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Establishment and Discontinuance Criteria for Runway Visual Range (RVR) at Category I Precision Landing System Runway

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16. Abstract

This report presents a benefit/cost analysis of and develops establishment and discontinuance criteria for the Touchdown Runway Visual Range (RVR) System at the first two Category I precision instrumented runways at an airport. These criteria developed herein will be effected through a change to FAA Order 7031.2C, Airway Planning Standard Number One (APS-1). APS-1 contains the policy and summarizes the criteria used in determining eligibility of terminal locations for establishment, discontinuance and improvements of air navigation facilities and air traffic control services.

Applying the RVR benefit/cost criteria to 470 Category I runways at 359 airport traffic control tower locations identifies 103 airports satisfying the criteria for an initial Category I Touchdown RVR and 107 airports satisfying the criteria for both a first and second Category I Touchdown RVR, for a total of 317 qualifying runways. However, since benefit/cost criteria are only but one of several inputs to the FAA decisionmaking process relative to investment in airport facilities and equipment, the ultimate site-specific investment action must be based on all pertinent factors and considerations.

The sensitivity of the criteria results to several key assumptions is also examined.

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EXECUTIVE SUMMARY

This report documents a benefit/cost analysis of the Touchdown Runway Visual Range (RVR) System at the first two Category I precision instrumented runways at an airport. Based on this analysis, revised establishment criteria and new discontinuance criteria for the Touchdown RVR System at such locations are developed for publication in FAA Order 7031.2C, Airway Planning Standard Number One (APS-1). APS-1 contains the policy and summarizes the criteria used in determining eligibility of terminal locations for establishment, discontinuance and improvements of air navigation facilities and air traffic control services.

The establishment criteria developed in this report replace previous criteria which were based simply on traffic activity. Additionally, the revised criteria address the establishment of a Touchdown RVR System at the second Category I precision instrumented runway at an airport, whereas the previous criteria addressed only the establishment of an initial Touchdown RVR System. The newly developed discontinuance criteria will necessitate a tantamount change to paragraph 7g(2) of Order 6560.10B which currently provides that "RVR systems presently installed at Category I locations not meeting the...requirements of Order 7031.2B (currently designated Order 7031.2C) may be retained..." RVR is a required component of Category II and III precision instrumented runways, per the criteria in Order 6560.10B, and as such is not subject to the criteria developed in this report.

The primary benefits of the Touchdown RVR System is the provision of better information to the air traffic controller and the pilot, allowing aircraft to land and takeoff when they otherwise could not. These benefits are computed, in part, from a site-specific percentage of time when visibility conditions will allow landings and takeoffs with an RVR but would not allow them without it. Although this percentage is relatively small, the benefits can be substantial at high activity runways. Only Category I precision instrumented runways (i.e., with a Category I Instrument or Microwave Landing System) with an acceptable means of disseminating RVR data to pilots (e.g., airport traffic control tower, combined station/tower, or where appropriate, a remote approach control facility) and a benefit/cost ratio of at least unity will be considered candidates for establishment of a Touchdown RVR System. Further, the provisions of FAA Order 6560.10B, Runway Visual Range, and the siting and installation standards of FAA-STD-008 must be met. An existing Touchdown RVR System at a Category I precision instrumented runway may be considered for discontinuance when the benefit/cost ratio falls beneath 0.40, the point at which net recurring operations and maintenance costs generally begin to exceed net benefits.

Applying the revised establishment criteria to 470 Category I runways at 359 traffic control tower locations identifies 103 airports satisfying the criteria for an initial Category 1 Touchdown RVR and 107 airports satisfying the criteria for both a first and second Category I Touchdown RVR, for a total of 317 qualifying runways. The 210 qualifying initial runways compares to 194 qualifying candidates for an initial Touchdown RVR System under the previous criteria. Applying the difference of 16 installations to their respective life-cycle costs results in a potential and conceptual budgetary impact of approximately $3.0 million (1985 present value dollars).

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CHAPTER I - INTRODUCTION

Good management of proposed capital investments requires analysis and comparison of benefits and costs. FAA evaluates many of its investments in terminal navigation aids, communication aids, and air traffic control services for the National Airspace System by applying standard establishment and discontinuance "criteria." These criteria are summarized in FAA Order 7031.2C, Airway Planning Standard Number One - Terminal Air Navigation Facilities and Air Traffic Control Services (APS-1) (Reference 1). For less expensive equipment and facilities, the criteria are normally expressed in simple traffic activity thresholds, e.g., an airport with 50,000 annual aircraft operations qualifies for an Automatic Terminal Information Service. More complex and expensive facilities and equipment are normally supported by more complex criteria based on benefit versus cost considerations.

This report documents a benefit/cost analysis of the Touchdown Runway Visual Range (RVR) System at the first two Category I precision instrumented runways at an airport over an economic life-cycle of 15 years. Based on this analysis, revised establishment criteria and new discontinuance criteria for the Touchdown RVR System at such locations are developed. RVR is a required component of Category II and III precision instrumented runways, per the criteria in Order 6560.10B, and as such is not subject to the benefit/cost based criteria developed in this report. A discussion of benefit/cost analysis as applied to FAA investment and regulatory analyses in general may be found in Economic Analysis of Investment and Regulatory Decisions - A Guide (Reference 2).

A. Kinds of Benefits and Costs

FAA's economic criteria are based on four broad categories of benefits and three categories of costs. These categories are briefly outlined below, but as indicated not all apply to RVR:

- Safety benefits stem from the assumption that many investments reduce accidents or accident risk. Since the Federal Aviation Regulations (FAR's) account for whether or not an RVR system is operating, no incremental safety benefits accrue from a Touchdown RVR System.

- Avoided flight disruption benefits in the form of reduced aircraft variable operating costs and passenger time savings are realized when an investment results in opening an airport to traffic when it otherwise would have been closed. Avoided flight disruptions are the principal benefit of the Touchdown RVR System.

- Productivity benefits result when an investment reduces required resources or when it permits more to be accomplished with the same resources. The RVR system, in itself, does not reduce manpower requirements, but as indicated below it may reduce controller workload.

- <u>Other benefits</u> can be better described and recognized qualitatively rather than quantitatively. Airport traffic control tower controllers find the Touchdown RVR system useful because it reduces the need to make repeated human observations during periods of marginal weather conditions.

- <u>Facilities and equipment costs</u> include the capital expenditure for the equipment or facility and operational start-up costs (e.g., site improvements to accommodate and install it). Ideally, these costs should be estimated on a site-specific basis to account for the existence or lack of siting problems. In a discontinuance benefit/cost analysis, onetime costs of discontinuing operation are considered.

- <u>Operation and maintenance costs</u> include recurring labor, materials and overhead costs.

- <u>Life-cycle costs</u> are the discounted present value sum of facilities and equipment costs and operation and maintenance costs over the (economic) life of the investment.

B. "Critical" Values and Activity Forecasts

Standardized monetary values are assigned to benefits to provide a common basis for comparing costs and benefits. Standard unit values for these and other so-called "critical" values are provided in <u>Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs</u>. Critical values should be updated over time per the provisions outlined in Reference 3 to insure that the criteria reflect changes in these values and costs.

Aviation activity projected site-specifically in the FAA's Aviation Data Analysis System (ADA) is an important variable for most benefits and costs. Benefits and costs are computed for each of 15 years, discounted to present value at the 10 percent discount rate prescribed by the Office of Management and Budget (Reference 4), and summed to their present value over an assumed economic life of 15 years. The useful life of the investment may be longer, but a 15 year economic life assumption results in a more conservative investment strategy with respect to obsolescence, technological and policy changes, etc.

C. How Criteria are Applied

Benefit/cost criteria are applied in two phases. Phase II is the complete benefit/cost analysis supported by the computerized Aviation Data Analysis System (ADA) maintained by the FAA's Office of Aviation Policy and Plans. Phase I criteria are an abbreviated form of Phase II and are designed to approximate the Phase II benefit/cost ratio in instances where ADA is inaccessible. Phase I criteria are easily applied with available data and without the aid of a computer. Either or both phases are used by the FAA regional offices and others to screen locations for Facilities and Equipment (F&E) budget submissions or reprogrammings, with Phase II controlling. A site is considered a qualified candidate if it satisfies the criteria for three consecutive FAA annual traffic activity counts. An installation may be discontinued if the benefits expected to be realized over the remainder of its life-cycle fall below the recurring operation and maintenance costs, adjusted for any onetime shutdown costs. This can occur if traffic activity drops significantly or reanalysis suggests that the investment doesn't provide the degree of benefits previously projected. Both phases for the Touchdown RVR System are described and derived in this report.

Meeting the economic criteria is usually a necessary condition for including a site in the budget. However, when the number of qualifying sites is larger than what overall budget constraints allow, some sites may not be funded, even if economically justified. The converse is also true - locations may be excepted from meeting the economic criteria because of other factors.

D. <u>Changes from Previous Criteria</u>

This report provides the basis for revising the current Touchdown RVR System establishment criteria at Category I precision instrumented runways and provides newly developed discontinuance criteria for such runways for inclusion in FAA Order 7031.2C, <u>Airway Planning Standard Number One</u> (APS-1) (Reference 1). The change in the establishment criteria reflects a marked improvement over the previous criteria which were based simply on annual traffic activity thresholds. Additionally, the revised criteria address the establishment of a Touchdown RVR System at the second Category I runway at an airport, whereas the previous criteria only addressed the establishment of an initial Touchdown RVR System.

E. <u>Organization of the Remainder of this Report</u>

Phase II benefit/cost criteria and simple Phase I criteria are summarized in Chapter II. Touchdown RVR System costs are outlined in Chapter III and Chapter IV describes and quantifies the benefits. Chapter V develops the simple Phase I criteria. The results and associated budget impact of applying the criteria are presented in Chapter VI. The sensitivity of the criteria results to several key assumptions and inputs is examined in Chapter VII. Finally, a number of appendices are separately provided in the interest of keeping the main text as simple and comprehensible as possible.

CHAPTER II - SUMMARY OF REVISED ESTABLISHMENT AND DISCONTINUANCE CRITERIA

A. Introduction

This chapter summarizes the revised establishment and newly developed discontinuance criteria developed in this report for the Touchdown RVR System at the first two Category I precision instrumented runways at an airport. The previous RVR establishment criteria are reproduced in Appendix A. The criteria will be effected through a change to FAA Order 7031.2C, Airway Planning Standard Number One, Terminal Air Navigation Facilities and Air Traffic Control Services (APS-1) (Reference 1).

Satisfying the criteria does not necessarily entail or insure automatic establishment or discontinuance, nor does it constitute an FAA commitment. Airway Planning Standard criteria are but one of several inputs to the FAA decisionmaking process relative to investment in facilities and equipment. The criteria in no way affect the responsibilities of the operating services to consider all other factors pertinent to the establishment/discontinuance decision.

The two phases of the Touchdown RVR System establishment and discontinuance criteria are described below:

B. Phase II (Benefit/Cost) Criteria

Phase II criteria are a site-specific computerized comparison (under the Aviation Data Analysis System (ADA) of the FAA Office of Aviation Policy and Plans) of the present value of the life-cycle monetary benefits with the present value of the life-cycle costs. A life-cycle of 15 years is assumed -- the standard economic life that is applied in benefit/cost analyses supporting most APS-1 criteria. Life-cycle benefits and costs are derived by discounting future benefits and costs to their present value at the OMB-prescribed discount rate of 10 percent and summing. The ratio of life-cycle benefits to life-cycle costs is calculated as the basis for determining whether a runway economically qualifies as an establishment or discontinuance candidate for a Touchdown RVR System.

1. Phase II Establishment Criteria: A Category I precision instrumented runway (i.e., equipped with a Category I Instrument Landing System or Microwave Landing System) satisfies the establishment criteria for a Touchdown RVR System if:

   a. An acceptable method is available for immediate dissemination of RVR value data to pilots (e.g., airport traffic control tower, combined station/tower, or where appropriate, a remote approach control facility);

   b. The provisions of FAA Order 6560.10B, Runway Visual Range, and the siting and installation standards of FAA-STD-008 can be met; and

   c. The ratio of the present value of life-cycle benefits (PVB) to the present value of life-cycle costs (PVC) equals or exceeds unity, or,

$$PVB/PVC \geq 1.00$$

2. Phase II Discontinuance Criteria: An existing Touchdown RVR System installation at a Category I precision instrumented runway satisfies the discontinuance criteria when the present value of continued operation and maintenance costs exceeds the present value of remaining life-cycle benefits, or expressed in terms of total life-cycle benefits and costs:

$$PVB/PVC < 0.40$$

Discontinuance of a Touchdown RVR System installation must be justified by a site-specific benefit/cost analysis and an assessment of operational and environmental factors pertinent to the affected runway.

In marginal cases where the benefit/cost ratio is not significantly higher or lower than the qualifying thresholds (e.g., .9 and 1.1 in the case of establishment and .3 and .5 in the case of discontinuance), additional screening taking into account considerations other than economics should be made. There is a significant amount of estimating that occurs in benefit/cost analysis that precludes it from being absolutely conclusive. An allowance for estimating error should be recognized and taken into account.

C. Phase I (Simple) Criteria

Phase I criteria are a set of generalized, simple criteria designed to initially identify potential establishment and discontinuance candidates. Unlike the Phase II benefit/cost criteria, Phase I criteria are readily applied with available data and without the aid of a computer. The purpose of Phase I criteria is to provide an approximation of the Phase II benefit/cost ratio. Under Phase I, a contributory value is computed for each user class by dividing site-specific activity by a given breakeven activity divisor. Summing the contributory values and multiplying by the RVR system design factor (as described below) and runway utilization factor yields the Phase I value. Although the Phase I and Phase II criteria usually yield comparable results, there will be some cases where they don't. This occurs in instances where the site-specific forecast activity growth, aircraft type mix, and/or site-specific weather is significantly different than the corresponding national average value(s) embodied in the Phase I criteria. Phase II criteria results always prevail over Phase I since Phase II is more detailed and site-specific.

1. Phase I Establishment Criteria: A Category I precision instrumented runway (i.e., equipped with a Category I Instrument Landing System or Microwave Landing System) satisfies the Phase I establishment criteria for a Touchdown RVR System if:

   a. An acceptable method is available for immediate dissemination of RVR value data to pilots (e.g., airport traffic control tower, combined station/tower, or where appropriate, a remote approach control facility);

   b. The provisions of FAA Order 6560.10B, Runway Visual Range, and the siting and installation standards of FAA-STD-008 can be met; and

c. The Phase I value, computed as outlined in Figure II-1, equals or exceeds 1.00.

FIGURE II-1

Phase I Criteria for Touchdown RVR System at Category I Precision Instrument Runway

User Class			Contribution
Air Carrier:	$\frac{ACAP}{145} + \frac{ACITN}{6500}$	=	x.xx
Air Taxi:	$\frac{ATAP}{10,000} + \frac{ATITN}{73,000}$	=	x.xx
General Aviation:	$\frac{GAAP}{8,900}$	=	x.xx
Military:	$\frac{MILAP}{1,900}$	=	+ x.xx

Subtotal			x.xx
x RVR System Design Factor			x x.xx

Subtotal			x.xx
x Runway Utilization Factor			x .xx

Phase I Value			x.xx
			=======

Establishment: Phase I Value $\geq$ 1.00
Discontinuance: Phase I Value < 0.40

where for each of the first three years of operation, ACAP, ATAP, GAAP and MILAP are the numbers of annual instrument approaches by user class, ACITN and ATITN are the numbers of annual itinerant operations of the air carrier and air taxi user classes, the RVR system design factor is from Table II-1, and the runway utilization factor is the percentage of total airport operations that can be expected to use the candidate runway during instrument weather conditions. If a site-specific runway utilization factor is unavailable and cannot be estimated, the appropriate national average default value from Table II-2 may be substituted.

TABLE II-1

RVR System Design Factors

System Design of Proposed RVR Investment	Number of Currently Existing RVR Systems* of this Design Type	Factor
"New Generation"	0	1.00
	≥ 1	3.17
Tasker 500	≥ 0	0.60

* Category I, II, or III.

TABLE II-2

Default Runway Utilization Factors

(Use only if site-specific value is unavailable and cannot be estimated)

Total Number of Precision Instrumented Runways at Airport (All Categories)	Runway Utilization Factor per Runway (%)				
	1	2	3	4	5
1	100				
2	61	39			
3	45	35	20		
4	42	32	18	8	
≥ 5	41	31	17	8	3

For example, if the airport has three precision instrumented runways with one being Category II and two being Category I, the default runway utilization factors for the first and second Category I runways would be 35 and 20 percent, respectively.

2. Phase I Discontinuance Criteria: An existing Touchdown RVR System at a Category I precision instrumented runway satisfies the Phase I discontinuance criteria when the Phase I value, computed using the methodology outlined in Figure II-1, falls beneath 0.40.

3. Scope: The above (Phase I) criteria are based primarily on volume of air traffic and frequency and incidence of IFR weather. As such, these criteria are general in nature and do not cover all situations which may arise. Therefore, in cases where unique site-specific operational factors exist that may warrant special considerations (e.g., troublesome terrain features in the vicinity of the airport, significant remoteness of the runway from the tower, etc.), narrative and explanatory reference should be included in the Annual Call for Estimates so that such factors may be considered in the overall investment decisionmaking process.

4. Illustrative Application of Phase I Criteria

For the purpose of illustration, Muskegon County Airport (MKG), Muskegon, MI, is used as an example to demonstrate how the Phase I criteria are applied, based on FY 1985 activity data. Muskegon has one precision instrumented runway, Category I Runway 32. Runway 32 is already equipped with a Touchdown RVR System. According to FAA Air Traffic Activity, Fiscal Year 1985 (Reference 5), Muskegon had the following relevant traffic activity during Fiscal Year 1985:

Air Carrier Instrument Approaches (ACAP)	-	587
Air Carrier Itinerant Operations (ACITN)	-	9,303
Air Taxi Instrument Approaches (ATAP)	-	553
Air Taxi Itinerant Operations (ATITN)	-	7,697
General Aviation Instrument Approaches (GAAP)	-	675
Military Instrument Approaches (MILAP)	-	42

The procedure outlined in Figure II-2 shows a Phase I value of 5.74, well above the qualifying threshold of 1.00.

D. Runway Visual Range at Category II and Category III Precision Instrumented Runways

RVR is specified as a component of Category II and Category III precision instrumented runways in Order 6560.10B, "Runway Visual Range (RVR)," dated May 9, 1977. As such, the above criteria do apply to such runways.

FIGURE II-2

<u>Illustrative Application of Phase I Criteria</u>
(Runway 32, Muskegon County Airport (MKG), Muskegon, MI)

User Class					Contribution
Air Carrier:	$\frac{587}{145}$	+	$\frac{9,303}{6,500}$	=	5.48
Air Taxi:	$\frac{553}{10,000}$	+	$\frac{7,697}{73,000}$	=	0.16
General Aviation:	$\frac{675}{8,900}$			=	0.08
Military:	$\frac{42}{1,900}$			=	+ 0.02
Subtotal					5.74
RVR System Design Factor (from Table II-1)					x 1.00
Subtotal					5.74
x Runway Utilization Factor (from Table II-2)					x 1.00
Phase I Value					5.74

CHAPTER III - TOUCHDOWN RVR SYSTEM COSTS

There are three categories of costs associated with the Touchdown RVR System that are relevant in this analysis -- nonrecurring costs, recurring costs, and life-cycle costs:

1. Nonrecurring costs consist of capital expenditures for facilities, equipment, and operational start-up.

2. Nonrecurring costs consist of operations and maintenance costs for labor, materials and overhead.

3. Life-cycle costs are the discounted present value sum of recurring and nonrecurring costs over an assumed economic life-cycle of 15 years. It is assumed that recurring costs occur at the beginning of the life-cycle and therefore their present value equals their "as-spent" value. Constant dollars are used throughout this analysis and recurring costs are assumed constant for each year of the life-cycle. The present value of a uniform series of constant values is simply a cumulative discount factor times the constant annually recurring value. In this case, the cumulative discount factor over 15 years at the ten percent discount rate prescribed by the Office of Management and Budget (Reference 4) is 7.977.[1/] Letting

   FE = nonrecurring costs, and

   OM = recurring operation and maintenance costs,

   the present value of the life-cycle costs of the Touchdown RVR System, PVC, can be expressed as:

   $$PVC = FE + (OM \times 7.977).$$

Marginal life-cycle costs are summarized in Table III-1 by design type - a "new generation" RVR and the solid state Tasker 500 system that is presently in the field. The life-cycle costs of each design type are further differentiated based on RVR equipage currently at the airport (i.e., before the potential investment). Most establishments to be made under the criteria developed in this report are expected to be the "new generation" system. Because the "new generation" RVR has not been completely developed as of the date of this report, the possibility exists of investment considerations based on the current Tasker 500 system. In consideration of this, life-cycle costs of both design types are outlined in Table III-1. The costs outlined in Table III-1 are expected or typical average costs. Site-specific cost estimates should be submitted in the annual Call for Estimates when candidates sites are found to satisfy the criteria, reflecting the proposed design type, site-peculiar installation costs, and year of dollars in which costs are denominated.

1/ The cumulative discount factor, 7.977, is the sum of $1/(1+i)^{n-0.5}$ for $n = 1$ to 15, where 'i' is the OMB-prescribed discount rate of 10 percent (per Reference 4) and 'n' is each year of an assumed economic life of 15 years. The 0.5 factor in the exponent effects mid-year, as opposed to end-of-year, discounting.

The discontinuance factor of 0.40, in relation to the benefit/cost ratio, is based on the ratio of the recurring costs of continuing to operate and maintain the RVR to total life-cycle costs, less an allowance for dismantling and relocation or disposal costs. (Original) nonrecurring costs represent "sunk" costs and therefore are irrelevant to the discontinuance decision. The corresponding ratios for the four columns in Table III-1 are .49, .37, .51, and .48, respectively. For Phase I purposes, the arithmetic mean of these (.46) less an allowance of .06 for dismantling and relocation or disposal costs, or .40, is accepted as a reasonable order-of-magnitude measure of the discontinuance threshold.

TABLE III-1

Marginal Life-cycle Costs of Touchdown System at Category 1 Precision Instrumented Runway (1985 Present Value Dollars) 1/

	(A)	(B)	(C)	(D)
	"New Generation" RVR		Tasker 500 RVR	
	Airport With No Existing "New Gen" RVR RWY	Airport With Existing "New Gen" RVR RWY(S)	Airport With No Existing RVR RWY	Airport With Existing RVR RWY(S)
Nonrecurring Costs	$ 96,600	$ 37,300	$ 158,100	$ 156,100
Recurring Costs				
Annual Opns. & Maint.	$ 11,400	$ 2,740	$ 20,610	$ 18,396
% Discount Factor 2/	7.977	7.977	7.977	7.977
Total Disc., 15 Yrs. 3/	$ 90,900	$ 21,900	$ 164,400	$ 146,700
Total Life-cycle Costs	$ 187,500	$ 59,200	$ 322,500	$ 302,800

1/ Source: APO-220, from "Runway Visual Range Life-cycle Cost Comparison," Martin Marietta Corp., October 31, 1985 (Reference 6).

2/ Sum of 1/(1+i) (n-0.5) for n - 1 to 15, where 'i' is the OMB-prescribed discount rate of 10 percent and 'n' is each year of an estimated economic life of 15 years.

3/ Rounded to the nearest $100.

