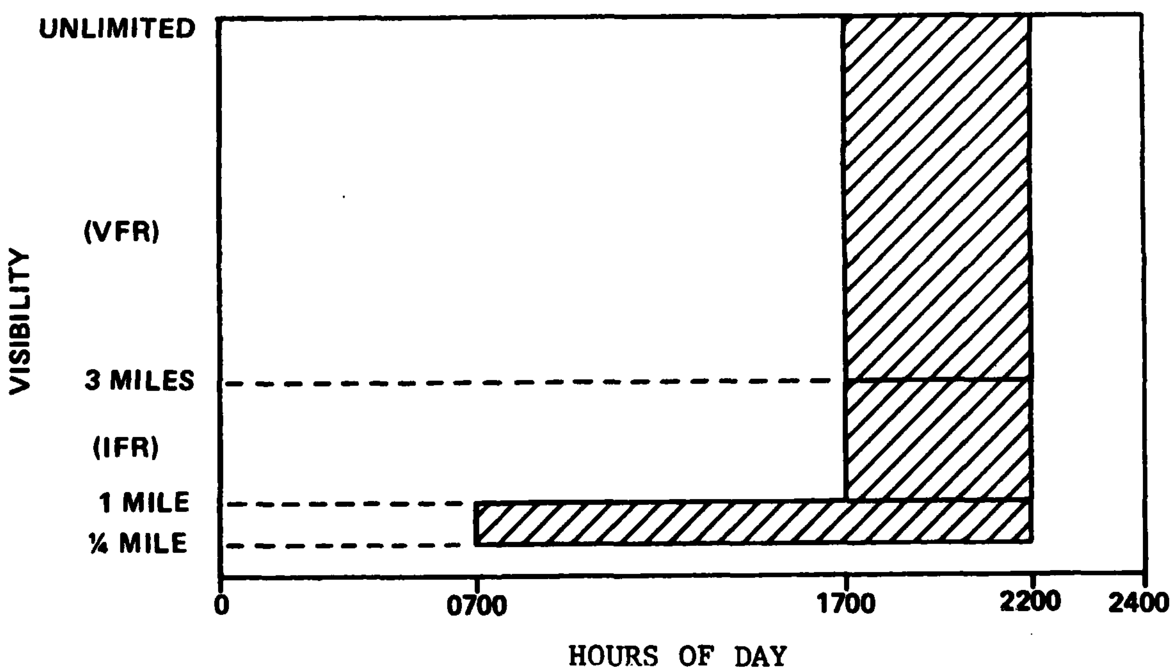



Figure 3. Periods When ASDE Provides Assistance

The shaded areas represent only that portion of the time when ASDE was considered to be of benefit to the controllers in expediting aircraft flow. Consulting the report dated July 1975 entitled "Ceiling-Visibility Climatological Study and System Enhancement Factors" (Reference 9), the ceiling vs. visibility data, for example, at Greater Pittsburgh Airport (Appendix B) indicates different levels of ceilings and visibility. For the purposes of this analysis the ceiling-visibility condition $\geq$1500 feet and 3 miles will be considered VFR conditions which occur 82.9 percent of the time at Greater Pittsburgh Airport. Ceiling-visibility conditions less than these (<1500 feet and/or 3 miles) at Pittsburgh occur 17.1 percent of the time and are considered IFR conditions. This is also the period during which instrument approaches are counted. It is realized that all landing installations do not have an initial approach altitude of 1,500 feet, but the decision was made to use a nominal approach altitude for this study to permit comparison between airports and to avoid the use of variable approach altitudes for each airport. The climatological data contains both ceiling and visibility conditions, but it should be noted that visibility is the factor of importance for this study.

First of all, consider the VFR conditions during the period 1700 hours to 2200 hours which are busy but also dark hours during portions of the year. Reviewing records for the actual time of sunset over a period of a year and during the time of 30 minutes before sunset until 2200 hours, it is dark an average of 62 percent of the 5-hour period from 1700 hours to 2200 hours. Therefore, 3.1 hours of each VFR day [(5 hours) (0.62) = 3.1] were considered for an annual average of the period when ASDE will assist in expediting aircraft flow. This also took into consideration that daylight saving time is in effect from March through October.

Next, consider the IFR conditions during the period of 0700 hours to 2200 hours, which are generally the busy hours for an airport. This period was reduced by considering only the two following IFR conditions:

1. During the period of 0700 hours to 2200 hours when the visibility is less than 1 mile but greater than or equal to 1/4-mile visibility.

2. During the period of 1700 hours to 2200 hours when the visibility is less than 3 miles but greater than or equal to 1-mile visibility.

To illustrate, at Greater Pittsburgh Airport, IFR conditions occur 17.1 percent, but the periods under consideration occur only 2.2 percent and 14.3 percent, respectively.

Aircraft Flow

The magnitude of the contribution of ASDE at any particular airport depends on the runway layout, location of turnoffs, runway combinations used, taxiway configuration, and distribution of traffic. In order to determine specifically where the use of an ASDE will assist in expediting aircraft flow, an analysis of each phase of the aircraft operation from arrival to departure was completed. This analysis is divided into two segments of control, ground and local, each estimating operation rates with and without ASDE.

1. Ground Control - An aircraft lands and after clearing the runway is handed off to ground control for guidance to the terminal area for air carrier (A/C) and air taxi (A/T) aircraft and to a general aviation (GA) area for the GA traffic. Generally this requires minimal guidance because A/C or A/T aircraft are familiar with the taxiway configuration and possible areas of conflict. A delay, if it occurs, is usually in waiting for a gate. GA or military arriving traffic generally experience no routine delay from the runway to the ramp because their taxiway system is often separated from the A/C or A/T traffic.

   Departing aircraft taxiing from the gate or ramp to the end of the runway encounter a majority of the ground delay. No routine delay that would be minimized through the use of ASDE could be identified in the area of aircraft pushback or ramp traffic. Taxi times were found to be relatively independent of traffic density in VFR conditions, with the exception of departure holds at runway ends. During Category II conditions, there was an addition of approximately 50 percent in taxi time, but a large percentage can be attributed to an inability to see by the pilot. Some of the taxi slowdown during Category II conditions may be due to the fact that departure waiting lines exist under these conditions, and there is no particular urgency to expedite traffic flow.

   The conclusion drawn from the analysis of the ground controllers' use of ASDE is that there is no identifiable routine action or time that can be improved with the use of ASDE. Of course, stress or tension is reduced as a direct result of the removal of uncertainty of aircraft locations. The task of attempting to quantify this into monetary terms is not considered realistic. Presumably there would be some safety benefit.

2. Local Control - The capacity of local control is dependent on many external factors. These include visibility and other weather conditions, terminal ATC procedures, runway configuration, traffic demand, demand mix (i.e., arrivals versus departures), aircraft type mix, aircraft weight mix, and aircraft service mix (i.e., IFR versus VFR). This analysis does not examine all of these factors, but it is important to recognize that they exist when arriving at a generalized case.

For arrival aircraft, no queuing or delay time was identified as a result of the local controller not having ASDE. Arrival delays prior to landing occur while the aircraft is being handled by approach control. Delays associated with aircraft movement after clearing the runway were treated in the previous ground control discussion. This is not completely in agreement with the operational procedures for local control, which are to retain control of aircraft until clear of the last active runway for which he is responsible. However, this division did not appear significant for the generalized case as airports with procedures that require aircraft crossing an active runway did not appear in enough cases to include in this analysis. An analysis of a specific airport may allow some improvement in aircraft movement for arriving aircraft with the use of ASDE.

The local controller's primary use of ASDE is to expedite departures following an arrival or a previous departure when his visibility is obscured. Departure aircraft are the local controller's responsibility from the time of entrance into the departure queue until they leave the runway and are turned over to departure control or released. To determine the extent that local control can improve the rate of releasing departures, an examination of different runway utilizations during IFR and VFR conditions, with and without the use of ASDE, was completed.

a. IFR Conditions

(1) Single Runway - Mixed Operation - Normal single-runway operation with an equal mix of arrivals

and departures would be a cyclical operation based on the following:

| | Time (Sec.) |
|---|---|
| Landing aircraft arrives at landing decision point and is given clearance to land | 0 |
| Preceding departure is given vector and handoff to departure control | 10 |
| Landing aircraft touches down | 20 |
| Following arrival reports over outer marker | 20 |
| Departing aircraft is cleared to position-and-hold on the runway | 35 |
| Landing aircraft reaches runway exit | 70 |
| Communication between controller and landing aircraft pilot that he is clear of the runway | 75 |
| Departing aircraft is given clearance for takeoff roll, includes communication | 80 |
| Departing aircraft lifts off and communicates with the local controller | 120 |
| Cycle repeats, or the next landing aircraft is waved off because of a conflict in runway occupancy. The cycle is repeated 30 times per hour to yield 60 operations/hour. | |

The arrival runway occupancy time is dependent on the aircraft type, exit ramp type and location, touchdown (velocity, rate of descent, crab angle, roll angle, and position), and roll out deceleration. Departure occupancy time is dependent on aircraft type and load. The inter-arrival spaces depend on the ability of the approach controller to deliver perfectly spaced arrivals to the outer marker and the final approach velocity profile. The uniform profile is magnified during periods of reduced visibility for local control. The improvement afforded by the use of ASDE will be to expedite departures following arrivals during the IFR and VFR periods illustrated in Figure 3.

When the local controllers lose sight of the runways, they rely on pilot position reports. For example, when ASDE is not available, the controller uses reports from the arriving aircraft or the number 1 departure at the run-up pad to determine touchdown time (in order to clear the next departure onto the runway), from the arrival aircraft on runway turnoff initiation (to permit clearing the departure for takeoff).

The impact of the completely blind operation is evident. In addition to the average of 50 seconds of runway occupancy time for the arriving aircraft, this aircraft taxis an average of 15 seconds before notifying local control that he is clear of the runway. Allowing 5 more seconds for the communication between the pilot of the arriving aircraft and the controller, the departing aircraft is delayed 20 seconds more than it would be if the controller could notify the departing aircraft to roll immediately as soon as he determines that the arriving aircraft is leaving the runway. With the use of ASDE, the 20-second improvement in departure release is possible because of positive identification of aircraft position.

(2) Single Runway - Departures Only - When departures only use one runway and arrivals use another, the controller must rely on pilot communication that Departure 1 is off the runway before releasing Departure 2. Each departure is estimated to take 45 seconds from release by the controller to lift-off. Estimating 10 seconds from lift-off before the pilot contacts the controller and an additional 5 seconds for the communication, Departure 2

is delayed 15 seconds more than it would be if the local controller had the benefit of ASDE.

There are many other runway configurations and combinations that could be analyzed such as crossing runway and close-spaced parallel runways. However, at a majority of the airports an analysis of a single runway with mixed operations or just departures characterized the aircraft operations.

b. VFR Conditions

(1) Single Runway - Mixed Operations - During periods when the local controller's visibility is obscured by darkness, but it is VFR conditions and traffic is heavy, the use of ASDE can expedite aircraft departures. As during IFR conditions, the controller must rely on communication with the pilot to determine aircraft position. When VFR dark hours occur, each aircraft departure without ASDE must wait for an arrival to clear the runway before takeoff release. This builds in a delay of 10 seconds. The basis for this has been established by the controller having to wait 10 seconds in addition to the average 50-second runway occupancy time before the arriving pilot communicates that he is clear or the controller is able to determine visually that the aircraft is clear. This includes 5 seconds for the arriving pilot's communication.