CHAPTER IV - TOUCHDOWN RVR SYSTEM BENEFITS

A. Introduction

There are basically two types of visibility measurements currently reported as part of the weather information for the terminal area: (1) "prevailing visibility" measured by qualified human observers; and (2) "Runway Visibility Value" and "Runway Visual Range" measured by instruments:

Prevailing Visibility is measured by qualified human observers from the air traffic control tower or other air traffic control facility. It is defined as the greatest horizontal visibility equaled or exceeded throughout at least half the horizon circle which need not necessarily be continuous. It is measured and reported in statute miles or fractions thereof. Values are reported in discrete steps with the size of the steps increasing with the visibility.

Runway Visibility Value (RVV) is the visibility determined for a particular runway by instrumentation which is calibrated to indicate values comparable to those that would be seen by a human observer. It is measured and reported in statute miles or fractions thereof and is used in lieu of prevailing visibility in determining minima for a particular runway.

Runway Visual Range (RVR) is also measured by instrumentation and represents the horizontal distance a pilot will see from the approach end of the runway. RVR values are displayed by equipment in the associated air traffic control tower or air traffic facility and continuously updated. RVR is horizontal visual range, not slant visual range. It is reported in hundreds of feet in the increments shown in Table IV-1. RVR is used in lieu of RVV and/or prevailing visibility in determining minima for a particular runway. Touchdown RVR equipment serves the runway touchdown zone, while mid-RVR equipment is located midfield of the runway and rollout RVR equipment near the rollout end of the runway.

TABLE III-1

RVR Reporting Increments

RVR (Feet)	Reporting Increments (Feet)
Below 800	100
800 - 3000	200
3000 - 6500	500

B. The Underlying Principle

The relevant benefits in this analysis are those benefits that can be expected to be derived from having a Touchdown RVR System as opposed to not having it. As illustrated in Table IV-2 and explained in the following paragraphs, benefits accrue from a Touchdown RVR System since it permits a runway to remain open a greater percentage of time during periods of low visibility.

Column 1 of Table IV-2 lists ground or prevailing visibilities ranging from 1/8 mile to 1 1/4 miles. Columns 2 and 3 list the maximum equivalent atmospheric transmittance value corresponding to each ground or prevailing visibility value in Column 1, based on a 250-foot baseline length and the sighting of dark objects against the horizon day sky and 25 candles light intensity at night. This conversion was taken from Table A3-7C of Federal Meteorological Handbook Number One - Surface Observations (Reference 7), as reproduced in Appendix B to this report.

Columns 4 through 9 of Table IV-2 list maximum reportable RVR day and night values that would be computed from the transmittance factors in Columns 2 and 3, based on a 250-foot baseline length and runway light intensity settings (LS) 3 (400 candles), 4 (2,000 candles) and 5 (10,000 candles). This conversion was taken from Table A3-6B of Federal Meteorological Handbook Number One - Surface Observations (Reference 7), as reproduced in Appendix C to this report.

Columns 10 and 11 of Table IV-2 list the maximum equivalent transmittance values corresponding to the RVR values in Columns 4 through 9, based on a 250-foot baseline length and the sighting of dark objects against the horizon day sky and 25 candles light intensity at night. Again, these values were taken from Table A3-6B of Reference 7, as reproduced in Appendix C to this report.

Columns 12 and 13 of Table IV-2 list the equivalent ground or prevailing visibility value corresponding to each transmittance value in Columns 10 and 11, where Columns 12 and 13 are based on a 250-foot baseline length and the sighting of dark objects against the horizon day sky and 25 candles light intensity at night. This conversion was taken from Table A3-7C of Reference 7, as reproduced in Appendix B to this report. In other words, Columns 12 and 13 show the equivalent visibility of RVR in terms of miles. The average differences between the values in Columns 12 and 13 and those in Column 1 are listed in Column 14 and constitute the basis of ascribing benefits to RVR.

Benefits accrue when the availability of a Touchdown RVR System makes approaches and takeoffs possible when they would have been impossible without it. This condition occurs when the RVR reports more than the landing or takeoff minima while an observer of prevailing visibility would report less. The time during which this condition occurs will be termed "RVR landing time" in the case of landing benefits (the subject of Section C of this chapter) and "RVR takeoff time" in the case of takeoff benefits (the subject of Section D).

TABLE IV-2

Comparison Of RVR And Ground (Prevailing) Visibility Values

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Maximum Equivalent Transmittance[1/]		Maximum Reportable RVR Value[2/]						Maximum Equivalent Transmittance[2/]		Equivalent Ground (Prevailing) Visibility[1/]		
			Day Light Setting			Night Light Setting							
Ground Visibility (Miles)	Day	Night	LS3	LS4	LS5	LS3	LS4	LS5	Day	Night	Day	Night	Average Difference
2/16 (1/8)	.415	.101	0800	1000	1400	1000	1000	1200	.616	.191	5/16	3/16	2/16 (1/8)
3/16	.534	.210	1200	1400	1800	1200	1600	1800	.682	.365	6/16	5/16	2/16 (1/8)
4/16 (1/4)	.614	.309	1400	1600	2200	1600	2000	2200	.729	.454	6/16	6/16	2/16 (1/8)
5/16	.671	.394	1800	1800	2400	2000	2400	2600	.747	.524	8/16	8/16	3/16
6/16	.731	.493	2400	2400	2800	2400	2800	3500	.778	.580	8/16	8/16	2/16 (1/8)
8/16 (1/2)	.783	.590	3000	3000	3500	3000	3500	4000	.823	.670	12/16	12/16	4/16 (1/4)
10/16 (5/8)	.819	.658	3500	3500	4000	3500	4500	5000	.842	.747	12/16	14/16	3/16
12/16 (3/4)	.845	.709	4500	4500	4500	4000	5000	6000	.857	.776	14/16	16/16	3/16
14/16 (7/8)	.864	.747	5000	5000	5000	4500	6000	6000+	.870	.819	16/16	20/16	4/16 (1/4)
16/16 (1)	.879	.778	5500	5500	5500	5500	6000+	6000+	.881	.799	14/16	18/16	2/16 (1/8)
20/16 (1 1/4)	.891	.802	6000+	6000+	6000+	6000	6000+	6000+	.891	.819	20/16	20/16	2/16 (1/8)
Average (Mean)													2/16 (1/8)

1/ Source: Table A3-7C of Reference 7 (reproduced as Appendix B to this report).

2/ Source: Table A3-6B of Reference 7 (reproduced as Appendix C to this report).

The Touchdown RVR System is a more reliable measurement of visibility for three reasons: first, it is located near the touchdown zone of the runway, while the human observer taking prevailing visibility measurements is not; second, it is calibrated against runway lights, as opposed to "prominent objects"; and third, its value is continuously measurable and available.

C. Annual Landing Benefits

1. Introduction

Annual landing benefits (ALB) attributable to the establishment of a Touchdown RVR System are computed for each user class by multiplying:

- o the percentage increase in instrument time the candidate runway can be expected to be open for landings, by
- o the current number of annual instrument approaches to the airport, by
- o the percentage of instrument approaches to the airport that can be expected to use the candidate runway, by
- o the respective unit cost of an instrument approach disruption.

Each of these steps is explained in detail below and illustrated with an example for Muskegon County Airport (MKG), Muskegon, MI. Muskegon has one precision instrumented runway, Category I Runway 32, already equipped with a Touchdown RVR System (source: References 17 and 19). For purpose of on-going illustration, it is assumed that Runway 32 is not RVR-equipped.

2. The Percentage Increase in Instrument Time the Candidate Runway can be Expected to be Open for Landings

The percentage increase in instrument time the candidate runway can be expected to be open for landings (PILT) can be expressed as:

$$PILT = \frac{RVRLT}{CILT}$$

where RVRLT is "RVR landing time," the additional percentage of time the candidate runway can be expected to be open for landings, and CILT is "current instrument landing time," the percentage of time the airport is not VFR but is open for landings under the lowest current instrument minima for the largest aircraft type utilizing the candidate runway. The ratio of RVRLT to CILT yields an approximation of the percentage of additional instrument approaches which can be expected to be completed as a result of the availability of a Touchdown RVR System. Before explaining how these variables can be derived, a discussion of source data is presented below.

At least four data sources provide statistics for specific airports from historical weather records showing the percentages of time the weather is at or below given categories or combinations of ceiling and/or visibility:

- Climatic Studies for Proposed Landing Systems (Reference 8) provides percentages of time ceilings are less than 100, 200, 300, 400, 500, 600, 800, 1,000, 1,500, 2,000 and 3,000 feet, and visibilities are less than 1/16, 1/8, 1/4, 1/2, 3/4, 1, 1-1/2, and 3 miles. The report is very detailed by breakdown of ceiling and visibility categories, but provides data on only 32 North American airports.

- Ceiling-Visibility Climatological Study and System Enhancement Factors (Reference 9) provides, for 271 airports, percentages of hourly weather observations falling within six ceiling and visibility combinations: (1) greater than or equal to 1,500 feet and 3 miles; (2) less than 1,500 feet and/or 3 miles; (3) less than 1,500 feet and/or 3 miles, but equal to or greater than 400 feet and 1 mile; (4) less than 400 feet and/or 1 mile, but equal to or greater than 200 feet and 1/2 mile; (5) less than 200 feet and/or 1/2 mile, but equal to or greater than 100 feet and 1/4 mile; and (6) less than 100 feet and/or 1/4 mile. Compared to Reference 8, there is thus less detail on specific ceilings and visibilities, but more sites.

- Wind-Ceiling-Visibility Data at Selected Airports (Reference 10) provides, for 283 airports, data on the same ceiling and visibility combinations in Reference 9, and additionally provides wind direction data.

- The Airport-Specific Data File (Reference 11), maintained by the FAA Office of Aviation Policy and Plans (FAA-APO), contains actual and estimated weather probabilities within eight ceiling (C) and visibility (V) combinations for over 1,600 airports, as follows:

$C \leq 200$ or $V \leq 0.50$
$C \leq 300$ or $V \leq 0.75$, but $C > 200$ and $V > 0.50$
$C \leq 400$ or $V \leq 1.00$, but $C > 300$ and $V > 0.75$
$C \leq 600$ or $V \leq 1.50$, but $C > 400$ and $V > 1.00$
$C \leq 800$ or $V \leq 2.00$, but $C > 600$ and $V > 1.50$
$C \leq 1{,}000$ or $V \leq 2.50$, but $C > 800$ and $V > 2.00$
$C \leq 1{,}200$ or $V \leq 3.00$, but $C > 1{,}000$ and $V > 2.50$
$C \leq 1{,}500$ or $V \leq 3.00$, but $C > 1{,}200$ and $V > 2.50$

This file, an integrated database supporting the Aviation Data Analysis System, is used for Phase II RVR criteria processing. Table IV-3 outlines a matrix of national average weather probabilities based on a best functional fit of this database.

In some instances where weather data is unavailable or limited, interpolation (as illustrated below) and/or analogous analysis may be necessary to determine required weather variables. Any of the above sources may be used, as appropriate and available. If data on a given

TABLE IV-3

National Average Percentage Distributions Of Weather Observations Less Than Selected Ceilings And Visibilities *

VISIBILITY IN 16'S OF A MILE

CEILING (Feet)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	24	32	40	48
100	0.15	0.25	0.33	0.41	0.47	0.54	0.60	0.66	0.71	0.77	0.82	0.87	0.92	0.97	1.02	1.06	1.41	1.72	2.01	2.28
200	0.25	0.41	0.54	0.66	0.77	0.87	0.97	1.06	1.16	1.24	1.33	1.41	1.49	1.57	1.65	1.72	2.28	2.78	3.24	3.68
300	0.33	0.54	0.71	0.87	1.02	1.16	1.29	1.41	1.53	1.65	1.76	1.87	1.98	2.08	2.18	2.28	3.02	3.68	4.28	4.85
400	0.41	0.66	0.87	1.06	1.24	1.41	1.57	1.72	1.87	2.01	2.15	2.28	2.41	2.54	2.66	2.78	3.68	4.48	5.21	5.90
600	0.54	0.87	1.16	1.41	1.65	1.87	2.08	2.28	2.47	2.66	2.84	3.02	3.19	3.36	3.52	3.68	4.85	5.90	6.86	7.76
800	0.66	1.06	1.41	1.72	2.01	2.28	2.54	2.78	3.02	3.24	3.46	3.68	3.88	4.09	4.28	4.48	5.90	7.17	8.33	9.40
1,000	0.77	1.24	1.65	2.01	2.35	2.66	2.96	3.24	3.52	3.78	4.04	4.28	4.53	4.76	4.99	5.21	6.86	8.33	9.66	10.90
1,200	0.87	1.41	1.87	2.28	2.66	3.02	3.36	3.68	3.99	4.28	4.57	4.85	5.12	5.39	5.65	5.90	7.76	9.40	10.90	12.29
1,500	1.02	1.65	2.18	2.66	3.10	3.52	3.91	4.28	4.64	4.99	5.32	5.65	5.96	6.27	6.57	6.86	9.01	10.90	12.62	14.21
2,000	1.24	2.01	2.66	3.24	3.78	4.28	4.76	5.21	5.65	6.07	6.47	6.86	7.24	7.61	7.97	8.33	10.90	13.16	15.21	17.09
3,000	1.65	2.66	3.52	4.28	4.99	5.65	6.27	6.86	7.43	7.97	8.50	9.01	9.50	9.98	10.45	10.90	14.21	17.09	19.67	22.03

*/ Based on functional fit of FAA-APO's Airport Specific File (Reference 11).

Equation: Weather Probability (%) Based on National Weather Functional Fit = 100 * (1 - EXP (-m * (VISIBILITY * CEILING) ^ a)) candidate airport is not available from any of these or other acceptable sources, data based on a nearby airport, an average of neighboring airports, or as a last resort the national average from Table IV-3 may be used. As indicated above, Reference 11 is relied upon for actual Phase II processing.

The procedure for determining PILT, the percentage increase in instrument time the airport can be expected to be open for landings, is probably best explained by using an example - Runway 32 at Muskegon County Airport (MKG). As noted earlier, Muskegon's Runway 32 is already equipped with a Touchdown RVR System, but for purposes of illustration it is assumed that it is not. First, RVR landing time (RVRLT) must be determined -- the additional percentage of time the airport can be expected to be open for landings with a Touchdown RVR System. Muskegon's landing minima on Runway 32 are 200 feet ceiling and 1/2 mile visibility (References 17 and 19).

Since a Touchdown RVR System can be expected to "effectively" reduce the landing visibility minimum by 1/8 mile (as derived in Table IV-2), RVR landing time for Muskegon is the percentage of time that visibility is between 1/2 mile and 3/8 mile (1/2 less 1/8). Since none of the above sources provides site-specific data corresponding to visibility between 3/8 and 1/2 mile, interpolation must be used. While any acceptable source of data may be used, Reference 9 is used here for the purpose of illustration. Data on ceiling and visibility categories for Muskegon, as provided in Reference 9, are reproduced in Figure IV-1. Substituting from Figure IV-1 (for local data) and Table IV-3 (for national average data), RVR landing time for Muskegon can be estimated through interpolation as follows:

$$\frac{\text{Local \% Between 200-1/2 \& 200-3/8}}{\text{Local \% Between 200-1/2 \& 100-1/4}} = \frac{\text{Nat'l. Avg. \% Between 200-1/2 \& 200-3/8}}{\text{Nat'l. Avg. \% Between 200-1/2 \& 100-1/4}}$$

$$\frac{\text{RVRLT}}{0.6\%} = \frac{1.06\% - 0.87\%}{1.06\% - 0.41\%}$$

$$\text{RVRLT} = 0.6\% \times (0.19\%/0.65\%) = \underline{0.18\%}$$

Next, the current instrument landing time (CILT) must be determined -- the percentage of time the airport is not VFR but is open under the lowest current instrument minima for the largest aircraft type utilizing the candidate runway. For purposes of the criteria developed in this report, this is defined as the difference in time that the ceiling/visibility is less than 1,500 feet and/or 3 miles but equal to or greater than the current instrument minima. Continuing with the reliance on Reference 9 for the Muskegon illustration (as reproduced in Figure IV-1), data on the percentage of time that the ceiling/visibility is less than 1,500 feet and/or 3 miles is expressly provided, as well as the percentage of time less than the current instrument minima of 200-1/2. In this case, therefore, interpolation is not necessary:

$$\text{CILT} = 13.5\% + 1.8\% = \underline{15.3\%}$$

PILT, the percentage increase in instrument time the airport can be expected to be open for landings, is the ratio of RVRLT to CILT, or:

FIGURE IV-1

Ceiling-Visibility Climatological Data For Muskegon, MI (MKG)

STATION#14840 MUSKEGON, MICHIGAN

PERIOD OF RECORD 01/48-12/52; 01/60-12/64

HOUR GROUP		NO.OF OBS	CEILING-VISIBILITY CATEGORIES (%) (1)	(2)	(3)	(4)	(5)	(6)	SYSTEM ENHANCEMENT FACTORS (%) VOR	CAT1	CAT2	MIN*
JAN	ALL	7440	63.7	36.3	29.8	3.9	1.1	1.5	82.2	10.6	3.1	4.1
FEB	"	6809	73.5	26.5	22.6	2.5	0.7	0.7	85.3	9.4	2.7	2.6
MAR	"	7440	78.1	21.9	17.6	2.8	0.7	0.8	80.4	12.9	3.1	3.6
APR	"	7200	85.2	14.8	12.4	1.4	0.4	0.6	84.2	9.5	2.5	3.8
MAY	"	7440	91.3	8.7	6.3	1.3	0.4	0.7	72.3	14.8	4.8	8.2
JUN	"	7200	93.8	6.2	4.7	0.7	0.3	0.4	76.5	11.9	5.4	6.3
JUL	"	7440	93.4	6.6	5.2	0.7	0.1	0.5	79.4	11.2	2.2	7.1
AUG	"	7439	91.5	8.5	6.6	1.0	0.4	0.5	78.2	11.6	4.5	5.7
SEP	"	7198	91.2	8.8	7.7	0.8	0.2	0.1	87.3	8.7	2.4	1.6
OCT	"	7440	87.9	12.1	8.5	1.2	0.8	1.6	70.7	9.6	6.3	13.3
NOV	"	7200	80.2	19.8	16.0	1.7	0.7	1.4	80.7	8.6	3.5	7.2
DEC	"	7439	69.7	30.3	24.9	3.6	1.0	0.8	82.1	11.9	3.4	2.6
ANN	07-13	25578	80.6	19.4	16.1	2.0	0.6	0.7	83.0	10.4	2.9	3.7
	14-21	29229	86.3	13.7	11.8	1.3	0.3	0.4	85.6	9.4	2.4	2.6
	22-06	32878	82.8	17.2	13.1	2.1	0.8	1.3	76.0	12.1	4.6	7.3
	ALL	87685	83.3	16.7	13.5	1.8	0.6	0.8	81.0	10.8	3.4	4.8

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)

$$PILT = \frac{\text{RVRLT or RVR Landing Time}}{\text{CILT or Current Instrument Landing Time}}$$

For the Muskegon illustration, PILT is:

$$\frac{0.18\%}{15.30\%} = .0098\text{, or } \underline{1.18\%}$$

In other words, a Touchdown RVR System at Muskegon's Runway 32 can be expected to allow it to effectively remain open for landings 1.18% more of total instrument time. This is also an approximation of the additional percentage of instrument approaches which can be completed without disruption. The next step is to determine the current number of annual instrument approaches to the airport (i.e., prior to the prospective investment).

3. The Current Number of Annual Instrument Approaches to the Airport

Counts of annual instrument approaches (AIA's) may be obtained from a number of sources, including the Aviation Data Analysis System (ADA) (maintained by the FAA's Office of Aviation Policy and Plans, APO-110), Terminal Area Forecasts (published annually by FAA-APO-110), FAA Air Traffic Activity (published annually by the FAA's Office of Management Systems (FAA-AMS), the Airport Master Record (FAA Form 5010-1), the Airport Master File (maintained by the FAA's National Flight Data Center), the airport manager, or any other generally accepted source. In the absence of counts or to evaluate suspected counts, Appendix D provides and describes regression formulae for estimating annual instrument approaches.

For purposes of continuing illustration, FAA Air Traffic Activity, Fiscal Year 1985 (Reference 5) provides the following data on annual instrument approaches by user class for Muskegon during Fiscal Year 1985:

Air Carrier	-	587
Air Taxi	-	553
General Aviation	-	675
Military	-	42
		1,857

4. The Percentage of Instrument Approaches to the Airport that can be Expected to Use the Candidate Runway

The utilization of the candidate runway (RU), or the proportion of the airport's approaches which would use the candidate runway during instrument weather conditions, is an important factor in estimating the benefits of a Touchdown RVR System. Where a site-specific runway utilization factor is known or where it can be estimated from other site-specific data, it should be used. Lacking site-specific data, the appropriate national average value may be used. Estimates of national average runway utilization factors are outlined in Table IV-4.

TABLE IV-4

National Average Runway Utilization Factors */

Total Number of Precision Instrumented Runways at Airport (All Categories)	Runway Utilization Factor per Runway (%) 1	2	3	4	5
1	100				
2	61	39			
3	45	35	20		
4	42	32	18	8	
5	41	31	17	8	3

*/ Source: Estimates adopted by analogy from Reference 18. As an example, if an airport has three precision instrumented runways, with one being Category II and two being Category I, the associated national average runway utilization factors for the first and second Category I runways would be 35 and 20 percent, respectively.

In the case of Muskegon, which has one precision instrumented runway (Runway 32), the runway utilization factor is 100 percent.

5. The Unit Costs of Instrument Approach Disruptions

An FAA-APO document entitled "Benefits of Reduced Flight Disruption" (Reference 12) provides a standardized methodology for estimating the average unit costs of instrument approach flight disruptions -- delays, diversions, cancellations and overflights. This document, modified and expanded for specific application to RVR and updated to incorporate 1985 critical values, is reproduced as Appendix E to this report. In summary, Appendix E provides the following unit costs of instrument approach disruptions (CIAD) by user class in 1985 dollars:

Air Carrier:	
Hub Airports	$6,468
Non-Hub Airports	2,960
Air Taxi	420
General Aviation	179
Military	508

6. Summary of Annual Landing Benefits

Summarizing Sections IV-C-2, IV-C-3, IV-C-4 and IV-C-5, the annual landing benefits attributable to a Touchdown RVR System for each user class (ALB_{UC}) can be expressed as:

$$ALB_{UC} = PILT \times AIA_{UC} \times RU \times CIAD_{UC}$$

$$= \frac{RVRLT}{CILT} \times AIA_{UC} \times RU \times CIAD_{UC}$$

where PILT is the percentage increase in instrument time the candidate runway can be expected to be open for landings; AIA_{UC} is the current number of annual instrument approaches, by user class, to the airport (i.e., prior to the potential establishment of the Touchdown RVR System); RU, the runway utilization factor, is the percentage of instrument approaches to the airport that can be expected to use the candidate runway; $CIAD_{UC}$ is the unit cost of an instrument approach disruption by user class; RVRLT, RVR landing time, is the additional percentage of time the candidate runway can be expected to be open with a Touchdown RVR System; and CILT, current instrument landing time, is the percentage of time the airport is not VFR but is open under the lowest current minima for the largest aircraft type utilizing the candidate runway.