(2) Single Runway - Departures Only - In this situation, the improvement with ASDE is 10 seconds per departure. This assumes no conflict with traffic from other runways. The actual runway occupancy time for each departure is estimated at 45 seconds. The controller usually waits until the departing aircraft notifies him that he is off the runway before he releases the next departure. The 5-second delay from lift-off until the pilot begins to communicate plus the addition of 5 seconds for each communication would not be necessary with the aid of ASDE.

Other runway configurations and utilization could have been analyzed, but these two conditions are considered adequate to demonstrate the benefit of ASDE.

3. <u>Summary</u> - The effects of reduced visibility on departure rates, without and with ASDE, are illustrated in Table I.

TABLE I

Single Runway - VFR & IFR
Mixed Operations & Departures Only

| | | Runway Service Time for Departures* (Seconds) | | |
|---|---|---|---|---|
| | | Without ASDE | With ASDE | Improvements |
| IFR | Mixed | 70 | 50 | 20 |
| | Departures | 60 | 45 | 15 |
| VFR | Mixed | 60 | 50 | 10 |
| | Departures | 55 | 45 | 10 |

*During periods of limited visibility

## SECTION IV - WAITING LINE MODEL

The model used to obtain the differences in time required to serve a departure with and without the aid of an ASDE is a simple single-server queuing system (reference 10). The service times are the period from when an arrival passes over the threshold or a departure is released until the next departure is released. The functions used in the waiting line model are as follows:

| | | |
|---|---|---|
| $T_s$ | = | represents the mean of the service time (i.e., IFR, single runway, mixed operations, without ASDE will take 70 seconds per departure) |
| $\mu = \frac{1}{T_s}$ | = | mean number of departures handled by the runway per minute |
| $\lambda$ | = | arrival rate of departures at the end of the runway per minute. The arrival rate is assumed independnet of the queue length at the end of the runway. |
| $P = \frac{\lambda}{\mu}$ | = | probability of a departure having to wait at the end of the runway |
| $W = \frac{1}{\mu(1-P)}$ | = | the mean time a departure spends in the system (time in minutes a departure spends from arrival to the queue until lift-off from the runway) |
| $\Delta W = (W_i - W_j)$ | | where $i = 1,2,3,4$; $j = 5,6,7,8$. This is the mean time in minutes that a departure will benefit from the use of ASDE. The value of $W_i$ is the mean time a departure spends in the system without the aid of ASDE for the four cases shown in Table I. The value of $W_j$ is the mean time a departure spends in the system with the aid of ASDE for the four cases shown in Table I. |

The variable inputs to the model for a specific airport/ runway are as follows:

1. Itinerant Operations (Reference 12)

   a. Air Carrier (A/C)

   b. Air Taxi (A/T)

   c. General Aviation (GA)

   d. Military (MIL)

2. Climatological Conditions (Reference 9)

   a. Percent of VFR conditions (ceiling-visibility greater than or equal to 1,500 feet and 3 miles)

   b. Percent of IFR conditions (ceiling-visibility conditions between 400 feet and 1 mile and 100 feet and 1/4 mile)

   c. Percent of IFR conditions (ceiling-visibility conditions between 1,500 feet and/or 3 miles and 400 feet and 1 mile)

3. Runway Utilization (obtained from the specific ATCT)

   a. Number of runways with mixed operations for both IFR and VFR conditions. For example, at Greater Pittsburgh Airport during IFR or VFR conditions, one runway is used for mixed operations.

   b. Number of runways that are used for departures only during IFR and VFR conditions. For example, at the Greater Pittsburgh Airport during IFR or VFR conditions, one runway is used for departures only and one for arrivals only.

4. Average Departures per Hour

   a. Use published data for scheduled departures by hour for air commuter, local service, domestic trunk, international operations, and cargo operations (Reference 11)

   b. Add to the scheduled departures estimated departure rates for general aviation and military.

From these above inputs (1-4) the improvement in departure rates can be calculated for a specific airport.

c. Due to the wake turbulence following heavy jets, the departure rate must be modified to allow for the two (2) minutes' clearance after the heavy jet begins takeoff roll. Therefore, the number of heavy jet departures must be included as a variable input. It is assumed that all the heavy jet departures occur during the busy hours of 0700-2200 hours and are also uniformly distributed during this period.

In addition to these variable inputs, the model requires the following constants in order to complete the calculations:

1. General Aviation and Military Departure Rates (Reference 1)

   a. VFR

      (1) Percent GA departures during 1700-2200 hours = 12.4%

      (2) Percent MIL departures during 1700-2200 hours = 16.7%

   b. IFR

      (1) Percent GA departures during 0700-2200 hours = 93.4%

      (2) Percent MIL departures during 0700-2200 hours = 91.8%

      (3) Percent GA departures during 1700-2200 hours = 17.2%

      (4) Percent MIL departures during 1700-2200 hours = 18.0%

2. Factors Used for Estimating Aircraft Operating Costs (Reference 13)

| User Category | Aircraft* Operating Cost/Hr. (dollars) | Aircraft Operating Cost/Min. (dollars) |
|---|---|---|
| A/C | 800 | 13.33 |
| A/T | 250 | 4.17 |
| GA | 100 | 1.67 |
| MIL | 250 | 4.17 |

*Includes flying operations (i.e., crew, fuel and oil, insurance) and maintenance

With the input of all the variables and constants, it is possible to determine the benefits derived by the use of ASDE. An example of a completed calculation using the model is illustrated in Appendix A.

## SECTION V - OTHER CONSIDERATIONS

In addition to the safety benefits and expediting departure flow, other benefits attributed to the use of ASDE are reduced communications and a reduction in stress or tension. Communications are reduced because controllers can see the aircraft on the ASDE bright display, so they need not query pilots when information regarding their location is required. Stress or tension is reduced as a direct result of the removal of uncertainty. Quantifying these types of benefits to any acceptable finite degree does not seem possible. Also, not included as a benefit is a factor that includes growth in aviation activity. Therefore, these benefits have not been included as an input to the analysis and are underestimated to this extent.

Volume of traffic is used as the primary basis for determining if an airport should be a candidate for ASDE. Although there is little doubt that traffic load should have a dominant role in determining eligibility for ASDE, it should not be the sole factor. Low visibility conditions are considered a very important aspect when determining candidate ASDE locations, especially when considering different levels of ILS operations. Aircraft operations are authorized on a Category I ILS/ALS equipped runway with runway visual range (RVR) as low as 1,800 feet. The solid-state Category II ILS/ALS equipped runways now being installed at a number of airports will permit upgrading to Category IIIA. This will support approaches down to touchdown with RVR as low as 700 feet. Because of these possible operating conditions, it has been determined that any airport with a Category III equipped runway is a candidate for an ASDE-3 facility.

## SECTION VI - ASDE COST

An ASDE system will include the primary radar transmitter and receiver, the antenna along with a radome, and the display system.

Annual operating costs of the ASDE system are shown in Table II below. These costs, in part based on the operation of the ASDE-2, are considered liberal since the new equipment will be solid-state and require less maintenance along with fewer stocks and stores. The costs include recovery of the $750,000 (FY-75 dollars) capital investment over a 15-year period at 10 percent compound interest. No salvage value is included at the end of the estimated 15-year life of the equipment.

TABLE II

Estimated Annual ASDE Costs

| Cost Item | |
|---|---|
| Capital Recovery (13.147% per year) | $ 98,602 |
| Maintenace (0.88 man years @ $20,975) | 18,458 |
| Stocks and Stores | 11,100 |
| Other Costs (utilities) | 240 |
| Total Annual Costs | $128,400 |

Data sources: Equipment and installation costs - AAF; Maintenance - AAF-230; Stocks and stores - ALG-20; Other costs based on the electrical energy required to operate the equipment.

## SECTION VII - CRITERIA DEVELOPMENT

The queuing model described in Section IV was applied to 50 airport locations which had the greatest number of instrument approaches in FY-1974. The results of these calculations are given in Table III.

By computing benefit versus cost ratios for each of the 50 airports, certain common traffic activity levels were discerned which separated candidates from noncandidates. It should be noted that the data listed for each airport is in part an estimate. In a final analysis, specific inputs will be necessary from the regions. However, the data does illustrate relationships which were used to develop the planning standard criteria.

In the development of planning standard criteria, one objective is to reduce the error in selecting an airport for an ASDE that would not meet the benefit versus cost criteria. More important, however, we do not want to reject sites that would be candidates under benefit versus cost methodology. Of the 50 sample airports examined, 21 met planning standard criteria but 14 met benefit versus cost criteria. Washington - Dulles International Airport qualifies as an ASDE candidate because it has a Category III runway. These results are summarized in Table IV.

The numeric facility establishment criteria are as follows:

1. An airport is a candidate for ASDE provided that the airport has a Category III runway; or

2. The tower records 180,000 or more annual itinerant operations of which 100,000 or more are annual certificated route air carrier operations.

The discontinuance criteria are as follows:

150,000 or less annual itinerant operations, and/or less than 80,000 annual itinerant air carrier operations.

These discontinuance criteria are predicated on the fact that an ASDE in general is not needed at an airport with less than 150,000 itinerant operations. A review of the 50 sample airport locations indicates that at airports with less than 150,000 itinerant operations, a majority have a predominance of general aviation operations. This type of aircraft operation receives very minor benefits from the use of ASDE. Also,

TABLE III

Summary of Benefit/Cost Data on 50 Airports

| Airport | % VFR | % IFR 3 mi-1 mi | % IFR 1 mi-1/4 mi | A/C and A/T Scheduled Departures 0700-2200 | A/C and A/T Scheduled Departures 1700-2200 | Heavy Jet Sched. Dept. Daily Aver. | Annual Itinerant Operations A/C | Annual Itinerant Operations A/T | Annual Itinerant Operations GA | Annual Itinerant Operations MIL | Annual Instrument Operations | ASDE Installed | B/C Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. ORD | 83.7 | 13.4 | 2.3 | 780 | 246 | 73 | 573,306 | 58,729 | 44,122 | 4,341 | 682,320 | X | 4.76 |
| 2. ATL | 85.5 | 9.8 | 4.0 | 474 | 166 | 21 | 421,861 | 18,024 | 47,553 | 972 | 502,214 | X | 2.79 |
| 3. JFK | 84.5 | 11.8 | 3.0 | 338 | 152 | 53 | 305,746 | 29,560 | 24,246 | 611 | 362,104 | X | 2.77 |
| 4. LAX | 74.3 | 21.1 | 3.1 | 478 | 126 | 72 | 350,808 | 54,123 | 50,991 | 3,971 | 463,181 | X | 2.31 |
| 5. LGA | 83.5 | 13.7 | 2.4 | 300 | 97 | 14 | 265,316 | 15,464 | 57,744 | 643 | 339,152 | | 1.97 |
| 6. PIT | 82.9 | 14.3 | 2.2 | 282 | 98 | 5 | 185,408 | 39,862 | 40,605 | 10,854 | 280,459 | | 1.57 |
| 7. SFO | 84.5 | 14.1 | 0.9 | 286 | 83 | 28 | 275,096 | 15,843 | 40,192 | 4,801 | 335,932 | X | 1.51 |
| 8. DCA | 88.5 | 10.0 | 1.1 | 328 | 108 | 0 | 213,922 | 33,259 | 74,536 | 737 | 325,741 | | 1.53 |
| 9. PHL | 84.3 | 12.9 | 2.2 | 275 | 91 | 10 | 160,093 | 66,335 | 85,915 | 3,224 | 243,705 | | 1.42 |
| 10. DEN | 93.5 | 5.3 | 1.1 | 258 | 82 | 18 | 195,931 | 14,953 | 133,296 | 913 | 342,132 | | 1.35 |
| 11. BOS | 83.8 | 12.8 | 3.0 | 282 | 85 | 11 | 198,947 | 51,161 | 43,947 | 1,016 | 290,852 | X | 1.33 |
| 12. STL | 88.3 | 9.9 | 1.6 | 242 | 75 | 2 | 167,659 | 29,698 | 114,113 | 11,675 | 312,039 | | 1.28 |
| 13. MIA | 97.6 | 1.9 | 0.4 | 258 | 64 | 35 | 232,480 | 23,385 | 69,623 | 1,247 | 330,066 | | 1.25 |
| 14. DTW | 85.9 | 11.1 | 2.3 | 198 | 58 | 21 | 169,348 | 14,636 | 72,834 | 202 | 238,055 | | 1.07 |
| 15. CLE | 84.9 | 13.0 | 1.8 | 172 | 54 | 8 | 126,950 | 18,310 | 77,365 | 1,169 | 223,860 | | 0.96 |
| 16. IAH | 85.4 | 11.0 | 2.6 | 202 | 67 | 10 | 122,774 | 32,097 | 28,040 | 232 | 190,773 | | 0.95 |
| 17. MSP | 88.5 | 10.1 | 1.2 | 178 | 55 | 12 | 130,980 | 16,398 | 67,174 | 7,265 | 237,916 | | 0.94 |
| 18. EWR | 83.2 | 14.0 | 2.3 | 168 | 47 | 8 | 150,088 | 23,840 | 36,102 | 426 | 203,554 | X | 0.93 |
| 19. DAL | 91.3 | 7.6 | 0.9 | 44 | 14 | 8 | 168,091 | 31,829 | 134,920 | 2,003 | 216,068 | | 0.89 |
| 20. MEM | 90.6 | 8.1 | 1.1 | 143 | 47 | 1 | 110,544 | 18,002 | 143,426 | 2,606 | 172,636 | | 0.79 |
| 21. BAL | 87.0 | 9.3 | 2.7 | 124 | 38 | 1 | 74,878 | 31,233 | 101,305 | 2,580 | 203,173 | | 0.76 |
| 22. MSY | 89.1 | 8.1 | 2.0 | 140 | 42 | 7 | 101,603 | 10,572 | 32,505 | 1,254 | 171,499 | | 0.71 |
| 23. IND | 85.2 | 12.2 | 2.1 | 111 | 33 | 1 | 85,508 | 16,747 | 75,704 | 1,889 | 174,594 | | 0.69 |
| 24. SEA | 83.7 | 11.9 | 2.6 | 167 | 51 | 18 | 109,487 | 23,950 | 17,363 | 1,091 | 149,148 | X | 0.68 |
| 25. MCI | 90.0 | 8.9 | 0.9 | 190 | 66 | 1 | 103,785 | 43,283 | 14,398 | 1,079 | 117,176 | | 0.67 |
| 26. CMH | 86.7 | 11.4 | 1.5 | 74 | 24 | 0 | 57,603 | 17,783 | 115,405 | 3,428 | 192,427 | | 0.66 |
| 27. BDL | 83.6 | 12.2 | 3.1 | 84 | 21 | 0 | 66,433 | 42,555 | 388,551 | 15,434 | 85,955 | | 0.64 |
| 28. BNA | 89.9 | 8.4 | 1.4 | 77 | 21 | 0 | 53,032 | 6,638 | 102,450 | 4,367 | 163,715 | | 0.56 |
| 29. MKE | 85.4 | 11.0 | 2.8 | 108 | 33 | 2 | 76,087 | 7,228 | 87,523 | 5,628 | 112,754 | | 0.55 |
| 30. PDX | 89.0 | 7.5 | 2.0 | 102 | 27 | 5 | 78,194 | 3,253 | 57,738 | 10,114 | 146,767 | | 0.50 |

TABLE III (continued)

| Airport | % VFR | % IFR 3 mi-1 mi | % IFR 1 mi-1/4 mi | A/C and A/T Scheduled Departures 0700-2200 | A/C and A/T Scheduled Departures 1700-2200 | Heavy Jet Sched. Dept. Daily Aver. | Annual Itinerant Operations A/C | Annual Itinerant Operations A/T | Annual Itinerant Operations GA | Annual Itinerant Operations MIL | Annual Instrument Operations | ASDE Installed | B/C Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31. CVG | 85.5 | 11.6 | 2.4 | 95 | 22 | 1 | 84,265 | 16,166 | 29,238 | 576 | 102,777 | | 0.50 |
| 32. BUF | 85.8 | 11.5 | 2.2 | 93 | 30 | 0 | 73,841 | 10,382 | 41,887 | 1,139 | 103,667 | | 0.49 |
| 33. SAN | 80.7 | 16.6 | 1.7 | 82 | 16 | 1 | 73,068 | 7,650 | 71,427 | 3,573 | 102,999 | | 0.48 |
| 34. CLT | 86.6 | 9.6 | 3.0 | 78 | 22 | 1 | 63,675 | 6,287 | 109,114 | 3,693 | 103,533 | | 0.48 |
| 35. IAD | 87.6 | 8.3 | 3.1 | 78 | 36 | 7 | 57,666 | 3,878 | 59,694 | 7,858 | 120,135 | X | 0.46 |
| 36. DAY | 84.0 | 13.0 | 2.4 | 66 | 22 | 1 | 53,853 | 3,320 | 80.986 | 455 | 106,313 | | 0.42 |
| 37. SAT | 82.5 | 14.6 | 2.2 | 58 | 19 | 0 | 55,478 | 5,859 | 104,366 | 4,248 | 83,602 | | 0.39 |
| 38. ROC | 88.7 | 9.4 | 1.7 | 61 | 18 | 1 | 46,766 | 3,631 | 65,921 | 2,033 | 101,664 | | 0.38 |
| 39. SNA | 83.3 | 13.6 | 1.9 | 32 | 11 | 0 | 26,662 | 14,100 | 255,842 | 786 | 87,324 | | 0.38 |
| 40. SJC | 91.9 | 6.9 | 0.7 | 60 | 22 | 0 | 48,933 | 7,725 | 149,019 | 663 | 84,448 | | 0.37 |
| 41. OAK | 81.2 | 17.2 | 0.8 | 42 | 15 | 0 | 57,054 | 5,890 | 124,422 | 1,910 | 75,116 | | 0.36 |
| 42. SDF | 89.1 | 9.8 | 0.8 | 68 | 21 | 1 | 55,206 | 5,332 | 31,835 | 4,602 | 83,705 | | 0.35 |
| 43. BUR | 83.1 | 14.3 | 1.9 | 53 | 16 | 0 | 30,295 | 3,883 | 112,022 | 2,965 | 87,999 | | 0.34 |
| 44. BHM | 87.8 | 11.0 | 0.1 | 51 | 15 | 0 | 44,095 | 3,756 | 79,162 | 11,365 | 81,966 | | 0.33 |
| 45. ONT | 77.1 | 17.7 | 4.0 | 52 | 16 | 0 | 33,106 | 18,787 | 52,521 | 7,032 | 62,447 | | 0.30 |
| 46. HOU | 85.4 | 11.0 | 2.6 | 37 | 20 | 0 | 15,086 | 3,176 | 191,252 | 543 | 79,878 | | 0.30 |
| 47. LGB | 75.1 | 19.0 | 3.1 | 16 | 4 | 0 | 5,562 | 9,506 | 247,457 | 8,309 | 75,584 | | 0.27 |
| 48. TEB | 78.8 | 18.5 | 2.2 | 22 | 6 | 0 | 5,681 | 18,404 | 162,832 | 1,739 | 47,075 | | 0.19 |
| 49. TRI | 89.2 | 7.8 | 2.0 | 31 | 15 | 0 | 22,212 | 1,930 | 41,553 | 514 | 36,827 | | 0.15 |
| 50. ISP | 84.5 | 11.8 | 3.0 | 25 | 11 | 0 | 13,265 | 36 | 128,773 | 4,410 | 20,484 | | 0.12 |

## TABLE IV

Survey of Criteria (50 Airports)

Establishment Criteria

| Category | Number |
|---|---|
| Number of Airports with Benefit/Cost Ratio ≥1 | 14 |
| Numeric Criteria: 180,000 annual itinerant operations/ 100,000 air carrier | 20 |
| Numeric Criteria plus Category III Runway: 230,000 annual itinerant operations/ 120,000 air carrier/Category III runway | 21 1/ |

Summary Benefit/Cost Ratios for the 50 Airports

| | |
|---|---|
| $5.0 > B/C \geq 4.0$ = | 1 |
| $4.0 > B/C \geq 3.0$ = | 0 |
| $3.0 > B/C \geq 2.0$ = | 3 |
| $2.0 > B/C \geq 1.0$ = | 10 |
| $1.0 > B/C \geq 0.8$ = | 5 |
| $0.8 > B/C \geq 0.6$ = | 8 |
| $0.6 > B/C \geq 0.4$ = | 9 |
| $0.4 > B/C \geq 0.2$ = | 11 |
| $0.2 > B/C \geq 0$ = | 3 |

1/ Washington-Dulles International Airport is an ASDE-3 candidate because it has a Category IIIA runway even though it has a benefit/cost ratio of 0.46

during periods of limited visibility when ASDE is of assistance to tower controllers, general aviation operations are greatly reduced. This minimizes both the efficiency and safety benefits because aircraft traffic will be generally light.

## SECTION VIII - IMPACT OF CRITERIA

Based on projections of the Terminal Area Forecast of 1976-1986, there will be a total of 37 airports eligible under these proposed establishment criteria for ASDE. Table V outlines the number of airports that are candidates in FY-76 and those additional airports that will be candidates by FY-86.

TABLE V

Projected ASDE Candidates

| Region | FY-76 | FY-86 | Total |
|---|---|---|---|
| NE | 1 | 0 | 1 |
| EA | 7 | 3 | 10 |
| SO | 3 | 2 | 5 |
| GL | 4 | 3 | 7 |
| CE | 1 | 1 | 2 |
| SW | 2 | 1 | 3 |
| RM | 1 | 0 | 1 |
| WE | 3 | 2 | 5 |
| NW | 0 | 2 | 2 |
| AL | 0 | 0 | 0 |
| PC | 1 | 0 | 1 |
| Total | 23 | 14 | 37 |

The budget impact of the initial 23 ASDE facilities is estimated at $17.2 million.

## SECTION IX - SENSITIVITY ANALYSIS OF THE BENEFIT/COST CALCULATIONS

Benefit/cost (B/C) ratios have been calculated for 50 sample airports. The results of these calculations are listed in Table VI.

Efficiency benefits have been divided into three parts: night VFR and the two IFR visibility conditions. The safety benefit, which does not readily subdivide, is listed separately. The percentage contribution of each benefit component to the total benefit/cost ratio is shown also.

At the end of Table VI, averages of the percentages for each part are shown. The averages of the 14 airport locations (1-14) that have a B/C ratio greater than one illustrate that there is a 49-51 split between efficiency and safety benefits. These average percentages change approximately 8 percent for the 36 airport locations (15-50) that have a B/C ratio less than one. The split between efficiency and safety benefits for these latter airports is very close to 41 percent-59 percent.