In the case of Muskegon, a non-hub airport, the annual landing benefits of a Touchdown RVR System on Runway 32 can be computed as follows:

Air Carrier	$\frac{0.18\%}{15.30\%}$	x	587	x	100%	x	$2,960	=	$20,441
Air Taxi	$\frac{0.18\%}{15.30\%}$	x	553	x	100%	x	$ 420	=	2,732
General Aviation	$\frac{0.18\%}{15.30\%}$	x	675	x	100%	x	$ 179	=	1,421
Military	$\frac{0.18\%}{15.30\%}$	x	42	x	100%	x	$ 508	=	251
Total									$24,845

To arrive at life-cycle landing benefits, the procedure described in this section must be repeated for each year of an assumed economic life-cycle of 15 years, discounted to present value and summed. A further discussion of life-cycle benefits is deferred to Section E, following an analysis of annual takeoff benefits.

D. Annual Takeoff Benefits

1. Introduction

In addition to instrument approach benefits as discussed in Section C of this chapter, benefits also accrue to takeoffs when the availability of a Touchdown RVR System makes takeoffs possible when they would have been impossible without it. This condition occurs when the RVR reports more than the takeoff minima while an observer of prevailing visibility would report less. The time during which this condition occurs will be termed "RVR takeoff time."

Unless otherwise authorized, aircraft operating under Federal Aviation Regulation (FAR) Part 121 (domestic, flag, and supplemental air carriers and commercial operators of large aircraft), Part 123 (air travel clubs using large airplanes), Part 125 (airplanes having a seating capacity of 6,000 pounds or more), Part 129 (foreign air carriers), and Part 135 (air taxi and commercial operators) may not take off from a civil airport under IFR unless weather conditions are at or above the minima for IFR takeoff for that airport (Reference 13). Takeoff minima are stated as visibility only, except where the need to see and avoid an obstacle makes a ceiling value necessary.

If takeoff minima are not prescribed for a particular airport, the following standard minima apply to IFR takeoffs for aircraft operating under FAR Parts 121, 123, 125, 129 and 135: (1) for aircraft having two engines or less - 1 statute mile visibility; and (2) for aircraft having more than two engines - 1/2 statute mile visibility. However, for airports relevant to this analysis - those having precision instrument procedures, lower than standard takeoff minima may be authorized (Reference 14). On runways where standard takeoff minima are authorized, lower-than-standard minima of 1/4 mile or RVR 1600 are also authorized provided the operator's training program includes instructions on the proper procedures for accomplishing lower-than-standard takeoffs, a minimum crew of two is used, and when any of the following visual aids is available:

a. High Intensity Runway Lights (HIRL); or

b. Runway Centerline Lights; or

c. Runway Centerline Marking; or

d. In unusual circumstances where neither a, b, nor c are available, the runway is marked in such a manner that the pilot at all times has visual reference to the line of forward motion during the takeoff run.

If takeoff is based on RVR, a touchdown transmissometer is required and is controlling. Minima may be reduced to as low as RVR 600, but this requires mid RVR and rollout RVR - a condition beyond the scope of this report. This report and the criteria developed herein address only the establishment and discontinuance of an initial or second Touchdown RVR System.

The annual takeoff benefits (ATB) attributable to the Touchdown RVR System are computed for benefiting aircraft by multiplying:

- the percentage increase in time the candidate runway can be expected to be open for takeoffs, by
- the current number of annual departures from the airport made by aircraft of benefiting user classes, by
- the percentage of those departures that can be expected to use the candidate runway, by
- the respective unit cost of an instrument departure disruption.

Each of these steps is explained in detail below and again Muskegon's Runway 32 is used for illustration.

2. <u>The Percentage Increase in Time the Candidate Runway can be Expected to be Open for Takeoffs</u>

The percentage increase in time the candidate runway can be expected to be open for takeoffs (PITT) can be expressed as:

$$PITT = \frac{RVRTT}{CTT}$$

where RVRTT is "RVR takeoff time," the additional percentage of time the candidate runway can be expected to be open for takeoffs with a Touchdown RVR System and CTT is "current takeoff time," the percentage of time the candidate runway is currently open for takeoffs (i.e., prior to the potential establishment of a Touchdown RVR System). The ratio of RVRTT to CTT yields an approximation of the percentage of additional departures that can be expected to be completed by benefiting aircraft as a result of the availability of a Touchdown RVR System.

Since RVR can be expected to effectively increase reportable visibility by 1/8 mile, as explained in Section B of this chapter and derived in Table IV-2, RVRTT is the time that visibility is between the lower-than-standard visibility minimum of 1/4 mile on the one hand (from Section D-1) and 1/4 less 1/8 or 1/8 mile on the other hand. As in the case of landing benefits, References 8, 9, 10, 11 or any other acceptable source may be used to determine this data. If data for the candidate airport is unavailable, data based on a nearby airport, an average of neighboring airports, or the national average value may be used. On a national average basis, Table IV-3 in Section C shows visibility to be between 1/4 mile and 1/8 mile (corresponding to ceiling of less than 100 feet) 0.16 percent of the time.

Continuing the illustration for Muskegon using Reference 7, RVRTT can be estimated for Muskegon through interpolation as follows:

$$\frac{\text{Local \% Between 100-1/4 \& 100-1/8}}{\text{Local \% Less Than 100 - 1/4}} = \frac{\text{Nat'l Avg. \% Between 100-1.4 \& 100-1/8}}{\text{Nat'l Avg. \% Less Than 100 - 1/4}}$$

Substituting site-specific values from Figure IV-1 and national average values from Table IV-3:

$$\frac{RVRTT}{0.8\%} = \frac{0.41\% - 0.25\%}{0.41\%}$$

$$RVRTT = 0.8\% \times (0.16\%/0.41\%) = \underline{0.31\%}$$

Next, the current takeoff time (CTT) must be determined - the percentage of time that the candidate runway is currently open for takeoffs, or the percentage of time that visibility is 1/4 mile or greater. On a national average basis, Table IV-3 shows visibility to be equal to or greater than 1/4 mile (corresponding to a ceiling of less than 100 feet) 99.59 percent of the time (100% less 0.41%). For Muskegon, Figure IV-1 shows this to be 99.2 percent (100% less 0.8%).

The percentage increase in time the candidate runway can be expected to be open for takeoffs (PITT) is the ratio of RVRTT to CTT. For the Muskegon illustration, based on the above computations, PITT is:

$$\frac{0.31\%}{99.2\%} = .0027, \text{ or } \underline{0.31\%}$$

In other words, a Touchdown RVR System at Muskegon's Runway 32 can be expected to allow it to effectively remain open 0.31 percent more of the time. This is also an approximation of the additional percentage of departures which can be executed without disruption by benefiting aircraft. The next step is to determine the current number of annual departures from the airport by potentially benefiting aircraft (i.e., prior to the prospective investment).

3. The Current Number of Annual Departures from the Airport made by Benefiting Aircraft of Benefiting User Classes

Counts of annual operations may be obtained from a number of sources, including the Terminal Area Forecast Data System (maintained by the FAA's Office of Aviation Policy and Plans (FAA-APO-110), Terminal Area Forecasts (published annually by FAA-APO-110), FAA Air Traffic Activity (published annually by the FAA's Office of Management Systems (FAA-AMS), the Airport Master Record (FAA Form 5010-1), the Airport Master File (maintained by the FAA National Flight Data Center), the airport manager or any other generally accepted source.

Since operations are the sum of takeoffs and landings, the number of annual departures may be obtained by dividing the number of annual operations by two. As indicated at the outset of this section, takeoff benefits attributable to a Touchdown RVR System accrue to aircraft operating under FAR Parts 121, 123, 125, 129 and 135. For all practical purposes, at least within the accuracy of this analysis, aircraft operations falling under these FAR parts are counted as air carrier and air taxi operations. Therefore, takeoff benefits will be extended only to these user classes and none will be extended to the general aviation and military user classes. For purposes of continuing illustration and based on FAA Air Traffic Activity, Fiscal Year 1985 (Reference 5), the number of air carrier and air taxi departures at Muskegon during Fiscal Year 1985 can be estimated as:

Air Carrier: 9,303 Operations / 2 = 4,652 Departures
Air Taxi: 7,697 Operations / 2 = 1,630 Departures

4. The Percentage of Departures that can be Expected to Use the Candidate Runway

The percentage of benefiting departures than can be expected to use the candidate runway can be approximated by analogy with the percentage of instrument approaches that can be expected to use the candidate runway, as discussed in Section C-4 of this chapter. Where the site-specific runway utilization factor is available or where it can be estimated from other site-specific data, it should be used. Lacking site-specific data, the appropriate national average value from Table IV-4 may be used.

5. The Unit Costs of Instrument Departure Disruptions

As with the case of landing benefits discussed in Section C of this chapter, the methodology outlined in Appendix E to this report is again relied upon as the basis for estimating the unit costs of flight disruptions. In the case of departures, the applicable types of flight disruptions are delays and cancellations; diversions and overflights are not applicable. In summary, Appendix E provides the following unit costs of instrument departure disruptions (CDD) for the air carrier and air taxi user classes in 1985 dollars:

Air Carrier:	
Hub Airports	$5,643
Non-Hub Airports	2,087
Air Taxi	251

6. Summary of Annual Takeoff Benefits

Summarizing Sections IV-D-2, IV-D-3, IV-D-4 and IV-D-5, the annual takeoff benefits attributable to a Touchdown RVR System for the air carrier and air taxi user classes (ATB_{UC}) can be expressed as:

$$ATB_{UC} = PITT \times ITN_{UC}/2 \times RU \times CDD_{UC}$$

$$= \frac{RVRTT}{CTT} \times ITN_{UC}/2 \times RU \times CDD_{UC}$$

where PITT is the percentage increase in time the candidate runway can be expected to be open for takeoffs; ITN_{UC} is the current number of annual itinerant aircraft operations by benefiting user class (air carrier and air taxi, respectively) (i.e., prior to the potential establishment of the Touchdown RVR System); RU, the runway utilization factor, is the percentage of departures that can be expected to use the candidate runway; CDD_{UC} is the unit cost of an instrument departure disruption by benefiting user class; RVRTT, RVR takeoff time, is the additional percentage of time the candidate runway would be open with a Touchdown RVR System; and CTT, current takeoff time, is the percentage of time the candidate runway is currently open for takeoffs (i.e., prior to the potential establishment of a Touchdown RVR System).

In the case of Muskegon, a non-hub airport, the annual takeoff benefits of a Touchdown RVR System on Runway 32 can be computed as follows:

Air Carrier	$\frac{0.31\%}{99.2\%} \times \frac{9,303}{2} \times 100\% \times \$2,087 =$	$30,337
Air Taxi	$\frac{0.31\%}{99.2\%} \times \frac{7,697}{2} \times 100\% \times \$\ 251 =$	3,019

Total		$33,356

E. Life-Cycle Benefits

To arrive at life-cycle benefits, the procedures outlined in Sections IV-C (for annual landing benefits) and IV-D (for annual takeoff benefits) must be repeated for each year of an assumed economic life-cycle of 15 years, discounted to present value, and summed. For purposes of the criteria developed in this report, all factors other than annual aircraft activity (annual instrument approaches and annual air carrier and air taxi operations) are assumed to remain constant throughout the 15-year life-cycle. Therefore, life-cycle benefits (PBV) of a Touchdown RVR System can be expressed as:

$$PBV = \sum_{y=1}^{15} (ALB_y + ATB_y)/((1 + d)^{y-0.5})$$

where 'y' is each year of an assumed economic life of 15 years, 'ALB_y' is the landing benefits in year 'y', 'ATB_y' is the takeoff benefits in year 'y', 'd' is the OMB-prescribed discount rate of 10 percent (per Reference 4), and the 0.5 factor in the exponent of the denominator serves to effect mid-year, as opposed to end-of-year, discounting. Solutions for the expression $1/(1+d)^{y-0.5}$ are provided Table IV-5 for y = 1 through 15.

TABLE IV-5

Methodology For Computing The Present Value Of Life-Cycle Benefits

(A) YEAR (y)	(B) ANNUAL LANDING BENEFITS	(C) ANNUAL TAKEOFF BENEFITS	(D) TOTAL ANNUAL BENEFITS (NON-DISCOUNTED) (B)+(C)	(E) MID-YEAR DISCOUNT FACTOR @ 10 PERCENT 1/	(F) PRESENT VALUE (D) x (E)
1				.953	
2				.867	
3				.788	
4				.716	
5				.651	
6				.592	
7				.538	
8				.489	
9				.445	
10				.404	
11				.368	
12				.334	
13				.304	
14				.276	
15				.251	
TOTAL				7.977 2/	

1/ Present value of $1: $1/(1+d)^{y-0.5}$, where 'd' is the OMB-prescribed discount rate of 10 percent (per Reference 4) and 'y' is the year in column A. The 0.5 factor serves to effect mid-year, as opposed to end-of-year, discounting.

2/ Column, as printed, does not add to printed total because of independent rounding.

CHAPTER V - DEVELOPMENT OF PHASE I CRITERIA

In this chapter, Phase I establishment and discontinuance criteria for the Touchdown RVR System at Category I precision instrumented runways are developed. These criteria will be effected through a change to FAA Order 7031.2C, Airway Planning Standard Number One, Terminal Air Navigation Facilities and Air Traffic Control Services (APS-1) (Reference 1).

As outlined in the introduction and in numerous other parts of this report, most APS-1 benefit/cost criteria are applied in two phases. Phase II is the complete benefit/cost analysis supported by the computerized Aviation Data Analysis System (ADA) maintained by the FAA's Office of Aviation Policy and Plans. Phase I criteria are an abbreviated form of Phase II and are designed to approximate the Pnase II benefit/cost ratio in instances where ADA is inaccessible. Phase I criteria are easily applied with available data and without the aid of a computer. Either or both phases are used by FAA regional offices and others to screen locations for Facilities and Equipment (F&E) budget submissions or reprogrammings, with Phase II controlling. Chapter VI provides computer generated Phase I and Phase II results for 470 Category I precision instrumented runways at 359 airport traffic control tower locations for the forecast period FY 1985 through FY 1999.

The objective in developing Phase I criteria is to derive a simple relationship that when applied to first year traffic activity data will produce a reasonable approximation of the Phase II benefit/cost ratio. Multivariate regression analysis was used to determine the best-fitting relationship. To conform the the general format of other Phase I criteria in APS-1, the following format was established and sought:

$$BCII \sim BCI = \frac{(\text{Year 1 Activity } i,j) \times RU \times SDF}{\text{Constant } i,j}$$

where "BCII" is the ADA-computed Phase II benefit/cost ratio, "BCI" is the Phase I value, "Year 1 Activity i,j" is the level of relevant first year traffic activity by user class (air carrier, air taxi, general aviation, and military) by relevant activity measure (instrument approaches for all user classes and itinerant operations for the air carrier and air taxi user classes), "Constant i,j" is the corresponding fixed activity measures, "RU" is the runway utilization factor (as a percentage), and "SDF" is the system design cost factor.

Applying this to the first two Category I precision instrumented runways located at hub airports with airport traffic control towers, based on a system design factor of 1.00, yielded the following regression coefficients:

Air Carrier Instrument Approach Coefficient	-	.000069186
Air Carrier Itinerant Operation Coefficient	-	.000001542
Air Taxi Instrument Approach Coefficient	-	.000001000
Air Taxi Itinerant Operation Coefficient	-	.000000137
General Aviation Instrument Approach Coefficient	-	.000001119
Military Instrument Approach Coefficient	-	.000005303

Other diagnostics and statistics are reproduced as follows:

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	0.10407	0.02081	93.446	0.0001
Error	203	0.04522	0.00022		
U Total	208	0.14929			

Root MSE	0.01492	R-Square	0.6971
Dep Mean	0.01313	Adj R-Sq	0.6897
C.V.	113.67853		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
ACITN	1	0.000001542	0.00000083	1.861	0.0642
ATITN	1	0.000000137	0.00000012	1.191	0.2350
ACAP	1	0.000069186	0.00001536	4.503	0.0001
GAAP	1	0.000001119	0.00000056	2.001	0.0467
MILAP	1	0.000005303	0.00000502	1.056	0.2922

Collinearity Diagnostics

Number	Eigenvalue	Condition Number	Var Prop ACITN	Var Prop ATITN	Var Prop ACAP	Var Prop GAAP	Var Prop MILAP
1	2.52508	1.00000	0.0116	0.0492	0.0118	0.0399	0.0300
2	1.14435	1.48545	0.0192	0.0905	0.0163	0.1795	0.1148
3	0.80543	1.77062	0.0001	0.1086	0.0001	0.0901	0.8478
4	0.47336	2.30961	0.0005	0.7509	0.0015	0.6757	0.0057
5	0.05178	6.98295	0.9687	0.0008	0.9703	0.0148	0.0017

The ratio of "(1/Coefficient)/100" constitutes the term "Constant i,j" (divisor of 100 reflects denomination of runway utilization factor as a percent) as follows:

Air Carrier Instrument Approaches	-	145
Air Carrier Itinerant Operations	-	6,485 (6,500 rounded)
Air Taxi Instrument Approaches	-	10,000
Air Taxi Itinerant Operations	-	72,993 (73,000 rounded)
General Aviation Instrument Approaches	-	8,937 (8,900 rounded)
Military Instrument Approaches	-	1,885 (1,900 rounded)

It is important that there be a close relationship between the results of Phase I and Phase II. If not, either of two undesirable situations can occur. First, a location may satisfy Phase I but fail to reflect an acceptable benefit/cost ratio under Phase II, a situation which is termed "false alarm." Secondly, and more critically, a location may not satisfy Phase I but attain a benefit/cost ratio of 1 or more under Phase II, a situation which is termed "non-identification." The Phase I criteria resulting from the above coefficients yielded only 14 false alarm reversals and 6 non-identification reverals, a tolerable level for APS-1 criteria purposes.

The resulting Phase I criteria can be stated as follows:

a. Establishment. A Category I precision instrumented runway (i.e., equipped with a Category I Instrument Landing System or Microwave Landing System) satisfies the Phase I establishment criteria for a Touchdown RVR System if:

(1) An acceptable method is available for immediate dissemination of RVR value data to pilots (e.g., airport traffic control tower, combined station/tower, or where appropriate, a remote approach control facility);

(2) The provisions of FAA Order 6560.10B, Runway Visual Range, and the siting and installation standards of FAA-STD-008 can be met; and

(3) The Phase I value, computed using the methodology outlined in Figure V-1, equals or exceeds 1.00.

FIGURE V-1

Phase I Criteria for Touchdown RVR System at Category I Precision Instrument Runway

User Class			Contribution
Air Carrier:	$\frac{ACAP}{145} + \frac{ACITN}{6,500}$	=	x.xx
Air Taxi:	$\frac{ATAP}{10,000} + \frac{ATITN}{73,000}$	=	x.xx
General Aviation:	$\frac{GAAP}{8,900}$	=	x.xx
Military:	$\frac{MILAP}{1,900}$	=	+ x.xx
Subtotal			x.xx
x RVR System Design Factor			x x.xx
Subtotal			x.xx
x Runway Utilization Factor			x .xx
Phase I Value			x.xx

where for each of the first three years of operation, ACAP, ATAP, GAAP and MILAP are the numbers of annual instrument approaches by user class, ACITN and ATITN are the numbers of annual itinerant operations of the air carrier and air taxi user classes, the RVR system design factor is from Table V-1, and the runway utilization factor is the percentage of total airport operations that can be expected to use the candidate runway during instrument weather conditions. If a site-specific runway utilization factor is unavailable and cannot be estimated, the appropriate national average default value from Table V-2 may be substituted.

TABLE V-1

RVR System Design Factors

System Design of Proposed RVR Investment	No. of Currently Existing RVR Systems* of this Design Type	Factor
"New Generation"	0	1.00
	≥ 1	3.17
Tasker 500	≥ 0	0.60

* Category I, II, or III.

TABLE V-2

Default Runway Utilization Factors

(Use only if site-specific value is unavailable and cannot be estimated)

Total Number of Precision Instrumented Runways at Airport (All Categories)	Runway Utilization Factor per Runway (%) 1	2	3	4	5
1	100				
2	61	39			
3	45	35	20		
4	42	32	18	8	
≥ 5	41	31	17	8	3

For example, if the airport has three precision instrumented runways with one being Category II and two being Category I, the default runway utilization factors for the first and second Category I runways would be 35 and 20 percent, respectively.

b. Discontinuance. An existing Touchdown RVR System at a Category I precision instrumented runway qualifies for discontinuance when the Phase I value, computed using the methodology outlined in Figure V-1, falls beneath 0.40. Discontinuance of a Touchdown RVR System installation must be justified by a benefit/cost analysis (as provided in paragraph c below) and an assessment of operational and environmental factors pertinent to the affected runway.

c. Benefit/Cost Screening. Candidate runways which successfully meet the requirements of paragraph a or b above will be screened by the Phase II benefit/cost criteria developed and outlined in this report. The above (Phase I) criteria are based primarily on volume of air traffic and frequency and incidence of IFR weather. As such, these criteria are general in nature and do not cover all situations which may arise. Therefore, in cases where unique site-specific operational factors exist that may warrant special consideration (e.g., troublesome terrain features in the vicinity of the airport, significant remoteness of the runway from the tower, etc.), narrative and explanatory reference should be included in the Annual Call for Estimates so that such factors may be considered in the Phase II criteria and other investment decisionmaking processes. To the extent possible, site-specific costs, including the identity of the proposed system design type, should be included in the Annual Call for Estimates.

CHAPTER VI - RESULTS AND IMPACT OF CRITERIA

A. Results of Criteria

Table VI-1 outlines the results of applying the revised establishment and newly developed discontinuance criteria developed in this report to 470 (359 first and 111 second) Category I runways at 359 airport traffic control tower locations, based on a life-cycle extending from FY 1985 through FY 1999. Also outlined in Table VI-1 are the results of applying the previous criteria, which addressed only RVR establishment on the first Category I runway, to the same population of airports.

B. Impact of Criteria

The impact of the revised criteria may be assessed by comparing the number of runways which qualify under the revised criteria with the number that would qualify under the previous criteria. The revised criteria are more restrictive than the previous criteria, but also cover more runways. The previous criteria, which as indicated above addressed only the establishment of an initial Touchdown RVR System, identify 194 existing Category I precision instrumented runways satisfying the establishment criteria for a Touchdown RVR System. The revised RVR criteria, on the other hand, identify 317 qualifying runways -- 210 first Category I runways and 107 second Category I runways.

Applying the differential impact of 16 runways to their respective life-cycle costs results in a potential budgetary impact of approximately $3.0 million (1985 present value dollars). In all likelihood, however, this impact assessment is overstated since the FAA has historically not strictly adhered to the previous establishment criteria for the Touchdown RVR System. The previous RVR criteria, subsequent to their issuance, became suspect as being too lenient as a result of special site-specific studies by FAA regional personnel which suggested that RVR was not required in many cases where the criteria were satisfied. Subsequently, it became agency policy to require additional supporting meteorological and siting data beyond that required by the criteria to accompany all requests for RVR establishment.

TABLE VI-1

12/31/86 RVR COST/BENEFIT ANALYSIS IN 1985 DOLLARS

LOCID/	RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
ABE	ILS [2]	RVR [0]						
	13	200	.50	61%	4.08	3.27	2.22	INVEST
	06	200	.50	39%	8.27	7.30	.00	INVEST
ABI	ILS [1]	RVR [0]						
	35R	200	.50	100%	.48	.21	.62	UNQUALIFIED
ABQ	ILS [1]	RVR [0]						
	08	200	.50	100%	13.50	6.15	10.84	INVEST
ABY	ILS [1]	RVR [0]						
	04	200	.50	100%	.54	.44	.48	UNQUALIFIED
ACK	ILS [1]	RVR [0]						
	24	200	.50	100%	7.12	2.99	2.02	INVEST
ACT	ILS [1]	RVR [0]						
	19	200	.50	100%	.35	.17	.52	UNQUALIFIED
ACY	ILS [1]	RVR [0]						
	13	200	.31	100%	1.05	22.23	4.52	INVEST
ADS	ILS [1]	RVR [0]						
	15	250	1.00	100%	.24	.18	.33	UNQUALIFIED
AGC	ILS [2]	RVR [0]						
	10	200	.75	61%	.25	.18	.83	UNQUALIFIED
	28	251	.50	39%	.16	.14	.00	UNQUALIFIED
AGS	ILS [2]	RVR [0]						
	17	200	.50	61%	2.05	2.61	1.53	INVEST
	35	200	.50	39%	4.17	5.81	.00	INVEST
AKN	ILS [1]	RVR [0]						
	11	200	.50	100%	2.41	1.56	.76	INVEST
ALB	ILS [2]	RVR [0]						
	01	250	.75	61%	7.85	5.52	4.67	INVEST
	19	250	1.00	39%	15.91	12.09	.00	INVEST
ALN	ILS [1]	RVR [0]						
	29	250	.75	100%	.15	.08	.22	UNQUALIFIED
ALO	ILS [1]	RVR [0]						
	12	200	.50	100%	4.21	4.88	.77	INVEST
ALW	ILS [1]	RVR [0]						
	20	200	.50	100%	.13	.19	.62	UNQUALIFIED
AMA	ILS [1]	RVR [0]						
	04	200	.50	100%	5.27	6.87	2.81	INVEST
ANC	ILS [1]	RVR [0]	CATEGORY II OR III RUNWAYS QUALIFY					
APA	ILS [1]	RVR [0]						
	34R	200	.50	100%	.32	.19	.48	UNQUALIFIED
APN	ILS [1]	RVR [0]						
	01	200	.50	100%	.04	.04	.05	UNQUALIFIED
ARR	ILS [1]	RVR [0]						
	09	200	.50	100%	.21	.18	.42	UNQUALIFIED
ATL	ILS [8]	RVR [0]						
	27L	200	.50	8%	27.75	37.41	11.38	INVEST
	26L	200	.56	3%	32.99	47.98	.00	INVEST
ATW	ILS [1]	RVR [0]						
	03	200	.50	100%	5.33	12.00	.81	INVEST
AUS	ILS [2]	RVR [0]						
	31L	200	.50	61%	21.70	14.33	11.06	INVEST
	13R	200	.75	39%	44.00	31.01	.00	INVEST

LOCID/		RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
AVL	ILS [2]		RVR [0]						
		16	214	.75	61%	4.16	14.32	2.18	INVEST
		34	250	.50	39%	8.43	37.31	.00	INVEST
AVP	ILS [2]		RVR [0]						
		22	250	.75	61%	1.77	1.30	1.34	INVEST
		04	400	.75	39%	3.59	4.01	.00	INVEST
AZO	ILS [1]		RVR [0]						
		35	200	.50	100%	8.31	8.38	1.31	INVEST
BAF	ILS [1]		RVR [0]						
		20	200	.50	100%	.52	.36	.72	UNQUALIFIED
BAK	ILS [1]		RVR [0]						
		22	200	.50	100%	.06	.03	.07	UNQUALIFIED
BDL	ILS [3]		RVR [0]						
		24	200	.50	35%	14.28	17.35	10.64	INVEST
		33	250	.75	20%	25.87	34.80	.00	INVEST
BDR	ILS [1]		RVR [0]						
		06	250	.75	100%	.80	1.17	1.08	INVEST
BED	ILS [1]		RVR [0]						
		11	250	1.00	100%	.94	1.50	2.18	INVEST
BEH	ILS [1]		RVR [0]						
		27	250	.75	100%	.21	.23	.21	UNQUALIFIED
BET	ILS [1]		RVR [0]	CANNOT CALCULATE					
BFI	ILS [1]		RVR [0]						
		13R	260	1.00	100%	2.35	2.47	1.87	INVEST
BFL	ILS [1]		RVR [0]						
		30R	200	.50	100%	1.61	2.75	1.07	INVEST
BGM	ILS [2]		RVR [0]						
		34	200	.50	61%	1.96	1.88	1.93	INVEST
		16	250	.50	39%	3.98	4.57	.00	INVEST
BGR	ILS [2]		RVR [0]						
		15	200	.50	61%	4.72	6.35	2.36	INVEST
		33	200	.50	39%	9.57	14.15	.00	INVEST
BHM	ILS [1]		RVR [0]	CATEGORY II OR III RUNWAYS QUALIFY					
BIL	ILS [1]		RVR [0]						
		09L	200	.50	100%	6.47	5.15	2.03	INVEST
BIS	ILS [2]		RVR [0]						
		31	200	.50	61%	2.41	2.13	1.05	INVEST
		13	200	.75	39%	4.89	4.17	.00	INVEST
BJC	ILS [1]		RVR [0]						
		29R	200	.50	100%	.17	.10	.25	UNQUALIFIED
BMG	ILS [1]		RVR [0]						
		35	200	.50	100%	.14	.08	.25	UNQUALIFIED
BMI	ILS [1]		RVR [0]						
		29	200	.50	100%	.38	.25	.58	UNQUALIFIED
BNA	ILS [3]		RVR [0]						
		31	200	.50	35%	9.81	7.48	8.12	INVEST
		20R	250	.75	20%	17.78	15.24	.00	INVEST
BOI	ILS [1]		RVR [0]						
		10R	200	.50	100%	4.80	4.27	2.89	INVEST
BOS	ILS [5]		RVR [0]						
		33L	200	.31	31%	41.88	40.11	5.09	INVEST
		15R	250	.75	17%	72.81	75.50	.00	INVEST
BPT	ILS [1]		RVR [0]						
		12	200	.50	100%	.53	.44	.91	UNQUALIFIED

LOCID/		RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
BRO	ILS	[1]	RVR [0]						
		13R	200	.50	100%	1.72	1.09	.53	INVEST
BTL	ILS	[1]	RVR [0]						
		23	200	.50	100%	2.43	2.93	.51	INVEST
BTV	ILS	[1]	RVR [0]						
		15	200	.50	100%	6.51	3.08	3.27	INVEST
BUF	ILS	[2]	RVR [0]						
		05	200	.31	61%	28.33	22.08	11.71	INVEST
		23	200	.31	39%	57.43	49.24	.00	INVEST
BUR	ILS	[1]	RVR [0]						
		07	250	1.00	100%	42.87	36.64	9.56	INVEST
BWI	ILS	[4]	RVR [0]						
		15R	200	.50	32%	20.24	9.34	20.27	INVEST
		33L	200	.50	18%	36.10	18.33	.00	INVEST
CAE	ILS	[2]	RVR [0]						
		29	200	.50	39%	4.19	3.86	3.06	INVEST
CAK	ILS	[3]	RVR [0]						
		01	200	.50	45%	2.06	1.88	1.63	INVEST
		19	200	.50	35%	5.08	5.11	.00	INVEST
CGF	ILS	[1]	RVR [0]						
		23	300	1.00	100%	.17	.08	.21	UNQUALIFIED
CGI	ILS	[1]	RVR [0]						
		10	200	.50	100%	.12	.05	.23	UNQUALIFIED
CHA	ILS	[2]	RVR [0]						
		02	200	.50	39%	1.97	3.04	2.13	INVEST
CHO	ILS	[1]	RVR [0]						
		03	200	.50	100%	1.75	2.59	1.22	INVEST
CHS	ILS	[2]	RVR [0]						
		15	200	.31	61%	7.81	8.76	3.69	INVEST
		33	200	.75	39%	15.83	17.01	.00	INVEST
CIC	ILS	[1]	RVR [0]						
		13L	200	.50	100%	.23	.19	.37	UNQUALIFIED
CID	ILS	[2]	RVR [0]						
		09	200	.50	61%	5.12	4.81	1.94	INVEST
		27	250	.75	39%	10.38	10.96	.00	INVEST
CKB	ILS	[1]	RVR [0]						
		21	397	1.00	100%	.33	.51	.53	UNQUALIFIED
CLE	ILS	[3]	RVR [0]						
		28R	250	.50	35%	29.68	13.99	15.44	INVEST
		23L	250	.75	20%	53.77	28.21	.00	INVEST
CLL	ILS	[1]	RVR [0]						
		34	200	.50	100%	.38	.25	.80	UNQUALIFIED
CLT	ILS	[4]	RVR [0]						
		05	200	.50	32%	31.62	44.18	27.37	INVEST
		36R	200	.50	18%	56.39	86.68	.00	INVEST
CMH	ILS	[3]	RVR [0]						
		10L	200	.50	45%	15.18	8.25	10.68	INVEST
		10R	200	.50	35%	37.43	22.40	.00	INVEST
CMI	ILS	[1]	RVR [0]						
		31	200	.50	100%	2.97	2.40	1.34	INVEST
CNO	ILS	[1]	RVR [0]						
		26	250	1.00	100%	.62	.42	1.07	UNQUALIFIED
CNW	ILS	[1]	RVR [0]						
		17L	200	.75	100%	.04	.01	.03	UNQUALIFIED

LOCID/		RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
COE	ILS [1]		RVR [0]						
		05	345	.75	100%	.16	.30	.18	UNQUALIFIED
COS	ILS [2]		RVR [0]						
		17	200	.50	61%	4.63	3.99	3.19	INVEST
		35	206	.50	39%	9.38	8.92	.00	INVEST
COU	ILS [1]		RVR [0]						
		02	200	.50	100%	1.64	2.78	.70	INVEST
CPR	ILS [2]		RVR [0]						
		03	200	.50	61%	1.96	1.19	.79	INVEST
		07	300	.50	39%	3.98	3.23	.00	INVEST
CPS	ILS [1]		RVR [0]						
		30	250	.50	100%	.29	.12	.37	UNQUALIFIED
CRE	ILS [1]		RVR [0]						
		23	200	.50	100%	.14	.08	.29	UNQUALIFIED
CRP	ILS [2]		RVR [0]						
		35	200	.50	61%	4.29	3.19	3.42	INVEST
		13	200	.50	39%	8.70	7.13	.00	INVEST
CRQ	ILS [1]		RVR [0]						
		24	200	.50	100%	.62	.47	.67	UNQUALIFIED
CRW	ILS [2]		RVR [0]						
		23	250	.50	61%	5.43	12.44	3.10	INVEST
		05	494	1.00	39%	11.01	26.73	.00	INVEST
CSG	ILS [1]		RVR [0]						
		05	200	.50	100%	1.92	2.16	1.02	INVEST
CSM	ILS [1]		RVR [0]						
		17R	200	.75	100%	.07	.03	.18	UNQUALIFIED
CVG	ILS [4]		RVR [0]						
		18	200	.31	32%	28.67	26.00	11.53	INVEST
		09R	200	.50	18%	51.13	47.13	.00	INVEST
CXY	ILS [1]		RVR [0]						
		08	597	1.00	100%	.17	.26	.48	UNQUALIFIED
DAB	ILS [1]		RVR [0]						
		06L	200	.50	100%	3.92	3.21	1.78	INVEST
DAL	ILS [2]		RVR [0]						
		13L	200	.31	61%	22.13	5.32	19.54	INVEST
		31L	200	.31	39%	44.86	11.86	.00	INVEST
DAY	ILS [4]		RVR [0]						
		24R	200	.50	32%	19.45	15.93	9.38	INVEST
		24L	200	.50	18%	34.69	31.27	.00	INVEST
DBQ	ILS [1]		RVR [0]						
		31	200	.50	100%	2.43	2.48	.41	INVEST
DCA	ILS [1]		RVR [0] CATEGORY II OR III RUNWAYS QUALIFY						
DEC	ILS [1]		RVR [0]						
		06	200	.50	100%	.39	.21	.57	UNQUALIFIED
DEN	ILS [5]		RVR [0]						
		26L	200	.50	31%	35.98	23.04	26.03	INVEST
		35L	200	.50	17%	62.55	44.08	.00	INVEST
DET	ILS [2]		RVR [0]						
		15	250	1.00	61%	1.66	.35	1.02	UNQUALIFIED
		33	250	1.00	39%	1.06	.22	.00	UNQUALIFIED
DFW	ILS [7]		RVR [0]						
		18L	200	.31	17%	30.05	10.52	41.14	INVEST
		36L	200	.31	8%	44.83	17.26	.00	INVEST

LOCID/	RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
DHN	ILS [1]	RVR [0]						
	31	200	.50	100%	2.56	.69	1.02	UNQUALIFIED
DLH	ILS [2]	RVR [0]						
	27	200	.50	61%	2.22	6.71	1.51	INVEST
	09	452	.50	39%	4.51	17.10	.00	INVEST
DNV	ILS [1]	RVR [0]						
	21	200	.50	100%	.13	.08	.13	UNQUALIFIED
DPA	ILS [1]	RVR [0]						
	10	200	.75	100%	.48	.34	.74	UNQUALIFIED
DSM	ILS [2]	RVR [0]						
	30R	200	.50	61%	9.13	8.69	4.43	INVEST
	12L	200	.75	39%	18.50	18.18	.00	INVEST
DTW	ILS [5]	RVR [0]						
	21R	200	.50	17%	24.80	24.54	32.08	INVEST
	27	200	.50	8%	36.99	40.28	.00	INVEST
EDF	ILS [1]	RVR [0]						
	05	200	.31	100%	.24	.12	.29	UNQUALIFIED
ELM	ILS [2]	RVR [0]						
	06	200	.50	61%	2.17	2.13	1.45	INVEST
	24	280	.50	39%	4.40	5.40	.00	INVEST
ELP	ILS [1]	RVR [0]						
	22	200	.50	100%	8.87	1.41	6.78	INVEST
ENA	ILS [1]	RVR [0]						
	19	200	.50	100%	12.55	7.98	.94	INVEST
ERI	ILS [2]	RVR [0]						
	24	200	.50	61%	1.80	2.24	1.13	INVEST
	06	250	.75	39%	3.65	5.31	.00	INVEST
ESF	ILS [1]	RVR [0]						
	26	200	.50	100%	.28	.32	.57	UNQUALIFIED
EUG	ILS [1]	RVR [0]						
	16	200	.50	100%	2.99	5.75	2.00	INVEST
EVV	ILS [2]	RVR [0]						
	22	200	.50	61%	2.56	1.72	1.55	INVEST
	04	200	.75	39%	5.19	3.60	.00	INVEST
EWB	ILS [1]	RVR [0]						
	05	200	.50	100%	3.10	1.28	1.08	INVEST
EWR	ILS [3]	RVR [0]						
	22L	200	.31	35%	62.64	50.51	23.63	INVEST
	04L	200	.50	20%	113.46	97.90	.00	INVEST
FAI	ILS [2]	RVR [0]						
	19R	200	.50	39%	1.92	1.23	1.89	INVEST
FAR	ILS [2]	RVR [0]						
	17	200	.50	61%	2.79	2.63	1.49	INVEST
	35	200	.50	39%	5.65	5.86	.00	INVEST
FAT	ILS [1]	RVR [0]						
	29R	200	.50	100%	8.26	16.33	3.85	INVEST
FAY	ILS [1]	RVR [0]						
	04	200	.50	100%	5.84	9.42	1.60	INVEST
FLL	ILS [2]	RVR [0]						
	27R	200	.50	61%	10.87	4.59	16.59	INVEST
	09L	250	1.00	39%	22.04	10.65	.00	INVEST
FLO	ILS [1]	RVR [0]						
	09	200	.50	100%	.36	.27	.45	UNQUALIFIED

LOCID/	RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
FMY	ILS [1]	RVR [0]						
	05	250	1.00	100%	.24	.13	.33	UNQUALIFIED
FNT	ILS [2]	RVR [0]						
	27	200	.50	61%	1.94	1.14	1.18	INVEST
	09	250	.50	39%	3.94	2.99	.00	INVEST
FOE	ILS [1]	RVR [0]						
	31	200	.50	100%	.99	.68	.65	UNQUALIFIED
FOK	ILS [1]	RVR [0]						
	24	200	.50	100%	.24	.26	.80	UNQUALIFIED
FRG	ILS [1]	RVR [0]						
	14	250	1.00	100%	.73	.77	1.22	UNQUALIFIED
FSD	ILS [2]	RVR [0]						
	03	200	.50	61%	5.02	3.56	1.75	INVEST
	21	220	.56	39%	10.18	7.98	.00	INVEST
FSM	ILS [1]	RVR [0]						
	25	200	.50	100%	1.22	1.16	.65	INVEST
FTW	ILS [1]	RVR [0]						
	16L	200	.50	100%	.48	.16	.50	UNQUALIFIED
FTY	ILS [1]	RVR [0]						
	08R	250	.75	100%	.42	.48	.74	UNQUALIFIED
FWA	ILS [2]	RVR [0]						
	04	200	.50	61%	7.97	6.41	2.05	INVEST
	31	339	.75	39%	16.16	17.97	.00	INVEST
FXE	ILS [1]	RVR [0]						
	08	200	.75	100%	.09	.05	.14	UNQUALIFIED
GBG	ILS [1]	RVR [0]						
	02	207	.50	100%	.12	.09	.11	UNQUALIFIED
GCN	ILS [1]	RVR [0]	CANNOT CALCULATE					
GEG	ILS [2]	RVR [0]						
	03	200	.50	39%	5.39	12.47	4.60	INVEST
GFK	ILS [1]	RVR [0]						
	35L	200	.50	100%	2.78	4.33	.92	INVEST
GGG	ILS [1]	RVR [0]						
	13	200	.50	100%	.34	.26	.51	UNQUALIFIED
GJT	ILS [1]	RVR [0]						
	11	200	.50	100%	1.61	1.18	.75	INVEST
GLH	ILS [1]	RVR [0]						
	17L	200	.50	100%	.74	.13	.32	UNQUALIFIED
GMU	ILS [1]	RVR [0]						
	36	223	.75	100%	.15	.12	.44	UNQUALIFIED
GNV	ILS [1]	RVR [0]						
	28	200	.50	100%	2.53	4.92	2.25	INVEST
GON	ILS [1]	RVR [0]						
	05	200	.75	100%	.76	.87	1.11	UNQUALIFIED
GPT	ILS [1]	RVR [0]						
	13	200	.50	100%	2.55	2.10	.87	INVEST
GRB	ILS [2]	RVR [0]						
	36	200	.50	61%	5.04	6.46	1.30	INVEST
	06R	200	.50	39%	10.22	14.42	.00	INVEST
GRI	ILS [1]	RVR [0]						
	35	200	.50	100%	.15	.19	.46	UNQUALIFIED
GRR	ILS [2]	RVR [0]						
	08R	200	.50	61%	11.86	13.68	3.87	INVEST
	26L	200	.50	39%	24.04	30.52	.00	INVEST

LOCID/	RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
GSO	ILS [3]	RVR [0]						
	14	200	.50	45%	13.85	17.31	5.56	INVEST
	05	200	.50	35%	34.15	46.97	.00	INVEST
GSP	ILS [2]	RVR [0]						
	03	200	.31	61%	5.20	6.93	2.70	INVEST
	21	200	.50	39%	10.54	13.91	.00	INVEST
GTF	ILS [2]	RVR [0]						
	34	200	.50	61%	1.98	1.28	.87	INVEST
	03	200	.50	39%	4.03	2.85	.00	INVEST
GVT	ILS [1]	RVR [0]						
	17	200	.75	100%	.06	.01	.07	UNQUALIFIED
GYY	ILS [1]	RVR [0]						
	30	250	.75	100%	.31	.24	.44	UNQUALIFIED
HGR	ILS [1]	RVR [0]						
	27	200	.50	100%	.31	.21	.55	UNQUALIFIED
HIO	ILS [1]	RVR [0]						
	12	200	.50	100%	.21	.27	.52	UNQUALIFIED
HKS	ILS [1]	RVR [0]						
	16	200	.50	100%	.07	.09	.38	UNQUALIFIED
HKY	ILS [1]	RVR [0]						
	24	200	.50	100%	.25	.34	.48	UNQUALIFIED
HLG	ILS [1]	RVR [0]						
	03	200	.75	100%	.07	.03	.21	UNQUALIFIED
HLN	ILS [1]	RVR [0]						
	26	200	.50	100%	.84	.66	.39	UNQUALIFIED
HNL	ILS [2]	RVR [0]						
	04R	200	.50	61%	17.21	1.97	41.70	INVEST
	08L	200	.50	39%	34.88	4.39	.00	INVEST
HOB	ILS [1]	RVR [0]						
	03	200	.50	100%	.02	.03	.17	UNQUALIFIED
HOU	ILS [2]	RVR [0]						
	04	200	.50	61%	32.91	24.32	24.85	INVEST
	13R	250	.75	39%	66.71	60.06	.00	INVEST
HPN	ILS [2]	RVR [0]						
	16	200	.50	61%	2.45	4.31	2.58	INVEST
	34	276	1.00	39%	4.98	8.83	.00	INVEST
HRL	ILS [1]	RVR [0]						
	17R	200	.50	100%	4.68	2.92	2.91	INVEST
HSV	ILS [2]	RVR [0]						
	18R	200	.50	61%	4.33	2.83	2.19	INVEST
	36L	200	.50	39%	8.78	6.32	.00	INVEST
HTS	ILS [2]	RVR [0]						
	12	200	.50	61%	1.76	4.38	1.57	INVEST
	30	200	.75	39%	3.58	8.68	.00	INVEST
HUF	ILS [1]	RVR [0]						
	05	200	.50	100%	6.14	5.31	.48	INVEST
HUM	ILS [1]	RVR [0]						
	18	200	.50	100%	1.29	.85	1.23	UNQUALIFIED
HUT	ILS [1]	RVR [0]						
	13	200	.50	100%	.21	.20	.33	UNQUALIFIED
HVN	ILS [1]	RVR [0]						
	02	250	.75	100%	.87	1.18	1.12	INVEST
HYA	ILS [1]	RVR [0]						
	24	250	1.00	100%	7.21	3.35	2.03	INVEST