Those airport locations that have a large safety benefit B/C ratio (greater than 65 percent of total) also have in general a greater number of general aviation operations than the combined air carrier and air taxi operations for that airport. A detailed analysis of these airports would probably indicate that the average value used in the general calculations of safety benefits is too high for the aircraft that are most likely to be involved in an accident. The safety benefit uses the average value of a DC-9 and Boeing 727 which would be too high for an airport which has general aviation operations greater than 50 percent of the total operations. However, the criteria development model can be adapted to a specific airport that will produce a B/C analysis that is tailored to the actual aircraft operations. Except for the value placed on aircraft in the safety benefit calculation, the general criteria model produces fairly uniform results.

It is important to note that significant changes to the inputs of either additions to or reductions of the general criteria model would change the results of the B/C ratios. For example, if the model premise was changed to exclude efficiency benefits during VFR visibility conditions, the total B/C ratio would be reduced approximately 27 percent. This would reduce the number of qualifying airport locations from 14 to 8.

TABLE VI

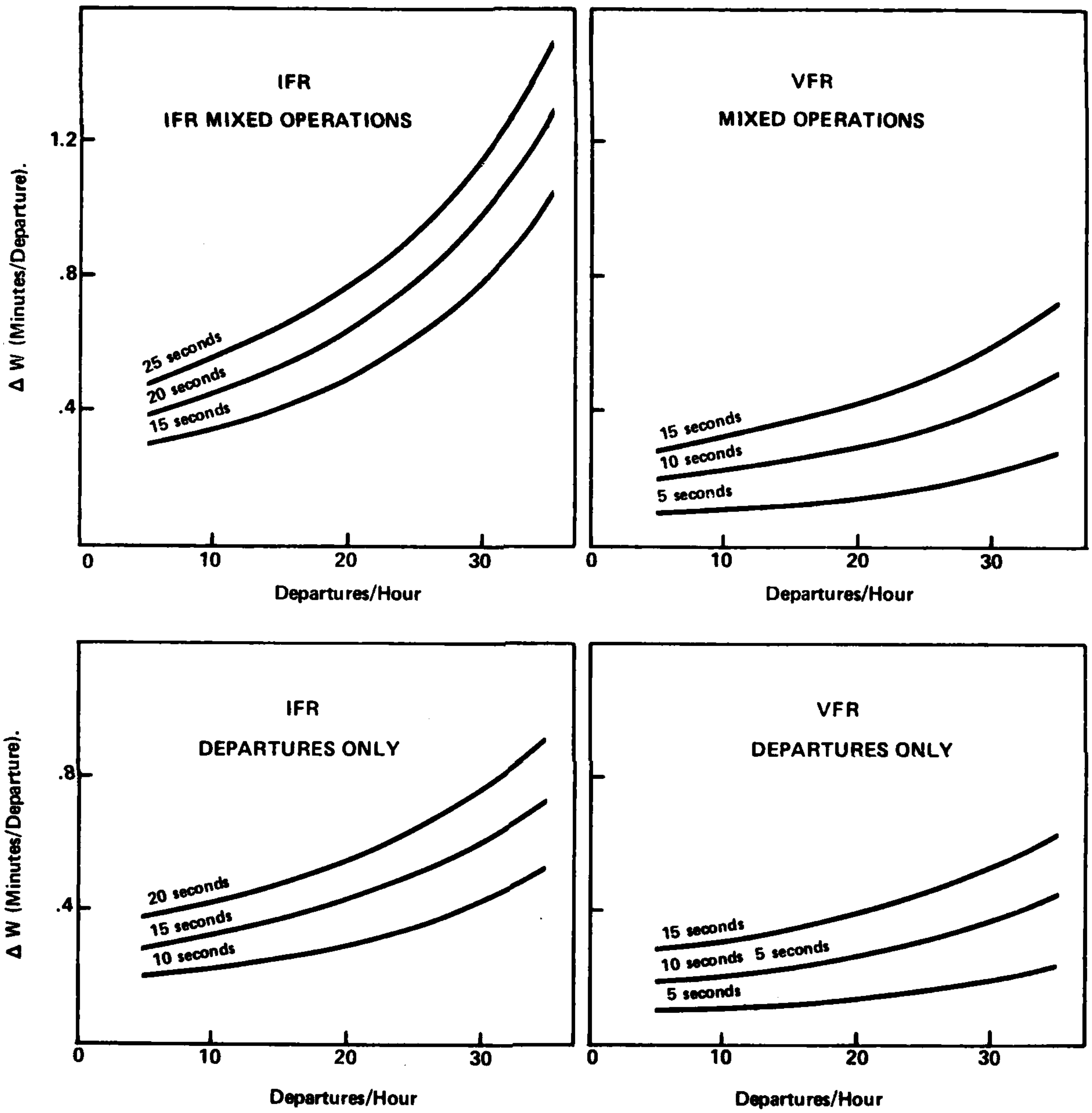
Analysis of Benefit/Cost Calculations

| | Efficiency Benefits | | | | | | Total Efficiency Benefits | | Total Safety Benefits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | VFR 3 mi-∞ | | IFR 3 mi-1 mi | | IFR 1 mi-1/4 mi | | | | | | Total |
| Airport | B/C Ratio | % Total | B/C Ratio | % Total | B/C Ratio | % Total | B/C Ratio | % Total | B/C Ratio | % Total | B/C Ratio |
| 1. ORD | 1.82 | 38.2 | 0.76 | 15.9 | 0.46 | 9.8 | 3.04 | 63.9 | 1.72 | 36.1 | 4.76 |
| 2. ATL | 0.83 | 30.0 | 0.30 | 10.8 | 0.39 | 14.0 | 1.52 | 54.8 | 1.27 | 45.2 | 2.79 |
| 3. JFK | 1.20 | 43.2 | 0.42 | 15.2 | 0.24 | 8.7 | 1.86 | 67.1 | 0.91 | 32.9 | 2.77 |
| 4. LAX | 0.55 | 23.7 | 0.36 | 15.8 | 0.23 | 9.9 | 1.14 | 49.4 | 1.17 | 50.6 | 2.31 |
| 5. LGA | 0.69 | 34.9 | 0.27 | 13.4 | 0.16 | 8.4 | 1.12 | 56.7 | 0.85 | 43.3 | 1.97 |
| 6. PIT | 0.53 | 33.9 | 0.22 | 14.0 | 0.11 | 7.0 | 0.86 | 54.9 | 0.71 | 45.1 | 1.57 |
| 7. DCA | 0.48 | 31.4 | 0.17 | 10.9 | 0.06 | 4.0 | 0.71 | 46.3 | 0.82 | 53.7 | 1.53 |
| 8. SFO | 0.44 | 29.1 | 0.18 | 12.2 | 0.04 | 2.8 | 0.66 | 44.1 | 0.85 | 55.9 | 1.51 |
| 9. PHL | 0.49 | 34.7 | 0.19 | 13.7 | 0.12 | 8.3 | 0.80 | 56.7 | 0.62 | 43.3 | 1.42 |
| 10. DEN | 0.40 | 29.3 | 0.05 | 3.8 | 0.04 | 2.8 | 0.49 | 35.9 | 0.86 | 64.1 | 1.35 |
| 11. BOS | 0.37 | 27.3 | 0.13 | 9.8 | 0.10 | 7.8 | 0.60 | 44.9 | 0.73 | 55.1 | 1.33 |
| 12. STL | 0.35 | 27.0 | 0.09 | 7.3 | 0.05 | 4.1 | 0.49 | 38.4 | 0.79 | 61.6 | 1.28 |
| 13. MIA | 0.38 | 30.4 | 0.02 | 1.7 | 0.02 | 1.4 | 0.42 | 33.5 | 0.83 | 66.5 | 1.25 |
| 14. DTW | 0.30 | 28.3 | 0.09 | 8.3 | 0.08 | 7.3 | 0.47 | 43.9 | 0.60 | 56.1 | 1.07 |
| 15. CLE | 0.22 | 22.8 | 0.10 | 10.7 | 0.05 | 5.1 | 0.37 | 38.6 | 0.59 | 61.4 | 0.96 |
| 16. IAH | 0.27 | 28.6 | 0.11 | 11.6 | 0.09 | 9.4 | 0.47 | 49.6 | 0.48 | 50.4 | 0.95 |
| 17. MSP | 0.23 | 24.4 | 0.08 | 8.4 | 0.03 | 3.6 | 0.34 | 36.4 | 0.60 | 63.6 | 0.94 |
| 18. EWR | 0.26 | 27.7 | 0.10 | 10.7 | 0.06 | 6.7 | 0.42 | 45.1 | 0.51 | 54.9 | 0.93 |
| 19. DAL | 0.28 | 31.0 | 0.05 | 5.2 | 0.02 | 2.7 | 0.35 | 38.9 | 0.54 | 61.1 | 0.89 |
| 20. MEM | 0.28 | 34.8 | 0.05 | 6.9 | 0.03 | 3.4 | 0.36 | 45.1 | 0.43 | 54.9 | 0.79 |
| 21. BAL | 0.15 | 19.8 | 0.05 | 6.3 | 0.05 | 6.4 | 0.25 | 32.5 | 0.51 | 67.5 | 0.76 |
| 22. MSY | 0.18 | 25.8 | 0.05 | 7.1 | 0.05 | 6.4 | 0.28 | 39.3 | 0.43 | 60.7 | 0.71 |
| 23. IND | 0.15 | 21.5 | 0.06 | 9.1 | 0.04 | 5.4 | 0.25 | 36.0 | 0.44 | 64.0 | 0.69 |
| 24. SEA | 0.16 | 23.4 | 0.08 | 11.2 | 0.06 | 9.8 | 0.30 | 44.6 | 0.38 | 55.4 | 0.68 |
| 25. MCI | 0.27 | 39.8 | 0.08 | 12.2 | 0.02 | 3.8 | 0.37 | 55.8 | 0.30 | 44.2 | 0.67 |
| 26. CMH | 0.11 | 16.9 | 0.05 | 6.6 | 0.02 | 3.1 | 0.18 | 26.6 | 0.48 | 73.4 | 0.66 |
| 27. BDL | 0.19 | 28.9 | 0.10 | 15.8 | 0.14 | 21.7 | 0.43 | 66.4 | 0.21 | 33.6 | 0.64 |
| 28. BNA | 0.10 | 17.7 | 0.03 | 5.6 | 0.02 | 3.5 | 0.15 | 26.8 | 0.41 | 73.2 | 0.56 |
| 29. MKE | 0.15 | 27.5 | 0.06 | 10.7 | 0.06 | 10.2 | 0.27 | 48.4 | 0.28 | 51.6 | 0.55 |
| 30. PDX | 0.10 | 19.6 | 0.00 | 0.7 | 0.03 | 5.8 | 0.13 | 26.1 | 0.37 | 73.9 | 0.50 |
| 31. CVG | 0.14 | 28.1 | 0.06 | 11.5 | 0.04 | 8.5 | 0.24 | 48.1 | 0.26 | 51.9 | 0.50 |
| 32. BUF | 0.14 | 28.0 | 0.06 | 11.5 | 0.03 | 7.3 | 0.23 | 46.8 | 0.26 | 53.2 | 0.49 |
| 33. SAN | 0.12 | 24.7 | 0.07 | 15.3 | 0.03 | 6.1 | 0.22 | 46.1 | 0.26 | 53.9 | 0.48 |
| 34. CLT | 0.13 | 26.4 | 0.04 | 8.8 | 0.05 | 10.5 | 0.22 | 45.7 | 0.26 | 54.3 | 0.48 |
| 35. IAD | 0.10 | 22.7 | 0.02 | 4.8 | 0.04 | 6.4 | 0.16 | 33.9 | 0.30 | 66.1 | 0.46 |
| 36. DAY | 0.10 | 22.7 | 0.03 | 8.1 | 0.02 | 5.4 | 0.15 | 36.2 | 0.27 | 63.8 | 0.42 |
| 37. SAT | 0.10 | 26.7 | 0.05 | 12.6 | 0.03 | 7.0 | 0.18 | 46.3 | 0.21 | 53.7 | 0.39 |
| 38. ROC | 0.08 | 22.4 | 0.02 | 5.8 | 0.02 | 3.8 | 0.12 | 32.0 | 0.26 | 68.0 | 0.38 |
| 39. SNA | 0.09 | 22.6 | 0.04 | 11.4 | 0.03 | 7.5 | 0.16 | 41.5 | 0.22 | 58.5 | 0.38 |
| 40. SJC | 0.12 | 32.0 | 0.03 | 7.3 | 0.01 | 2.9 | 0.16 | 42.2 | 0.21 | 57.8 | 0.37 |
| 41. OAK | 0.10 | 28.8 | 0.06 | 16.4 | 0.01 | 2.8 | 0.17 | 48.0 | 0.19 | 52.0 | 0.36 |
| 42. SDF | 0.10 | 27.6 | 0.03 | 9.1 | 0.01 | 2.6 | 0.14 | 39.3 | 0.21 | 60.7 | 0.35 |
| 43. BUR | 0.06 | 18.7 | 0.03 | 10.0 | 0.02 | 5.3 | 0.11 | 34.0 | 0.23 | 66.0 | 0.34 |
| 44. BHM | 0.09 | 26.6 | 0.03 | 10.2 | 0.00 | 0.3 | 0.12 | 37.1 | 0.21 | 62.9 | 0.33 |
| 45. ONT | 0.06 | 20.8 | 0.04 | 14.7 | 0.04 | 11.8 | 0.14 | 47.3 | 0.16 | 52.7 | 0.30 |
| 46. HOU | 0.05 | 17.0 | 0.02 | 7.2 | 0.03 | 7.6 | 0.10 | 31.8 | 0.20 | 68.2 | 0.30 |
| 47. LGB | 0.03 | 11.8 | 0.03 | 9.5 | 0.02 | 8.5 | 0.08 | 29.7 | 0.19 | 70.3 | 0.27 |
| 48. TEB | 0.03 | 16.6 | 0.03 | 13.0 | 0.01 | 7.5 | 0.07 | 37.1 | 0.12 | 62.9 | 0.19 |
| 49. TRI | 0.04 | 26.3 | 0.01 | 7.2 | 0.01 | 6.3 | 0.06 | 39.8 | 0.09 | 60.2 | 0.15 |
| 50. ISP | 0.03 | 28.9 | 0.02 | 13.3 | 0.02 | 14.8 | 0.07 | 57.0 | 0.05 | 43.0 | 0.12 |
| 1-14 Average | | 31.5 | | 10.9 | | 6.9 | | 49.3 | | 50.7 | |
| 15-50 Average | | 24.8 | | 9.7 | | 6.6 | | 41.1 | | 58.9 | |
| 1-50 Average | | 26.7 | | 10.0 | | 6.7 | | 43.4 | | 56.6 | |

The waiting line model was analyzed to determine its sensitivity to one of the primary inputs, the improvement in service times for each of the four departure cases (Table I, page 16). The results of this analysis are graphed and shown in Figure 4.

To illustrate the sensitivity of the 20-, 15-, 10-, and 10-second improvement in service times associated with the four weather/operations combinations, each was graphed using departure rates versus $\Delta W$ (mean time that a departure will benefit from the use of ASDE). These service times were then adjusted plus and minus 5 seconds; these results are plotted on the graphs. An analysis of the 5-second adjustments to the service times indicates that the efficiency benefit changes by approximately 40 percent. For example, if the improvement in departure service times for the four cases was reduced 5 seconds, the efficiency benefit would be reduced approximately 40 percent. Conversely, if the improvement in departure service times for the four cases was increased by 5 seconds, the efficiency benefit would increase by approximately 40 percent. The effect on the total B/C ratio will vary for each airport location depending upon the portion contributed by the efficiency benefit.

The total B/C ratio is sensitive to changes in the inputs of the safety benefits. For example, the existing premise that only one aircraft would be damaged during the 15-year life of ASDE is considered conservative; if this were doubled to include two aircraft colliding, each 50 percent damaged, the safety benefit would double. Conversely, if the safety benefit premise is restricted to the prevention of damage to one aircraft resulting in only 25 percent loss of value, the safety benefit would be reduced by 50 percent. The effect of these changes on the total B/C ratio of course varies for each airport depending on the portion of the total contributed by the safety benefit. However, considering the first case of doubling the safety benefit, at airports with a 50-50 percent split between efficiency and safety benefits the effect on the total B/C ratio would be to increase it by 25 percent.




Note: ΔW = The mean time that a departure will benefit from the use of ASDE

Figure 4. Sensitivity of Improvement in Departure Service Times

## REFERENCES


1. Handbook of Air Traffic Projections, Conus, 1962-1980, FAA, SRDS, Working Paper (Project 150-25), April 1964, page 25.

2. Airport Surface Detection Equipment (ASDE) Operational Effectiveness with and without Bright Display, FAA, SRDS, Report No. RD-64-141, October 1964.

3. Evaluation of the ASDE Bright Display, FAA, NAFEC, Report No. NA-69-20, April 1969.

4. Engineering and Development Program Plan - Airport Surface Traffic Control, FAA, OSEM, Report No. FAA-ED-08-1, July 1972.

5. A Preliminary Requirements Analysis for Airport Surface Traffic Control, FAA, SRDS, Report No. FAA-RD-73-6, January 1973.

6. Preliminary Operational System Description Airport Surface Traffic Control (Draft), FAA, TSC, March 1973.

7. Airport Surface Traffic Control Systems Deployment Analysis, FAA, SRDS, Report No. FAA-RD-74-6, January 1974.

8. Operations Analysis of Airport Surface Traffic Control (ASTC) System at O'Hare International Airport (Working Paper), Volumes I and II, DOT, TSC, November 1974.

9. Ceiling-Visibility Climatological Study and Systems Enhancement Factors, FAA, ASP, July 1975.

10. Waiting-Line Model, Ruiz-Pala, Avilla-Beloso and Hines, Reinhold Publishing Corp., N.Y., 1967, pages 25-28.

11. Profiles of Scheduled Air Carrier Airport Operations, Top 100 U.S. Airports, FAA, AVP, August 1974.

12. FAA Air Traffic Activity, FY-74, FAA, AMS, September 1974.

13. A Concept for New Establishment Criteria for Airport Surveillance Radar, FAA, AVP, NBSIR 74-593, October 1974.

# APPENDIX A

## An Illustration of ASDE Calculations

Estimates of the benefits of an ASDE have been developed in this report using primarily data contained in references 5 through 8. In actual practice, the Regions concerned will be asked to furnish the requisite data. The illustrative calculations below are for Greater Pittsburgh Airport using FY-74 data.

A. Determine daily scheduled A/C and A/T departures from Reference 11 (Profiles of Scheduled Air Carrier Airport Operations, August 1974):

Scheduled departures 0700-2200 hours = 282

Scheduled departures 1700-2200 hours = 98

B. Determine average daily GA and MIL itinerant departures from FAA Air Traffic Activity, FY-74 (Reference 12, Table 4):

General aviation annual itinerant operations = 40,605

Military annual itinerant operations = 10,854

1. IFR conditions during 0700-2200 hours

a. Determine the proportion of daily departures between 0700 and 2200 hours:

General aviation departures = 93.4%

Military departures = 91.8%

Average general aviation and military departures =

$$\left(\frac{40,605}{2}\right)\left(\frac{1}{365}\right)(0.934) + \left(\frac{10,854}{2}\right)\left(\frac{1}{365}\right)(0.918) = 65.60 \text{ daily departures}$$

b. Convert average daily activity to activity during IFR conditions:

Estimating that only GA and MIL activity falls off by 60% during low visibility, this then becomes:

(65.60)(0.4C) = 26.24 daily departures

2. IFR conditions during 1700-2200 hours

a. Determine the proportion of daily departures between 1700-2200 hours:

GA departures = 17.2%

MIL departures = 18.0%

Average GA and MIL departures =

$$\left(\frac{40,605}{2}\right)\left(\frac{1}{365}\right)(0.172) + \left(\frac{10,854}{2}\right)\left(\frac{1}{365}\right)(0.18) = \text{12.24 daily departures}$$

b. Convert average daily activity to activity during IFR conditions:

Estimating that GA and MIL activity falls off by 80% during low visibility conditions and this time period, this then becomes:

(12.24)(0.20) = 2.45 daily departures

3. VFR conditions during 1700-2200 hours

GA departures = 12.4%

MIL departures = 16.7%

Average GA and MIL departures =

$$\left(\frac{40,605}{2}\right)\left(\frac{1}{365}\right)(0.124) + \left(\frac{10,854}{2}\right)\left(\frac{1}{365}\right)(0.167) = \text{9.38 daily departures}$$

C. Determine average departures per hour:

1. a. IFR conditions for period 0700-2200 hours

$$\frac{26.24 + 282}{15\ \text{(hours)}} = \frac{308.24}{15} = \underline{20.55}\ \text{departures/hour}$$

b. IFR conditions for period 1700-2200 hours

$$\frac{2.45 + 98}{5 \text{ (hours)}} = \frac{100.45}{5} = \underline{20.09} \text{ departures/hour}$$

2. VFR conditions for period 1700-2200 hours

$$\frac{9.38 + 98}{5 \text{ (hours)}} = \frac{107.38}{5} = \underline{21.48} \text{ departures/hour}$$

D. Determine airport/runway utilization:

1. At Greater Pittsburgh approximately 91 percent of the operations during both VFR and IFR conditions are departures only on one runway and arrivals only on one runway

a. IFR:

(1) $\frac{20.55}{1}$ = 20.55 departures/hour/runway

(2) $\frac{20.09}{1}$ = 20.09 departures/hour/runway

b. VFR: $\frac{21.48}{1}$ = 21.48 departures/hour/runway

2. At Greater Pittsburgh approximately 9% of the operations are mixed on one runway.

a. IFR:

(1) $\frac{20.55}{1}$ = 20.55 departures/hour/runway

(2) $\frac{20.09}{1}$ = 20.09 departures/hour/runway

b. VFR: $\frac{21.48}{1}$ = 21.48 departures/hour/runway

3. Adjustment for Heavy Duty Jet Departures

Due to wake turbulence following heavy jets on departure, the improvement provided by the use of ASDE in releasing following departures must consider the minimum 2 minute separation. At Greater Pittsburgh there are 5 heavy jet departures (average) per day between 0700-2200 hours. During the period 1700-2200 hours, it is estimated that there are (5/15)(5) = 1.67 heavy jet departures.

The factor "W" for each visibility condition and the mean service time "T" are modified to take into consideration the 2 minute minimum separation behind each of the 5 heavy jet departures.