LOCID/		RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
IAD	ILS [5]		RVR [0]						
		19R	200	.31	31%	9.65	19.13	10.91	INVEST
		01L	200	.50	17%	16.78	33.75	.00	INVEST
IAG	ILS [1]		RVR [0]						
		28R	250	.50	100%	.73	3.25	.76	INVEST
IAH	ILS [4]		RVR [0]						
		26	200	.50	32%	34.27	42.46	35.91	INVEST
		14L	200	.50	18%	61.12	83.31	.00	INVEST
ICT	ILS [3]		RVR [0]						
		01R	200	.50	35%	8.41	7.52	4.10	INVEST
		19R	200	.50	20%	15.24	14.99	.00	INVEST
IDA	ILS [1]		RVR [0]						
		20	200	.50	100%	1.16	1.17	.59	INVEST
ILG	ILS [1]		RVR [0]						
		01	200	.50	100%	.84	1.35	.94	INVEST
ILM	ILS [1]		RVR [0]						
		34	200	.50	100%	3.56	3.47	1.11	INVEST
IND	ILS [4]		RVR [0]						
		13	200	.50	32%	13.43	8.72	9.70	INVEST
		31	200	.50	18%	23.96	17.11	.00	INVEST
INT	ILS [1]		RVR [0]						
		33	200	.50	100%	.47	.46	.59	UNQUALIFIED
IPT	ILS [1]		RVR [0]						
		27	495	1.00	100%	.15	.22	.67	UNQUALIFIED
ISO	ILS [1]		RVR [0]						
		04	200	.50	100%	1.93	2.59	.80	INVEST
ISP	ILS [2]		RVR [0]						
		06	200	.50	61%	5.83	6.83	4.09	INVEST
		24	250	.50	39%	11.83	16.29	.00	INVEST
ITH	ILS [1]		RVR [0]						
		32	250	.75	100%	2.76	3.11	1.28	INVEST
ITO	ILS [1]		RVR [0]						
		26	200	.50	100%	4.22	.95	2.74	UNQUALIFIED
JAN	ILS [2]		RVR [0]						
		33L	200	.50	39%	3.82	2.46	2.47	INVEST
JAX	ILS [2]		RVR [0]						
		13	200	.50	39%	8.50	13.42	7.19	INVEST
JFK	ILS [7]		RVR [0]						
		22L	200	.31	17%	20.88	11.97	30.85	INVEST
		31R	200	.50	8%	31.16	17.76	.00	INVEST
JLN	ILS [1]		RVR [0]						
		13	200	.50	100%	.57	1.37	.51	INVEST
JVL	ILS [1]		RVR [0]						
		04	200	.50	100%	.37	.22	.46	UNQUALIFIED
JXN	ILS [1]		RVR [0]						
		24	200	.50	100%	.22	.14	.44	UNQUALIFIED
KOA	ILS [1]		RVR [0]	CANNOT CALCULATE					
LAF	ILS [1]		RVR [0]						
		10	200	.50	100%	1.31	1.52	.52	INVEST
LAL	ILS [1]		RVR [0]						
		05	200	.50	100%	.16	.06	.20	UNQUALIFIED
LAN	ILS [2]		RVR [0]						
		10R	200	.50	61%	4.43	.61	1.01	UNQUALIFIED
		28L	200	.50	39%	2.83	.39	.00	UNQUALIFIED

LOCID/	RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
LAS	ILS [1]	RVR [0]						
	25	200	.50	100%	20.22	.00	24.02	UNQUALIFIED
LAW	ILS [1]	RVR [0]						
	35	200	.50	100%	.25	.12	.43	UNQUALIFIED
LAX	ILS [8]	RVR [0]						
	07L	200	.50	17%	48.01	64.83	43.01	INVEST
	25R	200	.50	8%	71.62	106.42	.00	INVEST
LBB	ILS [2]	RVR [0]						
	26	200	.50	61%	5.81	5.18	3.91	INVEST
	17R	200	.50	39%	11.78	11.55	.00	INVEST
LBE	ILS [1]	RVR [0]						
	23	250	.75	100%	.14	.12	.16	UNQUALIFIED
LCH	ILS [1]	RVR [0]						
	15	200	.50	100%	.50	.67	.80	UNQUALIFIED
LEX	ILS [2]	RVR [0]						
	04	200	.50	61%	6.03	2.96	2.37	INVEST
	22	250	1.00	39%	12.23	7.20	.00	INVEST
LFT	ILS [1]	RVR [0]						
	21	200	.50	100%	3.13	4.64	1.69	INVEST
LGA	ILS [3]	RVR [0]						
	22	200	.31	45%	73.68	50.32	6.76	INVEST
	13	250	.50	35%	181.67	154.29	.00	INVEST
LGB	ILS [1]	RVR [0]						
	30	200	.50	100%	7.67	7.25	5.98	INVEST
LIH	ILS [1]	RVR [0]						
	35	200	.50	100%	6.36	.73	5.91	UNQUALIFIED
LIT	ILS [2]	RVR [0]						
	04	200	.50	61%	6.66	5.40	4.11	INVEST
	22	200	.50	39%	13.50	12.04	.00	INVEST
LMT	ILS [1]	RVR [0]						
	32	200	.50	100%	.36	.43	1.05	UNQUALIFIED
LNK	ILS [2]	RVR [0]						
	17R	200	.50	61%	3.77	2.49	1.38	INVEST
	35L	200	.50	39%	7.65	5.56	.00	INVEST
LNS	ILS [1]	RVR [0]						
	08	200	.50	100%	.68	.59	.95	UNQUALIFIED
LRD	ILS [1]	RVR [0]						
	17C	200	.50	100%	.21	.14	.29	UNQUALIFIED
LSE	ILS [1]	RVR [0]						
	18	200	.50	100%	4.91	6.34	.83	INVEST
LUK	ILS [1]	RVR [0]						
	20L	250	.50	100%	.47	.38	.76	UNQUALIFIED
LVK	ILS [1]	RVR [0]						
	25	250	1.00	100%	.18	.22	.72	UNQUALIFIED
LWB	ILS [1]	RVR [0]						
	04	250	.50	100%	.23	.33	.44	UNQUALIFIED
LWM	ILS [1]	RVR [0]						
	05	250	.75	100%	.28	.46	1.54	UNQUALIFIED
LWS	ILS [1]	RVR [0]						
	26	200	.50	100%	.34	.65	.84	UNQUALIFIED
LYH	ILS [1]	RVR [0]						
	03	200	.50	100%	1.84	2.94	.85	INVEST
MAF	ILS [1]	RVR [0]						
	10	200	.50	100%	6.35	4.11	3.82	INVEST

LOCID/	RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
MBS	ILS [2]	RVR [0]						
	05	200	.50	61%	2.69	2.24	1.28	INVEST
	23	200	.50	39%	5.45	4.98	.00	INVEST
MCE	ILS [1]	RVR [0]						
	30	200	.50	100%	.13	.18	.15	UNQUALIFIED
MCI	ILS [3]	RVR [0]						
	01	200	.31	35%	20.61	25.27	20.64	INVEST
	09	200	.50	20%	37.34	46.97	.00	INVEST
MCN	ILS [1]	RVR [0]						
	05	217	.50	100%	.66	.57	.63	UNQUALIFIED
MCO	ILS [2]	RVR [0]						
	18R	200	.50	39%	18.14	45.13	23.56	INVEST
MDH	ILS [1]	RVR [0]						
	18	200	.50	100%	.18	.08	.34	UNQUALIFIED
MDT	ILS [2]	RVR [0]						
	13	250	.75	61%	4.46	4.02	2.67	INVEST
	31	285	1.00	39%	9.04	9.19	.00	INVEST
MDW	ILS [3]	RVR [0]						
	13R	250	1.00	45%	13.80	7.50	7.02	INVEST
	31L	288	1.00	35%	34.04	21.59	.00	INVEST
MEI	ILS [1]	RVR [0]						
	01	200	.50	100%	.49	.25	.59	UNQUALIFIED
MEM	ILS [6]	RVR [0]						
	36R	200	.31	31%	19.86	8.11	14.06	INVEST
	27	200	.50	17%	34.53	15.63	.00	INVEST
MFD	ILS [1]	RVR [0]						
	32	200	.50	100%	.38	.31	.60	UNQUALIFIED
MFE	ILS [1]	RVR [0]						
	13	200	.50	100%	1.60	1.11	1.10	INVEST
MFR	ILS [1]	RVR [0]						
	14	200	.50	100%	4.34	15.37	1.54	INVEST
MGM	ILS [2]	RVR [0]						
	09	200	.50	61%	2.66	2.25	1.55	INVEST
	27	200	.50	39%	5.40	5.03	.00	INVEST
MGW	ILS [1]	RVR [0]						
	18	200	.50	100%	.32	.22	.52	UNQUALIFIED
MHT	ILS [1]	RVR [0]						
	35	200	.50	100%	2.84	4.53	1.32	INVEST
MIA	ILS [5]	RVR [0]						
	09L	200	.31	41%	20.31	13.20	48.27	INVEST
	27R	200	.50	31%	48.68	26.21	.00	INVEST
MIE	ILS [1]	RVR [0]						
	32	200	.50	100%	.21	.17	.47	UNQUALIFIED
MKC	ILS [1]	RVR [0]						
	18	273	1.00	100%	.79	.76	.80	UNQUALIFIED
MKE	ILS [3]	RVR [0]						
	19R	200	.50	35%	17.59	20.42	11.13	INVEST
	07R	200	.50	20%	31.87	40.69	.00	INVEST
MKG	ILS [1]	RVR [0]						
	32	200	.50	100%	6.25	7.48	.79	INVEST
MLB	ILS [1]	RVR [0]						
	09R	200	.50	100%	3.83	4.58	2.25	INVEST
MLI	ILS [1]	RVR [0]						
	09	200	.50	100%	12.41	11.00	2.06	INVEST

LOCID/	RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
MLU	ILS [2]	RVR [0]						
	04	200	.50	61%	1.72	1.55	.96	INVEST
	22	200	.50	39%	3.48	3.46	.00	INVEST
MMU	ILS [1]	RVR [0]						
	23	250	.75	100%	.44	.28	.66	UNQUALIFIED
MOB	ILS [2]	RVR [0]						
	14	200	.50	61%	6.07	6.47	2.31	INVEST
	32	200	.50	39%	12.30	14.43	.00	INVEST
MOD	ILS [1]	RVR [0]						
	28R	250	.50	100%	.34	.68	.96	UNQUALIFIED
MOT	ILS [1]	RVR [0]						
	31	200	.50	100%	2.12	2.39	.62	INVEST
MRB	ILS [1]	RVR [0]						
	26	200	.50	100%	.12	.05	.07	UNQUALIFIED
MRY	ILS [1]	RVR [0]						
	10	200	.50	100%	3.89	3.96	1.79	INVEST
MSN	ILS [2]	RVR [0]						
	18	200	.50	61%	10.40	9.36	2.73	INVEST
	36	200	.50	39%	21.08	20.87	.00	INVEST
MSO	ILS [1]	RVR [0]						
	11	1200	2.00	100%	2.76	14.70	.93	INVEST
MSP	ILS [5]	RVR [0]						
	11R	200	.50	31%	37.90	23.40	37.41	INVEST
	04	200	.50	17%	65.89	44.75	.00	INVEST
MSY	ILS [3]	RVR [0]						
	28	200	.50	35%	14.40	12.37	19.52	INVEST
	01	250	.75	20%	26.09	25.28	.00	INVEST
MTN	ILS [1]	RVR [0]						
	32	250	.75	100%	.30	.15	.30	UNQUALIFIED
MVY	ILS [1]	RVR [0]						
	24	200	.50	100%	.43	.42	.86	UNQUALIFIED
MWA	ILS [1]	RVR [0]						
	20	200	.50	100%	.35	.16	.27	UNQUALIFIED
MWH	ILS [1]	RVR [0]						
	32R	200	.50	100%	.15	.28	.52	UNQUALIFIED
MYV	ILS [1]	RVR [0]						
	14	200	.50	100%	.09	.14	.06	UNQUALIFIED
NEW	ILS [1]	RVR [0]						
	18R	200	.50	100%	.65	.48	.73	UNQUALIFIED
OAK	ILS [3]	RVR [0]						
	11	200	.50	35%	14.31	17.43	10.59	INVEST
	27R	250	1.00	20%	25.92	34.86	.00	INVEST
OGG	ILS [1]	RVR [0]						
	02	200	.50	100%	13.74	1.73	10.80	INVEST
OKC	ILS [2]	RVR [0]						
	17R	200	.50	39%	9.55	9.35	9.09	INVEST
OLM	ILS [1]	RVR [0]						
	17	200	.50	100%	.19	.30	.74	UNQUALIFIED
OMA	ILS [3]	RVR [0]						
	32L	200	.50	35%	6.97	4.32	6.67	INVEST
	17	250	.75	20%	12.63	9.32	.00	INVEST
ONT	ILS [2]	RVR [0]						
	08L	200	.50	39%	21.33	26.76	10.63	INVEST

LOCID/	RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
OPF	ILS [1]	RVR [0]						
	09L	200	.50	100%	.11	.06	.13	UNQUALIFIED
ORD	ILS [11]	RVR [0]						
	32R	200	.31	17%	69.64	62.57	46.15	INVEST
	32L	200	.31	8%	103.90	102.71	.00	INVEST
ORF	ILS [2]	RVR [0]						
	05	250	.50	61%	16.55	16.13	10.10	INVEST
	23	295	.75	39%	33.56	38.13	.00	INVEST
ORH	ILS [1]	RVR [0]						
	11	200	.50	100%	.75	1.01	1.75	INVEST
ORL	ILS [1]	RVR [0]						
	07	200	.50	100%	.32	.43	.52	UNQUALIFIED
OSH	ILS [1]	RVR [0]						
	36	200	.50	100%	3.15	4.91	.83	INVEST
OSU	ILS [1]	RVR [0]						
	09R	200	.50	100%	.37	.13	.52	UNQUALIFIED
OWB	ILS [1]	RVR [0]						
	35	200	.50	100%	.21	.08	.30	UNQUALIFIED
OXR	ILS [1]	RVR [0]						
	25	250	.75	100%	.62	.61	.77	UNQUALIFIED
PAE	ILS [1]	RVR [0]						
	16	200	.50	100%	.40	.39	.83	UNQUALIFIED
PAH	ILS [1]	RVR [0]						
	04	200	.50	100%	2.44	1.81	.39	INVEST
PBF	ILS [1]	RVR [0]						
	17	200	.50	100%	.10	.08	.20	UNQUALIFIED
PBI	ILS [1]	RVR [0]						
	09L	200	.50	100%	12.23	4.25	10.74	INVEST
PDK	ILS [1]	RVR [0]						
	20L	200	.75	100%	.70	.67	1.03	UNQUALIFIED
PDT	ILS [1]	RVR [0]						
	25	200	.50	100%	.08	.09	.28	UNQUALIFIED
PDX	ILS [2]	RVR [0]						
	28R	250	1.00	39%	21.34	31.30	13.58	INVEST
PFN	ILS [1]	RVR [0]						
	14	200	.50	100%	1.99	1.84	1.06	INVEST
PHF	ILS [1]	RVR [0]						
	07	200	.50	100%	.96	.53	.98	UNQUALIFIED
PHL	ILS [4]	RVR [0]						
	27R	200	.50	32%	30.82	23.94	29.87	INVEST
	27L	200	.50	18%	54.96	46.96	.00	INVEST
PHX	ILS [1]	RVR [0]						
	08R	200	.50	100%	34.65	10.02	33.06	INVEST
PIA	ILS [1]	RVR [0]						
	31	220	.56	100%	11.52	12.99	1.70	INVEST
PIE	ILS [1]	RVR [0]						
	17L	200	.50	100%	3.11	6.51	2.49	INVEST
PIH	ILS [1]	RVR [0]						
	21	200	.50	100%	.31	.18	.41	UNQUALIFIED
PIT	ILS [5]	RVR [0]						
	28L	200	.31	31%	48.71	34.36	44.51	INVEST
	28R	200	.50	17%	84.68	64.51	.00	INVEST
PKB	ILS [1]	RVR [0]						
	03	250	.50	100%	.36	.95	1.38	UNQUALIFIED

LOCID/	RNWY	CEIL	VIS	UTIL	B/C I	B/C II	PREV CRIT	ACTION
PMD	ILS [1]	RVR [0]						
	25	200	.75	100%	.47	.15	.03	UNQUALIFIED
PNE	ILS [1]	RVR [0]						
	24	200	.50	100%	.53	.38	.85	UNQUALIFIED
PNS	ILS [1]	RVR [0]						
	16	200	.50	100%	8.47	6.21	1.90	INVEST
POC	ILS [1]	RVR [0]						
	26L	320	1.00	100%	.69	.57	1.13	UNQUALIFIED
POU	ILS [1]	RVR [0]						
	06	250	.50	100%	.49	.42	.80	UNQUALIFIED
PSC	ILS [1]	RVR [0]						
	21R	200	.50	100%	1.05	3.36	1.47	INVEST
PTK	ILS [1]	RVR [0]						
	09R	200	.50	100%	1.52	1.16	1.18	INVEST
PUB	ILS [2]	RVR [0]						
	08L	200	.50	61%	.21	.04	.21	UNQUALIFIED
	26R	200	.75	39%	.13	.02	.00	UNQUALIFIED
PVD	ILS [3]	RVR [0]						
	05R	200	.50	45%	9.66	8.17	3.85	INVEST
	23L	200	.50	35%	23.82	22.17	.00	INVEST
PWA	ILS [1]	RVR [0]						
	17L	200	.50	100%	.22	.29	.48	UNQUALIFIED
PWK	ILS [1]	RVR [0]						
	16	400	1.00	100%	.51	.48	.78	UNQUALIFIED
PWM	ILS [2]	RVR [0]						
	11	200	.50	61%	5.52	8.48	4.04	INVEST
	29	250	.75	39%	11.19	18.15	.00	INVEST
RAL	ILS [1]	RVR [0]						
	09	200	.50	100%	.67	.61	1.04	UNQUALIFIED
RAP	ILS [1]	RVR [0]						
	32	200	.50	100%	3.20	5.10	.92	INVEST
RBD	ILS [1]	RVR [0]						
	31	200	.75	100%	.15	.04	.21	UNQUALIFIED
RDD	ILS [1]	RVR [0]						
	34	200	.50	100%	1.06	1.25	.63	INVEST
RDG	ILS [1]	RVR [0]						
	36	250	.75	100%	.50	.55	1.03	UNQUALIFIED
RDU	ILS [2]	RVR [0]						
	05	200	.50	61%	20.40	45.47	9.33	INVEST
	23	200	.50	39%	41.34	101.41	.00	INVEST
RFD	ILS [1]	RVR [0]						
	36	200	.50	100%	1.52	3.37	.68	INVEST
RIC	ILS [4]	RVR [0]						
	16	220	.56	32%	6.71	4.91	4.91	INVEST
	07	220	.56	18%	11.96	9.64	.00	INVEST
RNO	ILS [1]	RVR [0]						
	16R	600	1.50	100%	8.08	7.60	7.58	INVEST
ROA	ILS [1]	RVR [0]						
	33	500	1.00	100%	5.33	5.68	1.81	INVEST
ROC	ILS [3]	RVR [0]						
	04	200	.31	45%	11.06	4.75	5.87	INVEST
	22	200	.50	35%	27.28	13.01	.00	INVEST
ROW	ILS [1]	RVR [0]						
	21	200	.50	100%	.43	.20	.29	UNQUALIFIED

LOCID/		RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
RST	ILS [2]	RVR [0]							
		13	200	.50	61%	2.99	7.91	1.39	INVEST
		31	200	.50	39%	6.07	17.65	.00	INVEST
SAC	ILS [1]	RVR [0]							
		02	200	.50	100%	.28	.51	.69	UNQUALIFIED
SAF	ILS [1]	RVR [0]							
		02	200	.75	100%	.03	.01	.07	UNQUALIFIED
SAN	ILS [1]	RVR [0]							
		09	336	1.00	100%	54.07	46.12	22.56	INVEST
SAT	ILS [3]	RVR [0]							
		30L	200	.50	35%	13.85	9.92	13.83	INVEST
		03	200	.75	20%	25.09	18.43	.00	INVEST
SAV	ILS [2]	RVR [0]							
		36	200	.50	61%	5.57	8.43	3.02	INVEST
		09	200	.50	39%	11.29	18.80	.00	INVEST
SBA	ILS [1]	RVR [0]							
		07	200	.50	100%	3.99	4.96	2.91	INVEST
SBN	ILS [2]	RVR [0]							
		27	200	.50	61%	7.98	9.75	1.73	INVEST
		09	250	.75	39%	16.17	22.26	.00	INVEST
SCK	ILS [1]	RVR [0]							
		29R	200	.50	100%	2.17	8.65	1.14	INVEST
SDF	ILS [3]	RVR [0]							
		19	200	.50	35%	14.20	5.01	5.82	INVEST
		29	250	.75	20%	25.72	12.02	.00	INVEST
SEA	ILS [2]	RVR [0]							
		34R	200	.50	39%	37.71	77.05	31.58	INVEST
SFB	ILS [1]	RVR [0]							
		09	200	.50	100%	.08	.11	.10	UNQUALIFIED
SFO	ILS [3]	RVR [0]							
		28L	200	.50	35%	51.49	41.25	12.06	INVEST
		19L	200	.75	20%	93.28	75.54	.00	INVEST
SGF	ILS [1]	RVR [0]							
		01	200	.50	100%	3.71	2.95	1.47	INVEST
SHV	ILS [2]	RVR [0]							
		32	200	.50	39%	2.98	1.64	2.40	INVEST
SJC	ILS [2]	RVR [0]							
		12R	200	.50	61%	27.05	24.34	12.82	INVEST
		30L	200	.50	39%	54.83	54.28	.00	INVEST
SJT	ILS [1]	RVR [0]							
		03	200	.50	100%	.40	.15	.74	UNQUALIFIED
SJU	ILS [2]	RVR [0]							
		10	200	.50	61%	6.61	1.24	13.55	INVEST
		08	204	.50	39%	13.41	2.78	.00	INVEST
SLC	ILS [3]	RVR [0]							
		16L	200	.50	35%	12.60	15.91	19.55	INVEST
SLE	ILS [1]	RVR [0]							
		31	200	.50	100%	.20	.19	.38	UNQUALIFIED
SLN	ILS [1]	RVR [0]							
		35	200	.50	100%	.97	1.45	.31	INVEST
SMF	ILS [2]	RVR [0]							
		34	200	.50	39%	7.74	20.20	8.47	INVEST
SMX	ILS [1]	RVR [0]							
		12	200	.50	100%	.55	.75	.97	UNQUALIFIED

LOCID/	RNWY...	CEIL...	VIS...	UTIL...	B/C I...	B/C II...	PREV CRIT...	ACTION
SNA	ILS [1]	RVR [0]						
	19R	200	.50	100%	26.47	32.32	9.85	INVEST
SNS	ILS [1]	RVR [0]						
	31	200	.50	100%	.17	.07	.32	UNQUALIFIED
SPI	ILS [2]	RVR [0]						
	04	200	.50	61%	3.86	3.02	1.16	INVEST
	22	200	.75	39%	7.83	6.48	.00	INVEST
SPS	ILS [1]	RVR [0]						
	33L	200	.50	100%	.06	.07	.65	UNQUALIFIED
SRQ	ILS [2]	RVR [0]						
	14	200	.50	61%	4.60	4.73	3.86	INVEST
	32	200	.50	39%	9.32	10.54	.00	INVEST
STJ	ILS [1]	RVR [0]						
	35	250	.75	100%	.14	.07	.13	UNQUALIFIED
STL	ILS [4]	RVR [0]						
	30L	200	.50	32%	46.71	21.01	49.39	INVEST
	24	250	.75	18%	83.29	47.70	.00	INVEST
STS	ILS [1]	RVR [0]						
	32	200	.50	100%	.31	.23	.51	UNQUALIFIED
STT	ILS [0]	RVR [0]	NO CATEGORY I RUNWAYS AT AIRPORT					
STX	ILS [1]	RVR [0]						
	09	250	.75	100%	2.71	.69	1.67	UNQUALIFIED
SUS	ILS [0]	RVR [0]	NO CATEGORY I RUNWAYS AT AIRPORT					
SUX	ILS [2]	RVR [0]						
	31	200	.50	61%	.85	1.45	.70	INVEST
	13	250	.75	39%	1.74	3.47	.00	INVEST
SWF	ILS [1]	RVR [0]	CATEGORY II OR III RUNWAYS QUALIFY					
SYR	ILS [2]	RVR [0]						
	10	250	.75	39%	14.69	8.88	7.45	INVEST
TCL	ILS [1]	RVR [0]						
	04	200	.50	100%	.31	.06	.36	UNQUALIFIED
TEB	ILS [1]	RVR [0]						
	06	250	.75	100%	1.66	.58	1.47	UNQUALIFIED
TIW	ILS [1]	RVR [0]						
	17	200	.50	100%	.21	.35	.58	UNQUALIFIED
TIX	ILS [1]	RVR [0]						
	36	200	.50	100%	.18	.18	.16	UNQUALIFIED
TLH	ILS [2]	RVR [0]						
	27L	200	.31	61%	6.34	6.00	2.43	INVEST
	36	236	.50	39%	12.85	12.56	.00	INVEST
TMB	ILS [1]	RVR [0]						
	09R	200	.50	100%	.10	.06	.17	UNQUALIFIED
TNT	ILS [1]	RVR [0]						
	09	320	.75	100%	.00	.00	.03	UNQUALIFIED
TOA	ILS [1]	RVR [0]						
	29R	200	.50	100%	.77	.55	1.27	UNQUALIFIED
TOI	ILS [1]	RVR [0]						
	07	528	1.75	100%	.02	.03	.02	UNQUALIFIED
TOL	ILS [2]	RVR [0]						
	07	200	.50	61%	6.24	5.17	2.21	INVEST
	25	200	.50	39%	12.66	11.54	.00	INVEST
TOP	ILS [1]	RVR [0]						
	13	420	.50	100%	.11	.11	.19	UNQUALIFIED