E. Using the waiting line model, determine the average waiting time for each departure:

1. IFR ceiling-visibility conditions (0700-2200 hours)

a. Mixed operations on one runway (9%)

$T_{s_1}$ = mean service time without ASDE = 70 seconds/departure

$T_{s_5}$ = mean service time with ASDE = 50 secon[illegible] departure

$$\mu_1 = \frac{1}{T_{s_1}} = \frac{1}{70/60} = 0.86 \text{ mean number of [illegible]tures/minute}$$

$$\mu_5 = \frac{1}{T_{s_5}} = \frac{1}{50/60} = 1.20 \text{ mean number [illegible] departure[illegible] minute}$$

$\lambda_a$ = arrival rate of departures at the end of the runway per minute

Using departure rate of 20.55 per hour fo[illegible] one runway

$$\lambda = \frac{20.55}{60} = 0.342 \text{ departures/minute}$$

P = probability of a departure h[illegible]ving to wait at the end of the runway

$$P_{1_a} = \frac{\lambda}{\mu_1} = \frac{0.342}{0.86} = 0.377 \text{ (without ASDE)}$$

$$P_{5_a} \quad \frac{\lambda}{\mu_5} = \frac{0.342}{1.20} = 0.285 \text{ (with AS[illegible]}$$

$W$ = mean time in minutes a departure spends in the system

$$W_{1_a} = \frac{1}{\mu_1 (1-P_{1_a})} = \frac{1}{(0.86)(1-0.377)} =$$

1.866 minutes/departure

Adjust for Heavy Jet Departures

$$W_{1_a} = \frac{(1.866)(308.24) + 5\left(\frac{120-70}{60}\right)}{308.24} =$$

1.80 minutes/departure (without ASDE)

$$W_{5_a} = \frac{1}{\mu_5 (1-P_{5_a})} = \frac{1}{(1.2)(1-0.285)} =$$

1.166 minutes/departure

Adjust for Heavy Jet Departures

$$W_{5_a} = \frac{(1.166)(308.24) + 5\left(\frac{120-50}{60}\right)}{308.24} =$$

1.185 minutes/departure (with ASDE)

$$\Delta W = W_{1_a} - W_{5_a} = 1.880 - 1.185 =$$

<u>0.695</u> minutes/departure

b. Departures only on the runway (91%)

$T_{s_2}$ = mean service time without ASDE = 60 seconds/departure

$T_{s_6}$ = mean service time with ASDE = 45 seconds/departure

$$\mu_2 = \frac{1}{T_{s_2}} = \frac{1}{60/60} = 1.00 \text{ mean number of departures/minute}$$

$$\mu_6 = \frac{1}{T_{s_6}} = \frac{1}{45/60} = 1.33 \text{ mean number of departures/minute}$$

$\lambda_a$ = arrival rate of departures at the end of the runway per minute

Using departure rate of 19.67 per hour for one runway

$$\lambda_a = \frac{20.55}{60} = 0.342 \text{ departures/minute}$$

P = probability of a departure having to wait at the end of the runway

$$P_{2_a} = \frac{\lambda a}{\mu_2} = \frac{0.342}{1.00} = 0.342 \text{ (without ASDE)}$$

$$P_{6_a} = \frac{\lambda a}{\mu_6} = \frac{0.342}{1.33} = 0.257 \text{ (with ASDE)}$$

W = mean time in minutes a departure spends in the system

$$W_{2_a} = \frac{1}{\mu_2(1-P_{2_a})} = \frac{1}{(1.0)(1-0.342)} =$$

1.520 minutes/departure

Adjust for Heavy Jet Departures

$$W_{2_a} = \frac{(1.520)(308.24) + 5\left(\frac{120-60}{60}\right)}{308.24} =$$

1.536 minutes/departure (without ASDE)

$$W_{6_a} = \frac{1}{\mu_6(1-P_{6_a})} = \frac{1}{(1.33)(1-0.257)} =$$

1.012 minutes/departure

Adjust for Heavy Jet Departures

$$W_{6_a} = \frac{(1.012)(308.24) + 5\left(\frac{120-45}{60}\right)}{308.24} =$$

1.032 minutes/departure (with ASDE)

$$\Delta W = W_{2_a} - W_{6_a} = 1.536 - 1.032 =$$

$\underline{0.504}$ minutes/departure

2. IFR ceiling-visibility conditions (1700-2200 hours)

a. Mixed operations on one runway (9%)

$T_{s_1}$ = 70 seconds/departure

$T_{s_5}$ = 50 seconds/departure

$$\mu_1 = \frac{1}{T_{s_1}} = \frac{1}{70/60} = 0.86$$

$$\mu_5 = \frac{1}{T_{s_5}} = \frac{1}{50/60} = 1.20$$

$$\lambda_b = \frac{20.09}{60} = 0.335 \text{ departures/minute}$$

$$P_{1_b} = \frac{\lambda}{\mu_1} = \frac{0.335}{0.86} = 0.390 \text{ (without ASDE)}$$

$$P_{5_b} = \frac{\lambda}{\mu_5} = \frac{0.335}{1.20} = 0.279 \text{ (with ASDE)}$$

$$W_{1_b} = \frac{1}{\mu_1(1-P_{1_b})} = \frac{1}{(0.86)(1-0.390)} =$$

1.906 minutes/departure

Adjust for Heavy Jet Departures

$$W_{1_b} = \frac{(1.906)(100.45) + \frac{5}{15}(5)\left(\frac{120-70}{60}\right)}{100.45} =$$

1.920 minutes/departure (without ASDE)

$$W_{5_b} = \frac{1}{\mu_5(1-P_{5_b})} = \frac{1}{(1.2)(1-0.279)} =$$

1.156 minutes/departure

Adjust for Heavy Jet Departures

$$W_{5_b} = \frac{(1.156)(100.45) + \frac{5}{15}(5)\left(\frac{120-50}{60}\right)}{100.45} =$$

1.175 minutes/departure (with ASDE)

$$\Delta W = W_{1_b} - W_{5_b} = 1.920 - 1.175 =$$

0.745 minutes/departure

b. Departures only on the runway (91%)

$$T_{s_2} = 60 \text{ seconds/departure}$$

$$T_{s_6} = 45 \text{ seconds/departure}$$

$$\mu_2 = \frac{1}{T_{s_2}} = \frac{1}{60/60} = 1.00$$

$$\mu_6 = \frac{1}{T_{s_6}} = \frac{1}{45/60} = 1.33$$

$$\lambda_b = \frac{20.09}{60} = 0.335 \text{ departures/minute}$$

$$P_{2_b} = \frac{\lambda_b}{\mu_2} = \frac{0.335}{1.00} = 0.335 \text{ (without ASDE)}$$

$$P_{6_b} = \frac{\lambda_b}{\mu_6} = \frac{0.335}{1.33} = 0.252 \text{ (with ASDE)}$$

$$W_{2_b} = \frac{1}{\mu_2(1-P_{2_b})} = \frac{1}{(1.0)(1-0.335)} =$$

1.504 minutes/departure

Adjust for Heavy Jet Departures

$$W_{2_b} = \frac{(1.504)(100.45) + \frac{5}{15}(5)\left(\frac{120-60}{60}\right)}{100.45} =$$

1.521 minutes/departure (w out ASDE)

$$W_{6_b} = \frac{1}{\mu_6(1-P_{6_b})} = \frac{1}{(1.33)(1-0.252)} =$$

1.005 minutes/departure

Adjust for Heavy Jet Departures

$$W_{6_b} = \frac{(1.005)(100.45) + \frac{5}{15}(5)\left(\frac{120-45}{60}\right)}{100.45} =$$

1.026 minutes/departure (with ASDE)

$$\Delta W = W_{2_b} - W_{6_b} = 1.521 - 1.026 =$$

<u>0.495</u> minutes/departure

3. VFR ceiling-visibility conditions (1700-2200 hours)

a. Mixed operations on one runway (9%)

$Ts_3$ = 60 seconds/departure (without ASDE)

$Ts_7$ = 50 seconds/departure (with ASDE)

$$\mu_3 = \frac{1}{Ts_3} = \frac{1}{60/60} = 1.00$$

$$\mu_7 = \frac{1}{Ts_7} = \frac{1}{50/60} = 1.20$$

Using a departure rate of 21.48 per hour for one runway

$$\lambda = \frac{21.48}{60} = 0.358 \text{ departures/minute}$$

$$P_3 = \frac{\lambda}{\mu_3} = \frac{0.358}{1.00} = 0.358 \text{ (without ASDE)}$$

$$P_7 = \frac{\lambda}{\mu_7} = \frac{0.358}{1.20} = 0.298 \text{ (with ASDE)}$$

$$W_3 = \frac{1}{\mu_3(1-P_3)} = \frac{1}{(1.0)(1-0.358)} =$$

1.558 minutes/departure

Adjust for Heavy Jet Departures

$$W_3 = \frac{(1.558)(107.38) + \frac{5}{15}(5)\left(\frac{120-60}{60}\right)}{107.38} =$$

1.574 minutes/departure (without ASDE)

$$W_7 = \frac{1}{\mu_7(1-P_7)} = \frac{1}{(1.2)(1-0.298)} =$$

1.187 minutes/departure

Adjust for Heavy Jet Departures

$$W_7 = \frac{(1.187)(107.38) + \frac{5}{15}(5)\left(\frac{120-50}{60}\right)}{107.38} =$$

1.205 minutes/departure (with ASDE)

$$\Delta W = W_3 - W_7 = 1.574 - 1.205 =$$

<u>0.369</u> minutes/departure

b. Departures only on the runway (91%)

$T_{s_4}$ = 55 seconds/departure (without ASDE)

$T_{s_8}$ = 45 seconds/departure (with ASDE)

$$\mu_4 = \frac{1}{T_{s_4}} = \frac{1}{55/60} = 1.09$$

$$\mu_8 = \frac{1}{T_{s_8}} = \frac{1}{45/60} = 1.33$$

Using a departure rate of 21.48 per hour for one runway

$$\lambda = \frac{21.48}{60} = 0.358 \text{ departures/minute}$$

$$P_4 = \frac{\lambda}{\mu_4} = \frac{0.358}{1.09} = 0.328 \text{ (without ASDE)}$$

$$P_8 = \frac{\lambda}{\mu_8} = \frac{0.358}{1.33} = 0.269 \text{ (with ASDE)}$$

$$W_4 = \frac{1}{\mu_4(1-P_4)} = \frac{1}{(1.09)(1-0.328)} =$$

1.365 minutes/departure

Adjust for Heavy Jet Departures

$$W_4 = \frac{(1.365)(107.38) + \frac{5}{15}(5)\left(\frac{120-55}{60}\right)}{107.38} =$$

1.382 minutes/departure (without ASDE)

$$W_8 = \frac{1}{\mu_8(1-P_8)} = \frac{1}{(1.33)(1-0.269)} =$$

1.029 minutes/departure

Adjust for Heavy Jet Departures

$$W_8 = \frac{(1.029)(107.38) + \frac{5}{15}(5)\left(\frac{120-45}{60}\right)}{107.38} =$$