LOCID/ RNWY...CEIL...VIS...UTIL...B/C I...B/C II...PREV CRIT...ACTION

TPA	ILS [3]	RVR [0]							
	18L	200	.50	35%	15.60	22.22	21.63	INVEST	
	18R	200	.50	20%	28.27	44.29	.00	INVEST	
TRI	ILS [1]	RVR [0]	CATEGORY II OR III RUNWAYS QUALIFY						
TTN	ILS [1]	RVR [0]							
	06	200	.50	100%	1.45	1.22	.99	INVEST	
TUL	ILS [3]	RVR [0]							
	17L	200	.50	35%	7.76	2.96	8.45	INVEST	
	17R	200	.75	20%	14.05	5.96	.00	INVEST	
TUS	ILS [1]	RVR [0]							
	11L	200	.50	100%	6.40	.77	5.76	UNQUALIFIED	
TVC	ILS [1]	RVR [0]							
	28	200	.50	100%	5.46	2.36	.82	INVEST	
TWF	ILS [1]	RVR [0]							
	25	200	.05	100%	.25	.16	.39	UNQUALIFIED	
TXK	ILS [1]	RVR [0]							
	22	200	.50	100%	.21	.17	.54	UNQUALIFIED	
TYR	ILS [1]	RVR [0]							
	13	200	.50	100%	.46	.63	.78	UNQUALIFIED	
TYS	ILS [2]	RVR [0]							
	05L	200	.50	39%	3.74	3.69	3.06	INVEST	
UCA	ILS [2]	RVR [0]							
	15	200	.50	61%	1.94	1.31	.60	INVEST	
	33	200	.50	39%	3.94	2.92	.00	INVEST	
VLD	ILS [1]	RVR [0]							
	35	200	.50	100%	.15	.18	.64	UNQUALIFIED	
VNY	ILS [1]	RVR [0]							
	16R	250	.75	100%	1.74	1.14	2.40	INVEST	
VPS	ILS [0]	RVR [0]	NO CATEGORY I RUNWAYS AT AIRPORT						
YIP	ILS [2]	RVR [0]							
	05R	200	.50	61%	7.88	6.57	1.11	INVEST	
	23L	200	.50	39%	15.98	14.67	.00	INVEST	
YKM	ILS [1]	RVR [0]							
	27	250	.50	100%	.35	.46	.63	UNQUALIFIED	
YNG	ILS [2]	RVR [0]							
	14	200	.50	61%	1.81	1.30	1.11	INVEST	
	32	200	.50	39%	3.67	2.90	.00	INVEST	

TOTAL NUMBER RUNWAYS WITH PHASE II BENEFITS > COST = 317
TOTAL NUMBER CAT I RUNWAYS CONSIDERED = 471
TOTAL NUMBER CATEGORY II OR III RUNWAYS = 64

CHAPTER VII - SENSITIVITY ANALYSIS

The criteria developed in this report, as well as the results and impact of their application, rely significantly on key assumptions, estimates and forecasts. It is important to have an idea of the extent to which the criteria and their results could change with possible changes in parametric values. The approach taken in this sensitivity analysis is to vary selected parametric values by given percentages and observe the results in the aggregate. This sensitivity analysis was performed for those parameters having the greatest influence on the results and impact and for those parameters which are somewhat judgmental in nature. Table VII-1 below outlines the results.

TABLE VII-1

Sensitivity Analysis Summary

Parameter and Variation	Total Number of Runways With B/C Ratio ≥ 1
NONRECURRING COSTS (F&E)	
20% decrease	319
10% decrease	319
No Change ($96,600)	317
10% increase	316
20% increase	315
ANNUAL OPERATIONS AND SUPPORT COSTS	
20% decrease	319
10% decrease	317
No Change ($11,400)	317
10% increase	316
20% increase	315
PASSENGER LOAD FACTORS	
20% decrease	298
10% decrease	314
No Change (per Appendix F)	317
HOURLY VALUE OF PASSENGERS' TIME	
$ 0	229
$ 12	285
No Change ($23.00)	317
NUMBER OF ESTIMATED ANNUAL INSTRUMENT APPROACHES TO RUNWAY	
75% decrease	304
50% decrease	282
No Change (as estimated by ADA per Appx. D)	317

INCREASED INTERVAL OF TIME RVR PERMITS RUNWAY TO BE OPEN FOR APPROACHES	
75% decrease	304
50% decrease	282
No Change (runway-specific time between current viz. minimum and current viz. minimum less one-eighth mile)	317

REFERENCES

1. FAA Order 7031.2B, Airway Planning Standard Number One, Terminal Air Navigation Facilities and Air Traffic Control Services.

2. Economic Analysis of Investment and Regulatory Decisions - A Guide, Report Number FAA-APO-82-1, January 1982.

3. Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Report Number FAA-APO-81-3, September 1981. Updated in APO Bulletin APO-84-3, same title.

4. Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits, Circular A-94 (Revised), Office of Management and Budget, March 27, 1972.

5. FAA Air Traffic Activity - Fiscal Year 1985, FAA-AMS-420.

6. "Runway Visual Range Life-Cycle Cost Comparison," Martin Marietta Corporation, October 31, 1985.

7. Federal Meteorological Handbook Number One, Surface Observations, Second Edition, Departments of Commerce, Defense and Transportation January 1, 1979.

8. Climatic Studies for Proposed Landing Systems, Volumes 1-32, Report Number FAA-ARD-64-54, June 1964.

9. Ceiling-Visibility Climatological Study and Systems Enhancement Factors, prepared for the FAA by the National Climatic Center (Asheville, NC), Report Number DOT-FA75WAI-547, June 1975.

10. Wind-Ceiling-Visibility Data at Selected Airports, Volumes 1-11, National Climatic Center (Asheville, NC), April 1981.

11. Airport-Specific Data File, Aviation Data Analysis System, database maintained by the FAA Office of Aviation Policy and Plans.

12. "Benefits of Reduced Flight Disruption," FAA Office of Aviation Policy and Plans, Systems Analysis Division, Systems Planning Branch, 1982. Published in Report Number FAA-APO-82-10, Establishment and Discontinuance Criteria for Precision Landing Systems, June 1983.

13. Code of Federal Regulations, Title 14, Aeronautics and Space.

14. Operations Specifications.

15. Aviation Data Analysis System, maintained by the FAA's Office of Aviation Policy and Plans (FAA-APO-110).

16. Airport Activity Statistics of Certificated Route Air Carriers, 12 Months Ended December 31, 1980, prepared jointly by the FAA and CAB.

17. U.S. Instrument Approach Procedures, August 29, 1985 to October 24, 1985.

18. Microwave Landing System Transition Plan (Draft), FAA Office of Aviation System Plans, October 1980.

19. Facility Master File, FAA-AES-400, June 1986.

20. Airport Activity Statistics of Certificated Route Air Carriers, 12 Months Ending December 31, 1983, prepared jointly by the FAA and CAB.

APPENDIX A

PREVIOUS ESTABLISHMENT CRITERIA FOR TOUCHDOWN RVR SYSTEM *

"21c(1) RVR with ILS

(a) A Touchdown RVR system (as per the criteria contained in FAA-STD-008, Order 6990.3) shall be installed with a Category I ILS with approach lights (when funds and equipment become available) provided that the airport can meet the requirements contained herein. Such qualification exists when the sum of the following three equations as applied to that airport is equal to or exceeds 1.0.

1. $.5 \times AEP \times (10^{-5}) = \frac{AEP}{200,000} = P$

2. $.2 \times AIA \times (7.14 \times 10^{-4}) = \frac{AIA}{7,000} = A$

3. $.3 \times VIZ \times (1.28 \times 10^{-2}) = \frac{VIZ}{260} = V$

where

AEP = Annual Enplaned Passengers

AIA = Annual Actual Instrument Approaches

VIZ = Mean Number of Annual Hourly Observations with Visibility $\leq$ 1/2 mile

P = Passenger Factor

A = Instrument Approach Factor

V = Visibility Factor

$P + A + V = 1.0$ to qualify for RVR installation

The sum of equations 1., 2., and 3. is called the RVR installation index.

NOTE 1. Any airport with less than 15 annual hourly observations of visibilities of 1/2 mile or less shall not qualify for an RVR system regardless of index value.

NOTE 2. The RVR is specified as a component of the Category II and Category III ILS within Order 6560.10B, Runway Visual Range (RVR).

Exceptions to the above criteria will be considered if supported by a staff study and the recommendation of the regional director.

(b) At an airport with multiple Category I ILS runways, only the primary runway will be considered for an RVR system. (Installation of multiple RVR systems will be considered if supported by a staff study and the recommendation of the regional director.)

"20f RVR with MLS. The criteria of paragraph 21c(1) shall apply to MLS.

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*Reproduced from FAA Order 7031.2C, Airway Planning Standard Number One, Terminal Air Navigation Facilities and Air Traffic Control Services.

APPENDIX B

Runway Visibility From Transmissometer
Conversion Table For 250-Foot Baseline*

DAY			NIGHT		
Corrected Transmissometer Reading		Visibility	Corrected Transmissometer Reading		Visibility
From	To		From	To	
.013*	.231	1/16	.018#	.101	1/8
.232	.415	1/8	.102	.210	3/16
.416	.534	3/16	.211	.309	1/4
.535	.614	1/4	.310	.394	5/16
.615	.671	5/16	.395	.493	3/8
.672	.731	3/8	.494	.590	1/2
.732	.783	1/2	.591	.658	5/8
.784	.819	5/8	.659	.709	3/4
.820	.845	3/4	.710	.747	7/8
.846	.864	7/8	.748	.778	1
.865	.879	1	.779	.802	1 1/8
.880	.891	1 1/8	.803	.822	1 1/4
.892	.901	1 1/4	.823	.839	1 3/8
.902	.909	1 3/8	.840	.853	1 1/2
.910	.916	1 1/2	.854	.865	1 5/8
.917	.922	1 5/8	.866	.875	1 3/4
.923	.927	1 3/4	.876	.884	1 7/8
.928	.932	1 7/8	.885	.896	2
.933	.937	2	.897	.908	2 1/4
.938	.944	2 1/4	.909	.922	2 1/2
.945	.951	2 1/2	.923	.942	3
.952	.962	3	.943	.957	4
.963	.970	4	.958	.966	5
.971	.975	5	.967	.972	6
.976	.979	6	.973	.977	7
.980	.982	7	.978	.980	8
.983	.984	8	.981	.983	9
.985	.986	9	.984	.985	10
.987	.987	10			
*If reading is less than .013, report the visibility at 1/16-			#If reading is less than .018, report visibility as 1/8-		

Computation based on the sighting of dark objects against the horizon sky during day and 25cp light intensity at night.

*Source: Table A3-7C of Federal Meteorological Handbook Number One, Surface Observations, Second Edition, Departments of Commerce, Defense and Transportation, January 1, 1979.

RVR-Transmission Conversion Table for 250-Foot Baseline*

Night					Day				
RVR (Ft)	LS 5	LS 4	LS 3	(AF) Other	RVR (Ft)	LS 5	LS 4	LS 3	(AF) Other
0600-	.001	.003	.007	.018	0600-	.030	.067	.150	.235
0600	.011	.020	.036	.064	0600	.104	.184	.328	.355
0800	.035	.055	.086	.126	0800	.197	.309	.447	.447
1000	.071	.102	.147	.192	1000	.290	.419	.517	.517
1200	.113	.155	.211	.255	1200	.375	.511	.572	.572
1400	.159	.208	.272	.314	1400	.448	.586	.617	.617
1600	.205	.259	.329	.366	1600	.511	.647	.653	.653
1800	.249	.308	.381	.413	1800	.564	.683	.683	.683
2000	.291	.353	.427	.455	2000	.610	.708	.708	.708
2200	.331	.394	.469	.492	2200	.650	.730	.730	.730
2400	.367	.432	.507	.525	2400	.684	.748	.748	.748
2600	.401	.466	.541	.555	2600	.714	.764	.764	.764
2800	.433	.497	.571	.581	2800	.739	.779	.779	.779
3000	.482	.546	.617	.622	3000	.777	.800	.800	.800
3500	.541	.603	.671	.671#	3500	.819	.824	.824	.824
4000	.591	.649	.714	.714#	4000	.843	.843	.843	.843
4500	.632	.687	.748	.748#	4500	.858	.858	.858	.858
5000	.666	.719	.777	.777#	5000	.871	.871	.871	.871
5500	.696	.746	.800	.800#	5500	.882	.882	.882	.882
6000	.721	.769	.820	.820#	6000	.890	.890	.890	.890
6000+					6000+				

NOTES:

1. Before entering this table with transmissivity value:
   a. Subtract background illumination.
   b. Divide by five if value was obtained while in HIGH mode.
2. (AF) Use column labeled "Other" when runway lights are not operating on LS 3, 4 or 5; e.g., turned off, inoperative, or otherwise not available.
3. Values identified by "#" were adjusted to accomplish necessary compatibility between respective equations.

*Source: Table A3-6B of Federal Meteorological Handbook Number One, Surface Observations, Second Edition, Departments of Commerce, Defense and Transportation, January 1, 1979.

APPENDIX D

ESTIMATION OF ANNUAL INSTRUMENT APPROACHES

1. Introduction

This appendix summarizes a method for estimating instrument approach activity. The method is useful in the absence of counts or to evaluate questionable or suspect counts. It is based on the number of operations, weather probabilities, the percentage of pilots equipped to make an instrument approach, and assumptions about local versus itinerant operations. The method was developed by Systems Control, Inc., (SCI), as documented in Preliminary Analysis of the Correlation Between Annual Instrument Approaches, Operations and Weather, FAA Report No. DOT-FA-78WA-4175, December 1980 (Reference D-1). A complete discussion of the method may be found in that report.

2. Model

The model is conceptually simple. The number of arrivals in all kinds of weather is apportioned according to the percentage of instrument and visual weather. Because there is more flight activity in good weather, the result is then adjusted downward by a constant depending on the user class - air carrier, air taxi, and general aviation. The model does not explicitly address the military user class.

SCI obtained counts of instrument approaches and total operations for several locations where good statistics were available. It then used the data in a regression model to estimate the fraction of total instrument approaches represented by each user class. The following equations resulted for the air carrier, air taxi, and general aviation user classes, respectively:

Instrument Approaches =

$$\frac{\text{Air Carrier Operations}}{2} \times \text{PIFR} \times .87$$

$$\frac{\text{Air Taxi Operations}}{2} \times (\text{PIFR-PC}) \times (1\text{-}R_{at}) \times .93$$

$$\frac{\text{GA Itinerant Operations}}{2} \times (\text{PIFR-PC}) \times (.8 - .5R_{ga})$$

where,

PIFR = probability of weather with ceiling less than 1500 feet and/or visibility less than 3 miles,

PC = probability of weather below IFR minima for the existing instrument approach with the lowest minima (minima are selected from approach charts using approach category B for air taxi and category A for general aviation),

R_{at} = ratio of air taxi operations to total operations, and

R_{ga} = ratio of general aviation itinerant operations to total operations.

Each of the above equations contains an operations count which is the independent variable from which the instrument approach count is derived. Since operations are the sum of takeoffs and landings, operations counts are in every case divided by two. In the general aviation user class, SCI obtained better results by excluding local operations. (Local operations are aircraft operating in the local traffic pattern, or those known to be departing for or arriving from flight in local practice areas within a 20 mile radius of the airport. Local operations include simulated instrument approaches or low passes at the airport.)

There is a term in each equation which adjusts for the site-specific percentage of time that weather is less than visual minima. The form of the equation is different among the user classes and was selected for best fit of the observed data.

The final term adjusts for errors in the overly-simplistic assumption that the proportion of total approaches which are instrument is the same as the proportion of total time when instrument weather conditions prevail. The assumption would be valid if all airmen, aircraft, and airports were suitably equipped for instrument landings and if pilots were never dissuaded by bad weather. In fact, however, not all pilots, aircraft and airports can handle instrument weather and flights on more casual missions are likely to stay on the ground in bad weather.

The air taxi and general aviation equations contain an additional refinement. SCI noted that GA airports with substantial air carrier activity tended to have a relatively greater proportion of GA and air taxi and general aviation users unaffected by bad weather. In other words, air taxi and general aviation operators whose destination is a major air carrier airport are more likely to make an instrument approach than to cancel the flight.

The precise form of each of the above equations was derived through regression analysis. The form which produced the best predictor was selected.

3. <u>Obtaining Weather Percentage</u>.

Weather percentages for PIFR and PC may be obtained from a number of sources, e.g., References D-2, D-3, D-4 and D-5. If the required weather data for a particular airport is unavailable, data based on a nearby airport, an average of neighboring airports, or as a last resort national average data (as outlined in Table IV-3 of the text of this report) may

FIGURE D-1

Ceiling-Visibility Climatological Data For Muskegon, MI (MKG)

STATION#14840 MUSKEGON, MICHIGAN PERIOD OF RECORD 01/48-12/52; 01/60-12/64

HOUR GROUP		NO.OF OBS	CEILING-VISIBILITY CATEGORIES (%) (1)	(2)	(3)	(4)	(5)	(6)	SYSTEM ENHANCEMENT FACTORS (%) VOR	CAT1	CAT2	MIN*
JAN	ALL	7440	63.7	36.3	29.8	3.9	1.1	1.5	82.2	10.6	3.1	4.1
FEB	"	6809	73.5	26.5	22.6	2.5	0.7	0.7	85.3	9.4	2.7	2.6
MAR	"	7440	78.1	21.9	17.6	2.8	0.7	0.8	80.4	12.9	3.1	3.6
APR	"	7200	85.2	14.8	12.4	1.4	0.4	0.6	84.2	9.5	2.5	3.8
MAY	"	7440	91.3	8.7	6.3	1.3	0.4	0.7	72.3	14.8	4.8	8.2
JUN	"	7200	93.8	6.2	4.7	0.7	0.3	0.4	76.5	11.9	5.4	6.3
JUL	"	7440	93.4	6.6	5.2	0.7	0.1	0.5	79.4	11.2	2.2	7.1
AUG	"	7439	91.5	8.5	6.6	1.0	0.4	0.5	78.2	11.6	4.5	5.7
SEP	"	7198	91.2	8.8	7.7	0.8	0.2	0.1	87.3	8.7	2.4	1.6
OCT	"	7440	87.9	12.1	8.5	1.2	0.8	1.6	70.7	9.6	6.3	13.3
NOV	"	7200	80.2	19.8	16.0	1.7	0.7	1.4	80.7	8.6	3.5	7.2
DEC	"	7439	69.7	30.3	24.9	3.6	1.0	0.8	82.1	11.9	3.4	2.6
ANN	07-13	25578	80.6	19.4	16.1	2.0	0.6	0.7	83.0	10.4	2.9	3.7
	14-21	29229	86.3	13.7	11.8	1.3	0.3	0.4	85.6	9.4	2.4	2.6
	22-06	32878	82.8	17.2	13.1	2.1	0.8	1.3	76.0	12.1	4.6	7.3
	ALL	87685	83.3	16.7	13.5	1.8	0.6	0.8	81.0	10.8	3.4	4.8

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)

be used. To illustrate, Figure D-1 reproduces weather data for Muskegon, MI from Reference D-3.

Ceiling and visibility condition (2) in Figure D-1 represents the value of PIFR at Muskegon--the percentage of time the ceiling is less than 1500 feet and/or the visibility is less than 3 miles, or 16.7 percent (for all time periods). PC is the percentage of time the weather is below minima for the lowest IFR approach. The U.S. Instrument Approach Procedures provides minima by category determined by approach speed. For Muskegon, the lowest minima are 200-1/2 for an ILS approach to Runway 32 for both categories A and B. The sum of ceiling and visibility conditions (5) and (6) in Figure D-1 represents the value of PC at Muskegon -- the percentage of time the ceiling and visibility are less than 200-1/2, or 1.4 percent (for all time periods). In cases where the required weather data are not available, values for PIFR and PC may be solved through interpolation from data that are available.

4. Obtaining Operations Counts

Operations counts may be obtained from a number of sources, including the Aviation Data Analysis System (maintained by the FAA's Office of Aviation Policy and Plans (APO-110)), Terminal Area Forecasts (published annually by FAA-APO-110), FAA Air Traffic Activity (published annually by the FAA's Office of Management Systems (FAA-AMS)), the Airport Master Record (FAA Form 5010-1), the Airport Master File (maintained by the FAA's National Flight Data Center), the airport manager, or any other generally accepted source.

5. Applying the Model

To apply the model, simply substitute the appropriate value for each variable in each equation and solve. To illustrate using the preceding analysis for Muskegon and Fiscal Year 1985 operations data from Reference D-7:

$$AIA_{AC} = \frac{\text{Air Carrier Operations}}{2} \times PIFR \times .87$$

$$= (9{,}303/2) \times .167 \times .87$$

$$= \underline{676}$$

$$AIA_{AT} = \frac{\text{Air Taxi Operations}}{2} \times (PIFR - PC) \times (1 - R_{at}) \times .93$$

$$= (7{,}697/2) \times (.167 - .014) \times (1-(7{,}697/68{,}552)) \times .93$$

$$= \underline{486}$$

$$AIA_{GA} = \frac{\text{GA Itinerant Operations}}{2} \times (PIFR - PC) \times (.8 - .5\ R_{ga})$$

$$= (29{,}334/2) \times (.167 - .014) \times (.8 - .5\ (29{,}334/68{,}552))$$

$$= \underline{1{,}315}$$

These estimates compare to Muskegon's reported FY 1985 annual instrument approaches of 587, 553 and 675 for the air carrier, air taxi and general aviation user classes, respectively, from Reference D-7.

References for Appendix D

D-1 Preliminary Analysis of the Correlation Between Annual Instrument Approaches, Operations and Weather, FAA Report No. DOT-FA-78WA-4175, December 1980.

D-2 Climatic Studies for Proposed Landing Systems, Volumes 1-32, Report Number FAA-ARD-64-54, June 1964.

D-3 Ceiling-Visibility Climatological Study and Systems Enhancement Factors, prepared for the FAA by the National Climatic Center (Ashville, NC), Report Number DOT-FA75WAI-547, June 1975.

D-4 Wind-Ceiling-Visibility Data at Selected Airports, Volumes 1-11, National Climatic Center (Asheville, NC), April 1981.

D-5 Airport Specific Data File, Airport Criteria Data System, database maintained by the FAA Office of Aviation Policy and Plans.

D-6 U.S. Instrument Approach Procedures.

D-7 FAA Air Traffic Activity, Fiscal Year 1985, FAA-AMS-420.

APPENDIX E

AVERAGE UNIT COSTS OF INSTRUMENT FLIGHT DISRUPTIONS [E-1/]

I. INTRODUCTION

When the weather is or forecast to be below landing minima at the destination airport, the pilot can do one of four things depending upon the circumstances: (1) circle the airport until conditions improve (delay); (2) fly to a nearby airport where conditions are better (diversion); (3) in the case of a multi-legged flight, continue to the next scheduled stop (overflight); or (4) if poor weather is forecast for an extended period, cancel the flight at the departure airport (cancellation). When the weather is or forecast to be below the takeoff minimum at the departure airport, the pilot can do one of two things: (1) wait until conditions improve (delay); or (2) cancel the flight (cancellation). Weather-caused flight disruptions -- delays, cancellations, diversions and overflights -- impose economic penalties on both aircraft operators and users. This appendix develops average unit economic costs of instrument flight disruptions based on assumed operating scenarios of prospective candidate locations for the Touchdown RVR System. Costs are developed separately for each user class: air carrier, air taxi, general aviation and military. The outline of the analysis is as follows:

II. Average Unit Instrument Approach Disruption Costs

A. Air Carrier

1. Scenario Development
2. Air Carrier Delays
   a. Costs Associated with Passengers
   b. Costs Associated with Aircraft Operation
   c. Summary of Air Carrier Delay Costs
3. Air Carrier Cancellations
   a. Costs Associated with Aircraft Operation
   b. Costs Associated with Passengers
   c. Summary of Air Carrier Cancellation Costs
4. Air Carrier Diversions
   a. Costs Associated with Aircraft Operation
   b. Costs Associated with Passengers
   c. Secondary Effects of Diversions
   d. Summary of Air Carrier Diversion Costs
5. Air Carrier Overflights
6. Relative Distribution of Approach Disruptions
7. Summary of Air Carrier Approach Disruption Costs

B. Air Taxi

1. Scenario Development
2. Air Taxi Delays
   a. Costs Associated with Aircraft Operation
   b. Costs Associated with Passenger
   c. Summary of Air Taxi Delay Costs

II. <u>AVERAGE UNIT INSTRUMENT APPROACH DISRUPTION COSTS</u>

A. <u>AIR CARRIER</u>

1. <u>Scenario Development</u>

Disruption of air carrier flights vary depending on the length of the flight and whether or not the destination is a hub or non-hub airport. In long-haul flights, airlines seldom cancel because the destination airport is forecast to be closed. If on arrival the destination airport is forecast to be open within thirty minutes or so, the aircraft likely will hold. Otherwise, it will likely divert to another airport. Short- and medium-haul flights tend to take delays on the ground at the departure airport to conserve fuel and to ease congestion at the destination airport. This saves equipment operating cost but neither crew cost or the cost of passenger delay. If below-minima weather is forecast to persist at the destination airport, the flight may be canceled. If the airport is an intermediate stop along a route it may be overflown, creating a diversion for passengers intending to deplane and a cancellation for those expecting to board the aircraft.

Airport facilities also affect flight scenarios. Large airports are more likely to have precision approach procedures with lower landing minima. With lower minima, the chance that the weather will improve sufficiently in the short term is greater. Additionally, larger airports are served by larger aircraft on average than are smaller airports, making diversion or cancellation costs relatively higher. Consequently, flights destined to large airports are more likely to be delayed, rather than diverted or canceled, than are flights destined to smaller airports. Because of these differences, flight disruption cost estimating equations are developed separately for hub and non-hub airports.

2. Air Carrier Delays

A sample of National Airspace Command Center (NASCOM) reported delays was examined for the six quarter period extending from January 1980 through June 1981.* The sample included days when below minima weather caused a significant number of delays of varying duration, as well as days when the number of weather-caused delays was comparably smaller. Analysis revealed that delays averaged 45 minutes at hub airports and 30 minutes at non-hub airports. For the purposes of the following analysis, it will be assumed that the 45 minute delay for hub airports consists of 15 minutes airborne delay and 30 minutes ground delay, based on FAA's Central Flow Control goal to limit airborne delay to an average of 15 minutes. For non-hub airports, the 30 minute delay will be apportioned between airborne delay of 10 minutes and ground delay of 20 minutes.

a. Costs Associated with Passengers

Passengers on a delayed flight are assumed to be delayed 45 minutes at hub airports and 30 minutes at non-hub airports. Passengers on a following flight may also be delayed because of the aircraft's late arrival. Equipment turnaround time, however, normally includes about 15 minutes of slack time. By foregoing scheduled slack time at subsequent, intermediate stops, delayed flights are able to make up some lost time. Nevertheless, boarding passengers would still have waited for the delayed flight and be delayed as much as passengers on the preceding legs, less the time made up by foregone slack time.

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* NASCOM compiles statistics only for flight delays exceeding 15 minutes minutes. NASCOM data is considered appropriate for RVR analysis since weather-caused flight disruptions are typically of this duration or longer.

An expression for passenger delay can be derived by examining what happens to each passenger on an aircraft when it is delayed and to each subsequent passenger. A sample of 624 flights from the Official Airline Guide (Reference E-2) was analyzed to estimate that, on average, an aircraft arriving at a destination has one additional destination to serve. Given a delay on the initial leg of 'L' minutes, the 'n' passengers on that leg experience an L-minute delay. On the remaining leg of the flight, the passengers experience a delay of L-15 minutes. The total approximate delay for hub airports is therefore n x (2L-15). Assuming L equals 45 minutes at hub airports, the total delay is 1.25 hours x n passengers.

The situation is slightly different at non-hub airports, since it is assumed that half of the passengers are thru-passengers and are delayed only once. For a 30 minute delay on the leg to the non-hub destination, all of the passengers are assumed to be delayed thirty minutes (n x 30). The n/2 boarding passengers on the next leg get the benefit of the 15 minute foregone slack time and are delayed n/2 x 15 minutes. But the n/2 thru-passengers who experienced the initial 30 minute delay will enjoy the 15 minutes worth of slack time that is foregone, thus reducing their total delay to 15 minutes also. The total approximate delay for non-hub airports, therefore, is (n/2 x 30) + (n/2 x 15) + (n/2 x 15) = 15n + 7.5n + 7.5n = 30n or .5 hours x n passengers.

b. Costs Associated with Aircraft Operation.

When an aircraft is delayed on the ground, the carrier incurs crew costs, and while airborne, full aircraft variable operating costs. Ground delay costs may be partially offset by foregoing scheduled slack time, so the 30 minute estimated ground delay is reduced to 15 minutes. From Reference E-3, crew costs on average represent approximately 26% of total aircraft variable operating costs. Using the term AOC_1 for air carrier aircraft hourly variable operating costs at hub airports, the following expressions result:

Airborne delay	.25 hours x AOC_1
Cround delay	.25 hours x AOC_1 x .26
Total	.32 x AOC_1

For non-hub airports, with an average 30 minute delay apportioned between airborne delay of 10 minutes and ground delay of 20 minutes less 15 minutes of foregone slack time, the following expressions result, with AOC_2 representing air carrier aircraft hourly variable operating costs at non-hub airports:

Airborne delay	.17 hours x AOC_2
Ground delay	.08 hours x AOC_2 x .26
Total	.19 x AOC_2

c. Summary of Air Carrier Delay Costs

Combining the costs associated with passengers and the costs associated with aircraft operation, the total costs per delayed air carrier aircraft, where V_{PT} represents the hourly value of a passenger's time, are estimated to be:

At hub airports: $(1.25\ V_{PT})\ n + 0.32\ AOC_1$

At non-hub airports: $(.5\ V_{PT})\ n + 0.19\ AOC_2$

3. Air Carrier Cancellations

Unless extremely poor weather is forecast to remain for several hours, air carriers generally do not cancel flights. But given a flight cancellation, the carrier incurs passenger handling expenses, and passengers suffer delay. The carrier also loses revenue from the flight while avoiding aircraft variable operating costs.

a. Costs Associated with Aircraft Operation

There are two cancellation costs which are proportional to hours of aircraft operation - the cost avoided when the air carrier does not conduct the flight and the cost incurred when the aircraft must be repositioned for a future flight.

Trunk airlines are typical of those operating at hub airports, while local service airlines are typical of those operating at non-hub airports. The average duration of a trunk air carrier flight in FY 1978, 1.25 hours (per Reference E-4), is taken as the hours of operation avoided by a flight canceled at a hub airport. The average local service flight duration of 0.58 hours (per Reference E-4) is assumed for non-hub airports.

Aircraft sometimes must be repositioned after a flight cancellation. An average of 1/2 hour extra flying time for repositioning is assumed. It is further estimated that 1/3 off canceled aircraft must be repositioned. Averaged for all cancellations, this yields 10 minutes extra flying time per cancellation (1/2 hour applied to 1/3 of the cancellations).

The following expressions of air carrier cancellation costs associated with aircraft operation result from the above analysis:

	Hub Airports	Non-Hub Airports
Repositioning aircraft (1/6 hour)	$0.167\ AOC_1$	$0.167\ AOC_2$
Less AOC savings	$-1.25\ AOC_1$	$-0.58\ AOC_2$
Total	$-1.083\ AOC_1$	$-0.413\ AOC_2$

These net negative costs represent the operating cost savings that result from a cancelled flight.

b. Costs Associated with Passengers

There are two cancellation costs associated with passengers: lost revenue and passenger handling expenses, which are costs to the air carrier, and delay, which is a cost to the passenger.

The prospective passenger must decide whether to schedule another flight, cancel his trip altogether, or seek an alternate mode of transportation. If the passenger elects to wait for the next available flight, the carrier retains the passenger's ticket revenue with little added expense, since flights do not generally operate at full capacity. If the passenger does not continue by air, the revenue is lost by the air carrier. Based on discussions with airline personnel, United Research (Reference E-5) developed estimates of the percentage of passengers who, after a cancellation, end up on another flight. The estimates range from 30% for short trips to 80% on longer trips. Airline personnel in a more recent survey could not update or verify these percentages. Because the reliability and speed of air transportation has improved, the upper end of the United Research range, 80%, is assumed in this study. This is expressible in terms of a per passenger cost to the air carrier as 20% of the average revenue per passenger, or .2 RPC.

It was determined through conversations with airline operations personnel that passengers waiting for flights that are later cancelled can easily have already spent two hours at an airport waiting for the weather to improve. After the weather improves, passengers must wait for the next available flight which, according to the same sources, can easily add an additional three hours of delay. It is assumed, then, that a cancelled flight results in an average total delay of five hours per passenger. This delay applies to the estimated 80 percent of those passengers who continue with their original plans to fly and also to the remaining passengers who divert to surface modes of transportation.

Air carrier cancellation costs associated with passengers on a per passenger basis are then:

Passenger handling expenses		V_{CLC}	
Revenue loss			.2 RPC
"Lost" passenger time (5 hours)	$5\ V_{PT}$		
Total	$5\ V_{PT} + V_{CLC} + .2\ RPC$		

c. <u>Summary of Air Carrier Cancellation Costs</u>:

Combining the costs associated with aircraft operation and the costs associated with passengers, the total costs per air carrier cancellation are estimated to be:

At hub airports: $(5\ V_{PT} + V_{CLC} + .2\ RPC)n - 1.083\ AOC_1$
At non-hub airports: $(5\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.413\ AOC_2$

It is additionally estimated that one half of the time cancellation of a flight results in cancellation of the following trip which the aircraft was scheduled to serve. Therefore, the above expressions are multiplied by 1.5:

At hub airports: $1.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 1.083\ AOC_1)$
At non-hub airports: $1.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.413\ AOC_2)$

4. <u>Air Carrier Diversions</u>

a. <u>Costs Associated with Aircraft Operation</u>

Arriving aircraft may divert to another airport if below-minima weather is forecast for an extended period of time. Additional flying time in holding over the original destination airport and flying to an alternate destination is estimated to average one hour. After the weather improves, the aircraft usually must be ferried to another airport before it resumes scheduled operations, requiring an additional estimated half hour. The total additional flight time per diversion is therefore estimated to be 1-1/2 hours at an aircraft operation cost of 1.5 AOC_1 for hub airports and 1.5 AOC_2 for non-hub airports.

b. Costs Associated with Passengers

Each passenger immediately "loses" one hour because of additional flight time. To this must be added the additional time required for the passenger to reach his desired destination. This may take the form of air or surface transportation and may involve the air carrier providing passengers with meals and overnight lodging. If the return trip is by air, an extra hour of flight time is assumed plus two hours of waiting for the destination airport to accept arriving aircraft. Similar amounts of time are likely for surface transportation. Total time lost due to a flight disruption thus totals an estimated four hours per passenger. Airlines incur extra passenger-handling expenses for food, housing, and return-trip fare. The per passenger expense is thus:

Passenger handling expenses	V_{DVC}
"Lost" passenger time (4 hours)	4 V_{PT}
Total	4 V_{PT} + V_{DVC}

c. Secondary Effects of Diversions

At non-hub airports there is a secondary effect of diversions, because the following trip on which the aircraft was scheduled to depart may be canceled. From fragmentary information obtained from airline data, it is estimated that this occurs on half of non-hub flights. Cancellation costs associated with passengers on a per passenger basis, as developed above in Section II-A-3-b, are:

$$5\ V_{PT} + V_{CLC} + .2\ RPC$$

The aircraft variable operating cost savings from avoiding the canceled leg are 0.58 AOC_2 (from Section II-A-3-a above). Combining these terms and multiplying by .5 to account for the estimate that half of the flights are affected, the secondary effect of an air carrier diversion at a non-hub airport is estimated to be:

$$0.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.58\ AOC_2)$$

d. Summary of Air Carrier Diversion Costs

Combining the terms derived above, the costs associated with the diversion of an air carrier aircraft are estimated to be:

At hub airports: $(4\ V_{PT} + V_{DVC})n + 1.5\ AOC_1$

At non-hub airports:

$$(4\ V_{PT} + V_{DVC})n + 1.5\ (AOC_2) + 0.5\ ((55\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.58\ AOC_2)$$

$$= (6.5\ V_{PT} + V_{DVC} + .5\ (V_{CLC} + .2\ RPC))n + 1.21\ AOC_2$$

5. Air Carrier Overflights

Overflights are assumed to apply at non-hub airports only. An overflight reduces aircraft variable operating costs, since when a stop is bypassed and the aircraft proceeds directly to its next destination, total flying time is reduced. These savings are offset in those instances when the pilot holds for a few minutes over the intended destination while deciding whether or not to attempt a landing.

An overflight results in a diversion for passengers intending to deplane and a cancellation for passengers intending to board the aircraft. The air carrier incurs extra passenger handling expenses when stops are overflown, just as it does with diversions and cancellations, and passengers, whether enplaning or deplaning, experience delays. For these reasons, an overflight is equated to a diversion plus a cancellation and, except for increased aircraft variable operating costs, costed accordingly. The per passenger cost of an air carrier overflight is therefore estimated to be:

For a diverted passenger:				
Passenger handling expenses		V_{DVC}		
"Lost" passenger time (4 hours)	$4\ V_{PT}$			
Subtotal	$4\ V_{PT}$ +	V_{DVC}		
For a canceled passenger:				
Passenger handling expenses			V_{CLC}	
"Lost" passenger time (5 hrs.)	$5\ V_{PT}$			
Revenue loss				.2 RPC
Subtotal	$5\ V_{PT}$ +		V_{CLC} +	.2 RPC
Total:	$(9\ V_{PT} + V_{DVC} + V_{CLC} + .2\ RPC)\ n$			

6. Relative Distribution of Approach Disruptions

In this section the relative distribution of approach disruptions is derived so that the cost equations derived above can be weighted and combined into single and separate expressions for hub and non-hub airports.

Civil Aeronautics Board/FAA statistics (Reference E-6) and a methodology developed by United Research, Inc. (Reference E-5) are used to develop relative distribution estimates. An informal survey of five airlines was taken to test the current validity of the United Research results and appropriate changes were made.

The CAB/FAA statistics summarized below from Reference E-6 infer that 2.5% and 8.2% of certificated route air carrier departures in CY 1980 were canceled at hub and non-hub airports, respectively.

Hub Classification	Number of Hubs	CY 1980 Departures Scheduled	CY 1980 Departures Scheduled and Completed* Number	Percent
Hubs:				
Large	25	2,905,923	2,840,474	97.7
Medium	41	1,058,438	1,031,238	97.4
Small	76	608,738	588,536	96.7
Total	142	4,573,099	4,460,248	97.5**
Non-Hubs	486	606,383	557,165	91.8

*Excludes extra sections **Weighted average

United Research found that about 2/3 of air carrier cancellations, on an annual basis, are due to weather. They also found that air carrier diversions are about 1/6 as frequent as cancellations and that 5/6 of these diversions are caused by weather. The survey referenced above supports the United Research findings, except that the survey suggested the ratio of diversions to cancellations is closer to 1/10 than 1/6.

Weather-caused cancellations = 2.5% x 2/3
= 1.7% of all flights

Weather-caused diversions = 2.5% x 1/10 x 5/6
= 0.2% of all flights

An FAA-APO report, Airfield and Airspace Capacity/Delay Policy Analysis (Reference E-7), estimated that about 6.6% of all air carrier departures and about 13.2% of all air carrier arrivals were delayed 15 minutes or longer in 1980. Data collected by the FAA through its NASCOM program shows that of delays to IFR aircraft of over 30 minutes for the period 1971 through 1980, an average of 29% were due to weather. Applying the NASCOM percentage to the APO delay data suggests that 3.8% of all flights are delayed because of weather (13.2% x 29%).

Recapitulating for hub airports:

Weather-Caused Flight Disruption	Hub Air Carrier Airports: Percent of all Flights	Hub Air Carrier Airports: Normalized Distribution %
Delays	3.8	67
Cancellations	1.7	30
Diversions	0.2	3
	---	---
	5.7	100

Given that 8.2% of all air carrier flights into non-hub airports were canceled in 1980, estimates for the percentage of weather-caused cancellations and diversions can be derived following the method used above to estimate these rates for hub airports:

Weather-Caused Cancellations	=	8.2% x 2/3
	=	5.5% of all flights
Weather-Caused Diversions	=	8.2% x 1/10 x 5/6
	=	0.7% of all flights

An informal survey of several commuter air carriers revealed that 20 to 30% of cancellations result from overflights. Applying the median of 25% and applying it to the 5.5% for cancellations yields overflights as accounting for 1.4% of all flights, with 4.1% remaining as pure cancellations. The delay experience at non-hub airports is assumed to be similar to that at hub airports.

Summarizing for non-hub airports:

Weather-Caused Flight Disruption	Non-Hub Air Carrier Airports: Percent of all Flights	Non-Hub Air Carrier Airports: Normalized Distribution %
Delays	3.8	38
Cancellations	4.1	41
Diversions	.7	7
Overflights	1.4	14
	----	---
	10.0	100

7. Summary of Air Carrier Approach Disruption Costs

Total estimated costs associated with weather-caused approach disruptions of air carrier flights can be determined by weighting the cost of each type of disruption by its relative frequency of occurrence and combining the respective results into one equation. For each equation, each term is multiplied below by its appropriate weight and a product obtained. Like variables are then summed and grouped into a single equation, representing the average unit cost of an air carrier approach disruption. The individual equations, their respective weights, and the resulting average equations for hub and non-hub airports are summarized below:

Hub Airports:

Disruption	Cost Equation	Weight
Delays	$(1.25\ V_{PT})n + 0.32\ AOC_1$	0.67
Cancellations	$1.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 1.083\ AOC_1)$	0.30
Diversions	$(4\ V_{PT} + V_{DVC})n + 1.5\ (AOC_1)$	0.03

		1.00

The average unit cost of an air carrier approach disruption at a hub airport is thus estimated to be:

$$(3.21\ V_{PT} + 0.03\ V_{DVC} + 0.45\ (V_{CLC} + .2\ RPC))n - 0.24\ AOC_1$$

Non-Hub Airports:

Disruption	Cost Equation	Weight
Delays	$(.5\ V_{PT})n + 0.19\ AOC_2$	0.38
Cancellations	$1.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.413\ AOC_2)$	0.41
Diversions	$(6.5\ V_{PT} + V_{DVC} + .5\ (V_{CLC} + .2\ RPC))n + 1.21 AOC_2$	0.07
Overflights	$(9\ V_{PT} + V_{DVC} + V_{CLC} + .2\ RPC)n$	0.14

		1.00

The average unit cost of an air carrier approach disruption at a non-hub airport is thus estimated to be:

$$(4.98\ V_{PT} + 0.21\ V_{DVC} + .79\ (V_{CLC} + .2\ RPC))n - 0.10\ AOC_2$$

B. AIR TAXI

1. Scenario Development

Little data exists on the behavior of air taxi operators faced with weather-caused flight disruptions. Air taxis are assumed to operate in much the same manner as certificated route air carriers at non-hub airports described above in Section II-A.

2. Air Taxi Delays

a. Costs Associated with Aircraft Operation

Air taxi delay duration is assumed to be the same as non-hub air carriers, with an average 30 minute delay apportioned between airborne delay of 10 minutes and ground delay of 20 minutes. No foregone slack time, however, is assumed. From Reference E-3, crew costs on average represent approximately 39% of total aircraft variable operating costs. Aircraft variable operating costs for weather-caused air taxi delays are then:

Airborne delay	$.17$ hours x AOC_3
Ground delay	$.33$ hours x AOC_3 x 0.39

Total:	$.30$ x AOC_3

where AOC_3 represents air taxi aircraft variable operating costs per airborne hour.

b. Costs Associated with Passengers

Air taxi passenger delay duration is assumed to be identical to that for air carriers at non-hub airports -- 0.5 hours per passenger.

c. Summary of Air Taxi Delay Costs

The total cost per delayed air taxi aircraft is thus estimated to be:

$(.5\ V_{PT})n + 0.30\ AOC_3$

Air Taxi Cancellations, Diversions and Overflights

The air taxi cancellations, diversions, and overflights are assumed to be the same as those for air carriers at non-hub airports, except for the adjustments noted below. All values for lost passenger time are taken as half of those associated with air carriers, because as a rule the number of passengers is smaller, the air taxi organization is smaller, and final decisions regarding the handling of diverted or canceled passengers are made more quickly. Returning a passenger to his original destination is also less time consuming since stage lengths are shorter. For cancellations, another difference is the percentage of revenue recovery used in the flight cancellation scenario. United Research (Reference E-5) estimated that 70% of air taxi passengers cancel their trips or use other means of travel when a flight is canceled. Finally, air taxis are presumed not to reimburse passengers for expenses when a flight is canceled due to poor weather:

Cancellation: $1.5\ ((2.5\ V_{PT} + .7\ RPT)n - 0.413\ AOC_3)$
Diversions: $(3.0\ V_{PT} + V_{DVT})n + .5(.7\ RPT))n + 1.21\ AOC_3$
Overflights: $(4.5\ V_{PT} + V_{DVT} + .7\ RPT)n$

where RPT is the average revenue per air taxi passenger, and V_{DVT} is the passenger handling expense for diverted air taxi passengers.