1.048 minutes/departure (with ASDE)

$$\Delta W = W_4 - W_8 = 1.382 - 1.048 =$$

0.334 minutes/departure

F. Determine total annual itinerant operations for A/C, A/T, GA, and MIL and that portion of each that occurs during VFR and IFR ceiling-visibility conditions:

| Type Operation | Itinerant Operations | Percent VFR | VFR Operations | IFR Operations |
|---|---|---|---|---|
| A/C | 185,408 | 82.9 | 153,703 | 31,705 |
| A/T | 39,862 | 82.9 | 33,046 | 6,816 |
| GA | 40,605 | 82.9 | 33,662 | 6,943 |
| MIL | 10,854 | 82.9 | 8,998 | 1,856 |

G. Determine percentages from Table 2 of departure rates for A/C, A/T, GA, and MIL (A/T is estimated to equal the departure rates for A/C):

1. IFR conditions:

a. Departures during 0700-2200 hours (these are constants that apply to all airports)

A/C = 87%

A/T = 87%

GA = 93.4%

MIL = 91.8%

b. Departures during 1700-2200 hours (these are constants that apply to all airports)

A/C = 27.8%

A/T = 27.8%

GA = 17.2%

MIL = 18.0%

2. VFR conditions: Departures during 1700-2200 hours (these are constants that apply to all airports)

A/C = 29.5%

A/T = 29.5%

GA = 12.4%

MIL = 16.7%

H. Determine the percentage of IFR conditions when the ceiling-visibility conditions are between:

1. less than 400 feet and 1 mile but greater than or equal to 100 feet and 1/4 mile (Reference 9)

$$\text{For Pittsburgh} = \frac{2.2}{17.1} = 12.865\%$$

2. less than 1500 feet and 3 miles but greater than or equal to 400 feet and 1 mile (Reference 9)

$$\text{For Pittsburgh} = \frac{14.3}{17.1} = 83.626\%$$

I. Determine benefits in dollars of ASDE expediting departures

1. IFR conditions (0700-2200 hours)

a. Mixed operations on one runway. Use the following factors to complete the benefit equation:

IFR operations from Part F, multiply by 0.5 to obtain departures, the percentage from Part G1a, the percent of IFR conditions from Part H1a, the $\Delta W$ from Part E1a, the average cost of aircraft operation per minute, and the percent of mixed runway utilization from Part D.

| | | |
|---|---|---|
| A/C - (31,705)(0.5)(0.87)(0.12865)(0.695)($13.33)(0.09) | = | $1,479 |
| A/T - (6,816)(0.5)(0.87)(0.12865)(0.695)($4.17)(0.09) | = | 99 |
| GA - (6,934)(0.5)(0.934)(0.12865)(0.695)($1.67)(0.09) | = | 44 |
| MIL - (1.856)(0.5)(0.918)(0.12865)(0.695)($4.17)(0.09) | = | 29 |
| TOTAL | | $1,651 |

b. Departures only on one runway. Use the following factors to complete the benefit equation:

IFR operations from Part F, multiply by 0.5 to obtain departures, the percentage from Part Gla, the percent of IFR conditions from Part Hla, the ΔW from Part Elb, the average cost of aircraft operation per minute, and the percent of departures-only runway utilization from Part D.

| | | | |
|---|---|---|---|
| A/C | - (31,705)(0.5)(0.87)(0.12865)(0.504)($13.33)(0.91) | = | $10,847 |
| A/T | - (6,816)(0.5)(0.87)(0.12865)(0.504)($4.17)(0.91) | = | 730 |
| GA | - (6,943)(0.5)(0.934)(0.12865)(0.504)($1.67)(0.91) | = | 319 |
| MIL | - (1,856)(0.5)(0.918)(0.12865)(0.504)($4.17)(0.91) | = | 210 |
| | TOTAL | | $12,106 |

2. IFR conditions (1700-2200 hours)

a. Mixed operations on one runway. Use the following factors to complete the benefit equation:

IFR operations from Part F, multiply by 0.5 to obtain departures, the percentage from Part Glb, the percent of IFR conditions from Part Hlb, the ΔW from Part E2a, the average cost of aircraft operation per minute, and the percent of mixed runway utilization from Part D.

| | | | |
|---|---|---|---|
| A/C | - (31,705)(0.5)(0.278)(0.836)(0.745)($13.33)(0.09) | = | $3,293 |
| A/T | - (6,816)(0.5)(0.278)(0.836)(0.745)($4.17)(0.09) | = | 221 |
| GA | - (6,934)(0.5)(0.172)(0.836)(0.745)($1.67)(0.09) | = | 56 |
| MIL | - (1,856)(0.5)(0.180)(0.836)(0.745)($4.17)(0.09) | = | 39 |
| | TOTAL | | $3,609 |

b. Departures only on one runway. Use the following factors to complete the benefit equation:

IFR operations from Part F, multiply by 0.5 to obtain departures, the percentage from Part Glb, the percent of IFR conditions from Part Hlb, the

ΔW from Part E2b, the average cost of aircraft operation per minute, and the percent of departures-only runway utilization from Part D.

| | | | |
|---|---|---|---|
| A/C | - (31,705)(0.5)(0.278)(0.836)(0.495)($13.33)(0.91) | = | $22,122 |
| A/T | - (6,816)(0.5)(0.278)(0.836)(0.495)($4.17)(0.91) | = | 1,488 |
| GA | - (6,943)(0.5)(0.172)(0.836)(0.495)($1.67)(0.91) | = | 376 |
| MIL | - (1,856)(0.5)(0.180)(0.836)(0.495)($4.17)(0.91) | = | 262 |
| | TOTAL | | $24,248 |

3. VFR conditions (1700-2200 hours)

a. Mixed operations on one runway. Use the following factors to complete the benefit equation:

VFR operations from Part F, multiply by 0.5 to obtain departures, the percentage from Part G2, the percent of the 1700-2200 hours period when it is dark on an annual basis (62%), the ΔW from Part E2a, the average cost of aircraft operations per minute, and the mixed runway utilization from Part D.

| | | | |
|---|---|---|---|
| A/C | - (153,703)(0.5)(0.295)(0.62)(0.369)($13.33)(0.09) | = | $6,223 |
| A/T | - (33,046)(0.5)(0.295)(0.62)(0.369)($4.17)(0.09) | = | 419 |
| GA | - (33,662)(0.5)(0.124)(0.62)(0.369)($1.67)(0.09) | = | 72 |
| MIL | - (8,998)(0.5)(0.167)(0.62)(0.369)($4.17)(0.09) | = | 65 |
| | TOTAL | | $6,779 |

b. Departures only on one runway. Use the following factors to complete the benefit equation:

VFR operations from Part F, multiply by 0.5 to obtain departures, the percentage from Part G2, the percent of the 1700-2200 hours period when it is dark on an annual basis (62%), the ΔW from Part E2b, the average cost of aircraft operations per minute, and the departure-only runway utilization from Part D.

| | | | |
|---|---|---|---|
| A/C | - (153,703)(0.5)(0.295)(0.62)(0.334)($13.33)(0.91) | = | $56,778 |
| A/T | - (33,046)(0.5)(0.295)(0.62)(0.334)($4.17)(0.91) | = | 3,819 |
| GA | - (33,662)(0.5)(0.124)(0.62)(0.334)($1.67)(0.91) | = | 655 |
| MIL | - (8.998)(0.5)(0.167)(0.62)(0.334)($4.17)(0.91) | = | 589 |
| | TOTAL | | $61,841 |

J. Total saved by expediting departures:

$1,651 + $12,106 + $3,609 + $24,248 + $6,779 + $61,841 = $110,234

K. Determine the safety benefit for Greater Pittsburgh. Using total instrument operations for FY-74 from Reference 12, Table 9.

Chicago O'Hare (base) = 682,320 operations

Greater Pittsburgh = 280,459 operations

Percentage $\frac{280,459}{682,320}$ = 41.1%

Safety benefit at O'Hare $220,800

Safety benefit at Pittsburgh (0.411)(220,800) = $90,749

L. Determine total benefits using inputs from Parts J and K:

$110,234 + $90,749 = $200,983

M. Determine the benefit/cost ratio by using the dollar benefits from Part L and the dollar cost of $128,400:

$$B/C = \frac{\$200,983}{\$128,400} = \underline{1.57}$$

A computer program has been developed to assist in the completion of the above calculations. This program will be used by ASP-110 during the screening of ASDE facility candidates, but it is also available to field and Headquarters offices through coordination with personnel from ASP-110.

# APPENDIX B

CEILING VS. VISIBILITY CLIMATOLOGICAL STUDY (HOURLY OBSERVATIONS)

STATION#94823 PITTSBURGH, PA. (GREATER) PERIOD OF RECORD 1/53-12/64

| HOUR GROUP | | NO.OF OBS | CEILING-VISIBILITY CATEGORIES (%) (1) | (2) | (3) | (4) | (5) | (6) | SYSTEM ENHANCEMENT FACTORS (%) VOR | CAT1 | CAT2 | MIN* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | ALL | 8924 | 71.3 | 28.7 | 22.9 | 3.9 | 0.9 | 1.0 | 79.9 | 13.5 | 3.0 | 3.6 |
| FEB | " | 8129 | 73.6 | 26.4 | 21.7 | 3.1 | 0.9 | 0.7 | 82.0 | 11.7 | 3.5 | 2.7 |
| MAR | " | 8925 | 78.0 | 22.0 | 18.5 | 2.6 | 0.5 | 0.4 | 83.9 | 11.8 | 2.4 | 1.9 |
| APR | " | 8635 | 85.6 | 14.4 | 12.6 | 1.2 | 0.3 | 0.2 | 87.8 | 8.5 | 2.3 | 1.4 |
| MAY | " | 8928 | 88.7 | 11.3 | 9.9 | 0.8 | 0.2 | 0.4 | 87.2 | 7.3 | 1.9 | 3.6 |
| JUN | " | 8640 | 87.7 | 12.3 | 10.7 | 1.1 | 0.2 | 0.3 | 86.7 | 8.7 | 1.9 | 2.7 |
| JUL | " | 8927 | 88.9 | 11.1 | 9.5 | 1.1 | 0.2 | 0.4 | 85.5 | 9.9 | 1.4 | 3.2 |
| AUG | " | 8928 | 87.8 | 12.2 | 10.2 | 1.2 | 0.2 | 0.5 | 83.8 | 9.9 | 1.8 | 4.5 |
| SEP | " | 8638 | 89.1 | 10.9 | 8.8 | 1.0 | 0.5 | 0.6 | 80.4 | 9.6 | 4.1 | 5.9 |
| OCT | " | 8916 | 86.9 | 13.1 | 11.2 | 1.2 | 0.2 | 0.4 | 85.9 | 9.1 | 1.5 | 3.4 |
| NOV | " | 8631 | 82.9 | 17.1 | 14.6 | 1.4 | 0.3 | 0.8 | 85.2 | 8.3 | 1.8 | 4.7 |
| DEC | " | 8924 | 74.4 | 25.6 | 21.6 | 2.8 | 0.5 | 0.8 | 84.4 | 10.8 | 1.8 | 3.0 |
| ANN | 07-13 | 30678 | 76.5 | 23.5 | 20.0 | 2.4 | 0.5 | 0.6 | 85.1 | 10.0 | 2.2 | 2.7 |
| | 14-21 | 35047 | 88.7 | 11.3 | 9.8 | 1.2 | 0.2 | 0.2 | 86.3 | 10.2 | 1.8 | 1.7 |
| | 22-06 | 39420 | 82.9 | 17.1 | 13.9 | 1.9 | 0.5 | 0.8 | 81.3 | 11.0 | 2.9 | 4.8 |
| | ALL | 105145 | 82.9 | 17.1 | 14.3 | 1.8 | 0.4 | 0.6 | 83.9 | 10.4 | 2.4 | 3.3 |

STATION#14777 WILKES BARRE, PA. PERIOD OF RECORD 1/49-12/64

| HOUR GROUP | | NO.OF OBS | CEILING-VISIBILITY CATEGORIES (%) (1) | (2) | (3) | (4) | (5) | (6) | SYSTEM ENHANCEMENT FACTORS (%) VOR | CAT1 | CAT2 | MIN* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | ALL | 11903 | 81.6 | 18.4 | 15.8 | 1.6 | 0.4 | 0.7 | 85.5 | 8.9 | 2.1 | 3.6 |
| FEB | " | 10847 | 83.0 | 17.0 | 13.4 | 2.2 | 0.6 | 0.8 | 78.5 | 13.0 | 3.5 | 5.0 |
| MAR | " | 11902 | 84.5 | 15.5 | 13.2 | 1.4 | 0.5 | 0.4 | 85.4 | 8.9 | 3.1 | 2.5 |
| APR | " | 11518 | 88.9 | 11.1 | 10.2 | 0.6 | 0.2 | 0.1 | 91.8 | 5.3 | 1.5 | 1.3 |
| MAY | " | 11903 | 90.2 | 9.8 | 9.0 | 0.4 | 0.1 | 0.3 | 92.3 | 3.9 | 1.3 | 2.6 |
| JUN | " | 11517 | 92.8 | 7.2 | 6.7 | 0.3 | 0.1 | 0.1 | 93.1 | 3.7 | 1.4 | 1.7 |
| JUL | " | 11902 | 92.8 | 7.2 | 6.5 | 0.4 | 0.1 | 0.3 | 90.0 | 5.5 | 0.8 | 3.7 |
| AUG | " | 11902 | 91.1 | 8.9 | 8.1 | 0.4 | 0.0 | 0.3 | 91.3 | 4.7 | 0.5 | 3.5 |
| SEP | " | 11513 | 89.3 | 10.7 | 9.6 | 0.4 | 0.2 | 0.5 | 89.7 | 3.6 | 1.8 | 4.9 |
| OCT | " | 11902 | 88.4 | 11.6 | 10.3 | 0.5 | 0.2 | 0.6 | 89.3 | 4.6 | 1.3 | 4.8 |
| NOV | " | 11518 | 84.5 | 15.5 | 13.5 | 1.1 | 0.4 | 0.5 | 87.1 | 7.2 | 2.3 | 3.4 |
| DEC | " | 11903 | 81.8 | 18.2 | 15.0 | 1.7 | 0.6 | 0.9 | 82.6 | 9.1 | 3.3 | 4.9 |
| ANN | 07-13 | 40902 | 84.2 | 15.8 | 13.9 | 1.0 | 0.3 | 0.6 | 88.0 | 6.5 | 1.9 | 3.6 |
| | 14-21 | 46739 | 90.8 | 9.2 | 8.1 | 0.6 | 0.2 | 0.2 | 88.2 | 7.0 | 2.5 | 2.3 |
| | 22-06 | 52589 | 87.0 | 13.0 | 11.1 | 1.1 | 0.3 | 0.6 | 85.3 | 8.1 | 2.1 | 4.5 |
| | ALL | 140230 | 87.4 | 12.6 | 10.9 | 0.9 | 0.3 | 0.5 | 87.0 | 7.2 | 2.1 | 3.6 |

CEILING VISIBILITY CONDITIONS (% OF TOTAL OBSERVATIONS)

(1) ≥ 1500 FEET AND 3 MILES

(2) < 1500 FEET AND/OR 3 MILES

(3) < 1500 FEET AND/OR 3 MILES, BUT ≥ 400 FEET AND 1 MILE

(4) < 400 FEET AND/OR 1 MILE, BUT ≥ 200 FEET AND 1/2 MILE

(5) < 200 FEET AND/OR 1/2 MILE, BUT ≥100 FEET AND 1/4 MILE

(6) < 100 FEET AND/OR 1/4 MILE

SYSTEMS ENHANCEMENT FACTORS (CEILING VISIBILITY CONDITIONS)

VOR=FREQ (3)/FREQ(2)

CAT1 ILS=FREQ(4)/FREQ(2)

CAT2 ILS=FREQ(5)/FREQ(2)

*BELOW MINIMUMS=FREQ(6)/FREQ(2)

Table 5 - HOURLY DEPARTURE RATES: Estimated Hourly Departure Rates for Daily CONUS Air Traffic Activity

| | Greenwich Mean Time (Zebra) | | | | | | | | Local Standard Time | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air Carrier | | General Aviation | | | Military | | | Air Carrier | | General Aviation | | | Military | | |
| | | | | VFR | | | VFR | | | | | VFR | | | VFR | |
| Hour | Sch | IFR | IFR | Itin | Lcl | IFR | Itin | Lcl | Sch | IFR | IFR | Itin | Lcl | IFR | Itin | Lcl |
| 0000-0059 | 6.1 | 5.5 | 3.8 | 4.1 | 5.8 | 4.7 | 4.8 | 2.8 | 0.8 | 1.0 | 0.4 | 0.3 | - | 0.6 | 0.8 | 0.1 |
| 0100-0159 | 5.9 | 6.4 | 2.3 | 2.4 | 4.2 | 3.3 | 4.3 | 2.0 | 0.7 | 0.8 | 0.3 | 0.2 | - | 0.7 | 0.6 | 0.1 |
| 0200-0259 | 4.8 | 5.0 | 1.4 | 1.6 | 2.4 | 3.2 | 2.2 | 1.4 | 0.6 | 0.6 | 0.1 | 0.2 | - | 0.5 | 0.3 | - |
| 0300-0359 | 3.4 | 3.9 | 1.1 | 1.1 | 1.1 | 2.5 | 1.5 | 0.8 | 0.4 | 0.5 | 0.2 | 0.2 | - | 0.6 | 0.6 | 0.2 |
| 0400-0459 | 2.2 | 2.9 | 0.8 | 0.7 | 0.3 | 1.7 | 0.9 | 0.4 | 0.4 | 0.6 | 0.5 | 0.6 | 0.3 | 0.9 | 0.6 | 0.3 |
| 0500-0559 | 1.3 | 1.5 | 0.4 | 0.6 | - | 1.1 | 0.6 | 0.2 | 0.5 | 0.8 | 0.9 | 1.6 | 1.1 | 1.7 | 1.2 | 0.2 |
| 0600-0659 | 0.9 | 1.3 | 0.4 | 0.4 | - | 1.0 | 0.9 | 0.2 | 2.1 | 3.3 | 2.8 | 3.7 | 1.9 | 2.4 | 2.4 | 0.9 |
| 0700-0759 | 0.7 | 1.0 | 0.3 | 0.3 | - | 0.4 | 0.6 | 0.2 | 6.3 | 6.4 | 6.5 | 6.3 | 4.3 | 5.3 | 6.3 | 3.9 |
| 0800-0859 | 0.5 | 0.9 | 0.2 | 0.2 | - | 0.4 | 0.3 | 0.3 | 7.1 | 6.4 | 8.1 | 8.0 | 6.7 | 8.3 | 8.3 | 10.0 |
| 0900-0959 | 0.6 | 0.5 | 0.2 | 0.2 | - | 0.4 | 0.5 | 0.4 | 6.9 | 6.5 | 7.1 | 8.5 | 9.7 | 8.6 | 6.2 | 10.8 |
| 1000-1059 | 0.6 | 0.7 | 0.6 | 0.5 | 0.4 | 0.8 | 0.9 | 0.4 | 5.7 | 5.5 | 6.9 | 8.3 | 9.3 | 7.6 | 6.8 | 10.9 |
| 1100-1159 | 1.9 | 2.0 | 1.8 | 1.4 | 0.9 | 1.2 | 1.5 | 0.8 | 5.2 | 5.4 | 6.7 | 7.5 | 8.4 | 6.7 | 6.7 | 9.0 |
| 1200-1259 | 4.4 | 4.0 | 4.5 | 3.4 | 2.0 | 2.5 | 3.4 | 3.5 | 5.4 | 5.6 | 6.5 | 7.3 | 6.4 | 6.8 | 8.8 | 6.6 |
| 1300-1359 | 6.0 | 5.0 | 6.3 | 5.7 | 3.8 | 5.1 | 5.3 | 8.7 | 5.6 | 5.4 | 7.5 | 8.3 | 8.2 | 8.3 | 10.1 | 9.0 |
| 1400-1459 | 6.5 | 6.0 | 7.2 | 7.3 | 5.9 | 6.7 | 6.9 | 9.6 | 5.7 | 5.7 | 9.3 | 8.7 | 8.0 | 8.1 | 7.5 | 12.4 |
| 1500-1559 | 6.0 | 6.3 | 7.1 | 7.8 | 8.0 | 7.9 | 6.8 | 9.7 | 6.3 | 6.1 | 9.3 | 8.8 | 9.4 | 6.9 | 7.6 | 7.0 |
| 1600-1659 | 5.8 | 6.0 | 7.0 | 7.9 | 8.6 | 8.8 | 6.4 | 9.8 | 6.3 | 6.2 | 8.3 | 7.9 | 7.9 | 5.7 | 6.8 | 5.3 |
| 1700-1759 | 5.6 | 5.6 | 6.8 | 7.7 | 8.4 | 7.0 | 7.3 | 8.2 | 6.7 | 6.5 | 7.5 | 5.4 | 8.0 | 5.1 | 4.9 | 4.0 |
| 1800-1859 | 5.5 | 5.6 | 6.7 | 7.7 | 8.0 | 7.5 | 8.5 | 8.1 | 7.0 | 6.3 | 4.5 | 3.2 | 5.4 | 4.4 | 4.1 | 2.0 |
| 1900-1959 | 5.9 | 5.5 | 8.5 | 8.1 | 7.9 | 7.1 | 8.1 | 10.6 | 6.0 | 5.3 | 2.2 | 1.8 | 3.5 | 3.6 | 4.4 | 2.9 |
| 2000-2059 | 6.4 | 6.3 | 9.4 | 8.5 | 8.0 | 7.8 | 8.4 | 8.4 | 5.5 | 5.5 | 1.7 | 1.1 | 1.3 | 2.6 | 2.1 | 2.8 |
| 2100-2159 | 6.3 | 6.2 | 9.1 | 8.7 | 8.5 | 6.9 | 7.6 | 6.0 | 4.3 | 4.2 | 1.3 | 0.9 | 0.2 | 2.3 | 1.2 | 0.7 |
| 2200-2259 | 6.1 | 5.9 | 7.9 | 7.8 | 8.2 | 6.3 | 6.2 | 4.9 | 2.8 | 3.2 | 1.0 | 0.7 | - | 1.4 | 1.2 | 0.6 |
| 2300-2359 | 6.6 | 6.0 | 6.2 | 5.9 | 7.6 | 5.7 | 6.1 | 2.6 | 1.7 | 2.2 | 0.4 | 0.5 | - | 0.9 | 0.5 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Sources: IFR based on FY 1962 Peak Day Enroute IFR Air Traffic Survey reports. General Aviation and Military VFR Itinerant based on 5% sample of VFR flight plans. Air Carrier Scheduled Departures are the average of May 1962, November 1962 and May 1963 schedules published in Official Airline Guide. General Aviation Local based on 1959 general aviation summer survey. Military local based on local flight activity survey in August 1961.