[illegible] Summary of Air Taxi Approach Disruption Costs

Air taxi approach disruption costs and the relative weight of each are summarized below:

Disruption	Cost Equation	Weight
Delays	$(.5\ V_{PT})n + 0.30\ AOC_3$	0.38
Cancellations	$1.5\ ((2.5\ V_{PT} + .7\ RPT)n - 0.413\ AOC_3)$	0.41
Diversions	$(3\ V_{PT} + V_{DVT})n + .5\ (.7\ RPT) + 1.21\ AOC_3$	0.07
Overflights	$(4.5\ V_{PT} + V_{DVT} + .7\ RPT)n$	0.14

		1.00

The average unit cost of an air taxi approach disruption is thus estimated to be:

$$(2.57\ V_{PT} + 0.21\ V_{DVT} + 0.79\ (.7\ RPT))n - 0.06\ AOC_3$$

[illegible] GENERAL AVIATION

[illegible] Scenario Development

Most flight disruption impacts due to weather in general aviation are felt by business travelers flying in relatively large aircraft equipped for IFR operations. The pattern of flight disruptions experienced in general aviation is probably similar to that estimated for air taxis, except that there are few secondary effects. The impact of flight disruptions on passengers is less because the aircraft in which they are traveling is generally available for use as soon as the weather clears. Because of the greater number of airports at which general aviation aircraft operate, diversion times are less. Interrupted trip expenses are incurred for meals and overnight accommodations in some cases.

Additional aircraft variable operating costs (AOC_4) and interrupted trip expenses for canceled (V_{CLG}) and diverted (V_{DVG}) passengers represent the major cost impacts resulting from approach disruptions of general aviation aircraft. No distinction is made between general aviation flight disruptions at hub and non-hub airports.

2. General Aviation Delays

General aviation delay duration is assumed to be the same as that for air taxi. Costs associated with aircraft operation are 0.30 AOC_4 and those with passengers are .5 V_{PT}, for a total of:

$$(0.5\ V_{PT})\ n + 0.30\ AOC_4$$

3. General Aviation Cancellations

When a general aviation aircraft is forced to cancel a flight due to poor weather, no additional flying time, lost revenue, or passenger handling expense is involved. What remains from the air taxi equation is merely $2.5V_{PT}\ n$.

4. General Aviation Diversions

The cost of a general aviation diversion is again similar to air taxi, but without the secondary effects. The equation is therefore:

$$(2.0\ V_{PT} + V_{DVG})n + 1.5\ AOC_4$$

5. Summary of General Aviation Approach Disruption Costs

General aviation flight disruption costs are weighted similar to those for air carriers at non-hub airports and air taxis, except the percentage for overflights is added to cancellations because overflights are presumed not to occur.

Disruption	Cost Equation	Weight
Delays	$(0.5\ V_{PT})n + 0.30\ AOC_4$	0.38
Cancellations	$2.5\ V_{PT}\ n$	0.55
Diversions	$(2.0\ V_{PT} + V_{DVG})n + 1.5\ AOC_4$	0.07

		1.00

The average unit cost of a general aviation approach disruption is thus estimated to be:

$$(1.71\ V_{PT} + 0.07\ V_{DVG})n + 0.22\ AOC_4$$

D. MILITARY

Military aircraft landing at civil airports fly non-commercially in a way that is very similar to general aviation. Losses or costs incurred from disruptions are in the form of lost passenger time and additional aircraft variable operating costs. The scenarios and equations for military aircraft are assumed identical to those for general aviation, except for different aircraft variable operating costs. The summary equation is thus:

$$(1.71\ V_{PT} + 0.07\ V_{DVM})n + 0.22\ AOC_5$$

E. SUMMARY

The following equations are reproduced from the preceding text:

Air Carrier:

Hubs: $(3.21\ V_{PT} + 0.03\ V_{DVC} + 0.45\ (V_{CLC} + .2\ RPC))n - 0.24\ AOC_1$

Non-hubs: $(4.98\ V_{PT} + 0.21\ V_{DVC} + 0.79\ (V_{CLC} + .2\ RPC))n - 0.10 AOC_2$

Air Taxi: $(2.57\ V_{PT} + 0.21\ V_{DVT} + 0.79\ (.7\ RPT))n - 0.06\ AOC_3$

General Aviation: $(1.71\ V_{PT} + 0.07\ V_{DVG})n + 0.22\ AOC_{4?}$

Military: $(1.71\ V_{PT} + 0.07\ V_{DVM})n + 0.22\ AOC_5$

F. VALUE OF VARIABLES

Average weather-caused approach disruption costs are estimated in generalized form in this appendix to permit substitution of new values for the variables as their values change and are updated over time. Specific costs can be estimated by substituting the appropriate value for each variable and deriving the solution. The following values, taken from Appendix F of this report except where indicated otherwise, are denominated in 1985 dollars:

V_{PT} = Hourly value of a passenger's time, $23.00 (Source: Reference E-11)

n = Number of passengers/occupants per flight leg by user class: air carrier - 61.4 passengers at hub airports and 16.1 passengers at non-hub airports (from Tables F-4 and F-5 of Appendix F); air taxi - 5.0 passengers (from Table F-7 of Appendix F); general aviation itinerant - 3.2 occupants (from Table F-9 of Appendix F); and military itinerant - 5.6 occupants (from Table F-11 of Appendix F)

AOC_1 = Air carrier aircraft variable operating cost per airborne hour at hub airports, $1,952 (from Table F-3 of Appendix F)

AOC_2 = Air carrier aircraft variable operating cost per airborne hour at non-hub airports, $1,809 (from Table F-3 of Appendix F)

AOC_3 = Air taxi aircraft variable operating cost per airborne hour, $274 (from Table F-6 of Appendix F)

AOC_4 = General aviation aircraft variable operating cost per airborne hour, $171 (from Table F-8 of Appendix F)

AOC_5 = Military aircraft variable operating cost per airborne hour, $1,185 (from Table F-10 of Appendix F)

V_{CLC} = Air carrier passenger handling expense for canceled passengers, $56; includes overnight lodging (Source: Reference E-8)

V_{DVC} = Air carrier passenger handling expense for diverted passengers, $81; includes overnight lodging, meals, and transportation to original destination (Sources: Reference E-8 and conversations with four airlines)

V_{DVT} = Air taxi passenger handling expense for diverted passengers, $68; includes overnight lodging and transportation to original destination (Sources: same as for V_{DVC} above)

V_{DVG} = General aviation passenger handling expense for diverted passengers, $68; (same as for V_{DVT})

V_{DVM} = Military passenger handling expense for diverted passengers, $68 (same as for V_{DVG})

RPC = Air carrier average revenue per passenger, $128; average domestic trip length of 750 miles applied to average ticket cost per passenger mile of 17 cents (Source: FAA-APO-110)

RPT = Air taxi average revenue per passenger, $25; average domestic trip length of 110 miles applied to average ticket cost per passenger mile of 22.6 cents (Source: FAA-APO-110)

G. UNIT COSTS OF INSTRUMENT APPROACH DISRUPTIONS

Substituting the values in Section II-F into the equations summarized in Section II-E and solving yields the following unit costs of approach disruptions in 1985 dollars:

Air Carrier - Hub	\$6,468
Air Carrier - Non-hub	2,960
Air Taxi	420
General Aviation	179
Military	508

III. AVERAGE UNIT INSTRUMENT DEPARTURE DISRUPTION COSTS

A. INTRODUCTION

The general methodology outlined in Section II of this appendix for estimating the average unit costs of instrument approach disruptions is also used in this section for estimating the average unit costs of instrument departure disruptions. While the same general methodology is used, several differences exist. The most significant of these are that the types of flight disruption are limited to delays and cancellations (diversions and overflights are not relevant) and only the air carrier and air taxi user classes are extended RVR takeoff benefits. In the interest of simplicity and avoiding repetition, the discussion is generally limited to differences from approach disruptions and assumes reader familiarity with Section II of this appendix.

B. AIR CARRIER

1. Air Carrier Delays

Delay durations at the departure airport are assumed to average 45 minutes at hub airports and 30 minutes at non-hub airports, based on the NASCOM sample discussed in Section II-A-2. The costs associated with passengers, therefore, are .75 x V_{PT} x n for hub airports and 0.5 x n for non-hub airports. With respect to aircraft operation, only crew costs, as opposed to full aircraft variable operating costs, are incurred since the entire duration of delay takes place on the ground.

Summarizing air carrier delay costs:

At hub airports: $(.75\ V_{PT})n + (.75 \text{ hours} \times .26\ AOC_1)$

$= (.75\ V_{PT})n + 0.20\ AOC_1$

At non-hub airports: $(.5\ V_{PT})n + (.5 \text{ hours} \times .26\ AOC_2)$

$= (.5\ V_{PT})n + 0.13\ AOC_2$

2. Air Carrier Cancellations

The costs of air carrier cancellations were addressed earlier in Section II-A-3. They are reproduced below:

At hub airports: $1.5((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 1.083\ AOC_1)$

At non-hub airports: $1.5((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.413\ AOC_2)$

3. Relative Distribution of Departure Disruptions

Within the accuracy of this analysis, the relative distribution of departure disruptions may be reasonably estimated by normalizing the relative frequency of approach disruptions as derived in Section II-A-6.

Weather-Caused Flight Disruption	Percent of all Flights (From Section II-6)	Normalized Distribution % for Application to Departures
Hub Airports		
Delays	3.8	69
Cancellations	1.7	31
	5.5	100
Non-Hub Airports		
Delays	3.8	48
Cancellations	4.1	52
	7.9	100

4. Summary of Air Carrier Departure Disruption Costs

Weighting the unit cost equations of air carrier departure delays and cancellations as derived above by their estimated relative frequency of occurrence results in the following equations:

Hub Airports:

Disruption	Cost Equation	Weight
Delays	$(.75\ V_{PT})n + 0.20\ AOC_1$	0.69
Cancellations	$1.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 1.083\ AOC_1)$	0.31
Average	$(2.84\ V_{PT} + 0.47\ (V_{CLC} + .2\ RPC))n - 0.37\ AOC_1$	1.00

Non-Hub Airports:

Disruption	Cost Equation	Weight
Delays	$(.5\ V_{PT})n + 0.13\ AOC_2$	0.48
Cancellations	$1.5\ ((5\ V_{PT} + V_{CLC} + .2\ RPC)n - 0.413\ AOC_2)$	0.52
Average	$(4.14\ V_{PT} + 0.78\ (V_{CLC} + .2\ RPC))n - 0.26\ AOC_2$	1.00

C. AIR TAXI

1. Air Taxi Delays

The costs associated with passengers delayed on an air taxi departure are assumed to be the same as those for passengers delayed on an approach -- $0.5 \times V_{PT} \times n$. With respect to aircraft operation, only crew costs, as opposed to full aircraft variable operating costs, are incurred since the entire duration of delay takes place on the ground. Summarizing air taxi delay costs:

$$(0.5\ V_{PT})n + .5 \text{ hours} \times .39\ AOC_3$$

$$= (0.5\ V_{PT})n + .20\ AOC_3$$

2. Air Taxi Cancellations

The costs of air taxi cancellations were addressed earlier in Section II-B-3. They are reproduced below:

$$1.5\ (82.5\ V_{PT} + .7\ RPT)n - 0.413\ AOC_3)$$

3. Summary of Air Taxi Departure Disruption Costs

Weighting the unit cost equations of air taxi delays and cancellations as derived above by their estimated relative frequency of occurrence results in the following equations:

Disruption	Cost Equation	Weight
Delays	$(0.5\ V_{PT})n + .20\ AOC_3$	0.48
Cancellations	$1.5\ ((2.5\ V_{PT} + .7\ RPT)n - 0.413\ AOC_3)$	0.52

Average	$(2.19\ V_{PT} + .5\ RPT)n - 0.23\ AOC_3$	1.00

D. SUMMARY

The following equations are reproduced from the preceding text:

Air Carrier:

Hub Airports: $(2.84\ V_{PT} + 0.47\ (V_{CLC} + .2\ RPC))n - 0.37\ AOC_1$

Non-Hub Airports: $(4.14\ V_{PT} + 0.78\ (V_{CLC} + .2\ RPC))n - 0.26\ AOC_2$

Air Taxi: $(2.19\ V_{PT} + .5\ RPT)n - 0.23\ AOC_3$

E. UNIT COSTS OF INSTRUMENT DEPARTURE DISRUPTIONS

Substituting the values in Section II-F into the equations summarized above yields the following unit costs of instrument departure disruptions in 1985 dollars:

Air Carrier

Hub Airports	$5,643
Non-Hub Airports	$2,087
Air Taxi	$ 251

References for Appendix E

E-1 Sources: "Benefits of Reduced Flight Disruption," Appendix B to Report Number FAA-APO-82-10, Establishment and Discontinuance Criteria for Precision Landing Systems, September 1983, and Establishment Criteria for Category I Instrument Landing System (ILS), Report Number FAA-ASP-75-1, December 1975. Modified here for specific application to RVR, expanded to account for instrument departures, and updated to incorporate 1985 critical values.

E-2 Official Airline Guide, September 1981.

E-3 Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Report Number FAA-APO-81-3, September 1981. Updated by Bulletin Number FAA-APO-84-3, June 1984, same title. See also Reference E-11.

E-4 Air Carrier Traffic Statistics, Civil Aeronautics Board, July 1979.

E-5 Economic Criteria for Federal Aviation Agency Expenditures, Gary Fromm, United Research Inc., Cambridge, MA, June 1962.

E-6 Airport Activity Statistics of Certificated Route Air Carriers, 12 Months Ended December 31, 1980, Prepared jointly by the FAA and CAB.

E-7 Airfield and Airspace Capacity/Delay Policy Analysis, FAA Office of Aviation Policy and Plans, November 1981.

E-8 Travel Market Yearbook, 1981.

E-9 On Time Performance of Trunk Air Carriers, Form 438, Civil Aeronautics Board, Bureau of Accounts and Statistics, monthly.

E-10 Aircraft Utilization and Propulsion Report, FAA, January 1976.

E-11 Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Work program currently in process to update Reference E-3 (scheduled for publication as an APO bulletin in early 1987).

APPENDIX F

CRITICAL VALUES

The FAA uses certain economic values, commonly referred to as "critical values," in the evaluation of investment and regulatory programs. This appendix outlines the critical values (on a natural average basis) that are applicable and used in this report: aircraft variable operating costs by aircraft type and user class (1985 dollars), the average number of passengers or occupants per aircraft by aircraft type by user class, and the value of time of air travelers (1985 dollars). Table F-1 outlines the tables in this appendix which address each of these criteria values. A complete discussion of why these and other critical values are used in FAA's economic analyses is outlined in References F-1 and F-2.

Several of the critical values derived in this appendix are weighted by national average fleet data. IN ACTUAL PHASE II BENEFIT/COST SCREENING, THE AVIATION DATA ANALYSIS SYSTEM (ADA) RELIES UPON SITE-SPECIFIC AIR CARRIER AND GENERAL AVIATION AIRCRAFT TYPE MIXES (BASED ON THE OFFICIAL AIRLINE GUIDE AND BASE-AIRCRAFT DATA RESPECTIVELY). Ideally, if the cognizant regional office can furnish further detailed information pertinent to the specific candidate site being evaluated, the need to use estimates based on national averages can be further reduced. Without site specific data, however, national average values must be substituted and used to estimate the critical values. It is recommended that national average values be used only if site-specific data are unavailable.

TABLE F-1

Index to Appendix F

	Air Carrier		Air	General	
	Hubs	Non-Hubs	Taxi	Aviation	Military
Distribution of Aircraft	F-2	F-2	F-6	F-8	F-10
Aircraft Variable Operating Costs	F-3	F-3	F-6	F-8	F-10
Average Number of Passengers per Flight	F-4 F-5	F-4 F-5	F-7	-	-
Average Number of Occupants per Flight	-	-	-	F-9	F-11

TABLE F-2

Relative Distribution Of Air Carrier Aircraft Used In Weighting Of Air Carrier Critical Values

Aircraft Type	Total Departures 1/	Relative Distribution For Application To Hub Airports 2/	Normalized Relative Distribution For Application To Non-Hub Airports
Turbofan, 4-Engine, Wide Body	40,757	.0080	
Turbofan, 4-Engine, Regular Body	203,660	.0400	.0426
Turbofan, 3-Engine, Wide Body	255,339	.0501	
Turbofan, 3-Engine, Regular Body	1,953,905	.3833	.4086
Turbofan, 2-Engine, Wide Body	18,967	.0037	
Turbofan, 2-Engine, Regular Body	1,842,097	.3614	.3852
Turboprop	614,784	.1206	.1285
Piston	168,039	.0330	.0351
Total	5,097,548	1.0000	1.0000

1/ Source: Reference F-3 based on Reference F-4.

2/ Total does not add exactly to 1.0000 due to independent rounding.

TABLE F-3

National Average Air Carrier Aircraft
Variable Operating Costs per Airborne Hour (1985 Dollars)

HUB AIRPORTS

Aircraft Type	(A) Relative Distribution 1/	(B) Cost Per Airborne Hr. 2/	(C) Extension (A) x (B)
Turbofan, 4-Engine, Wide Body	.0080	$5,541	$ 44.33
Turbofan, 4-Engine, Regular Body	.0400	3,240	129.60
Turbofan, 3-Engine, Wide Body	.0501	3,939	197.34
Turbofan, 3-Engine, Regular Body	.3833	2,317	888.11
Turbofan, 2-Engine, Wide Body	.0037	3,333	12.33
Turbofan, 2-Engine, Regular Body	.3614	1,707	616.91
Turboprop	.1206	459	55.36
Piston	.0330	234	7.72
Total	1.0000		$1,951.70 or $1,952

NON-HUB AIRPORTS

Aircraft Type	(A) Relative Distribution 1/	(B) Cost Per Airborne Hr. 2/	(C) Extension (A) x (B)
Turbofan, 4-Engine, Regular Body	.0426	$3,240	$ 138.02
Turbofan, 3-Engine, Regular Body	.4086	2,317	946.73
Turbofan, 2-Engine, Regular Body	.3852	1,707	657.54
Turboprop	.1285	459	58.98
Piston	.0351	234	8.21
Total	1.0000		$1,809.48 or $1,809

1/ From Table F-2. Total for hub airports does not exactly add to 1.0000 due to independent rounding.

2/ Includes costs of crew, fuel and oil, and maintenance. Values taken from Reference F-5.

TABLE F-4

National Average Number Of Passengers[1/] Per Air Carrier Flight[2/]

(See Table F-5 for further breakout by aircraft type)

At Hub Airports

$$\frac{\text{Total Number of Passenger Enplanements}}{\text{Completed Departures}} = \frac{272,737,327}{4,460,248} = 61.4 \text{ passengers}$$

At Non-hub Airports

$$\frac{\text{Total Number of Passenger Enplanements}}{\text{Completed Departures}} = \frac{8,639,252}{536,607} = 16.1 \text{ passengers}$$

1/ Number of "passengers," as opposed to "occupants," is relevant since crew costs are included in aircraft variable operating costs.

2/ Source: Reference F-4.

TABLE F-5

National Average Number Of Passengers Per Air Carrier Flight By Airport Type And Aircraft Type

Aircraft Type	Hub Airports: Average Number of Passengers 1/	Hub Airports: Distribution By Type 2/	Hub Airports: Extension	Non-Hub Airports: Average Number of Passengers 3/	Non-Hub Airports: Distribution By Type 2/	Non-Hub Airports: Extension
Turbofan, 4-Engine, Wide Body	208.1	.0080	1.66	-	-	-
Turbofan, 4-Engine, Regular Body	88.0	.0400	3.52	25.4	.0426	1.08
Turbofan, 3-Engine, Wide Body	140.0	.0501	7.01	-	-	-
Turbofan, 3-Engine, Regular Body	69.2	.3833	26.52	19.9	.4086	8.13
Turbofan, 2-Engine, Wide Body	122.1	.0037	.45	-	-	-
Turbofan, 2-Engine, Regular Body	54.4	.3614	19.66	15.7	.3852	6.05
Turboprop	20.8	.1206	2.51	6.0	.1285	.77
Piston	1.9	.0330	.06	2.2	.0351	.08
Total		1.0000	61.4		1.0000	16.1

1/ Source: Values reflect those from Reference F-6 but adjusted uniformly and proportionately to the extent necessary to reconcile with the weighted value of 61.4 in Table F-4.

2/ From Table F-2. Total for hub airports does not exactly add to 1.0000 due to independent rounding.

3/ Source: Values reflect those from Reference F-6 but adjusted proportionately for all aircraft types, except piston aircraft, to the extent necessary to reconcile with the weighted value of 16.1 in Table F-4.

TABLE F-6

Air Taxi Aircraft Variable Operating Costs per Airborne Hour (1985 Dollars)
(Includes Air Commuter)

Aircraft Type	(A) Hourly Variable Operating Costs 1/ Crew	(B) Fuel & Oil	(C) Maintenance	(D) Total	(E) Distribution by IFR Hours 2/	(F) Extension (D) x (E)
Single-Engine Piston, 1-3 Seats	$ 31.00	$ 21.31	$ 9.55	$ 61.86	.0002	$ 0.01
Single-Engine Piston, 4 + Seats	31.00	26.63	14.59	72.22	.1688	12.19
Twin-Engine Piston, Under 12,500 TOGW	51.00	53.55	62.80	167.35	.5767	96.51
Twin-Engine Turboprop, Under 12,500 TOGW	224.00	125.12	118.42	467.54	.1851	86.54
Twin-Engine Turboprop, Over 12,500 TOGW	224.00	454.22	276.04	954.26	.0032	3.05
Twin-Engine Turbojet/fan, Under 20,000 TOGW	366.00	577.48	248.45	1,919.93	.0554	66.03
Twin-Engine Turbojet/fan, Over 20,00 TOGW	366.00	811.29	311.95	1,489.24	.0033	4.91
Multi-Engine Turbojet/fan, Over 20,000 TOGW	596.00	899.56	706.12	2,191.68	.017	3.73
Rotary Piston	31.00	29.27	38.57	98.84	.0000	0.00
Rotary Turbine	61.00	51.41	85.41	197.82	.0055	1.09
Total					1.0000	$274.06 or $274

1/ Source: Reference F-5.

2/ Source: Reference F-3 based on References F-7 and F-8. Total does not add exactly to 1.0000 due to independent rounding.

TABLE F-7

National Average Number Of Passengers[1/]
Per Air Taxi Flight (Including Air Commuter)

Aircraft Type	(A) Distribution By IFR Hours[2/]	(B) Number Of Passengers[3/]	(C) Extension (A) x (B)
Single-Engine Piston, 1-3 Seats	.0002	.6	.00
Single-Engine Piston, 4 + Seats	.1688	2.1	.35
Twin-Engine Piston, Under 12,500 TOGW	.5767	5.4	3.11
Twin-Engine Turboprop, Under 12,500 TOGW	.1851	7.3	1.35
Twin-Engine Turboprop, Over 12,500 TOGW	.0032	7.3	.02
Twin-Engine Turbojet/fan, Under 20,000 TOGW	.0554	2.3	.13
Twin-Engine Turbojet/fan, Over 20,000 TOGW	.0033	2.3	.01
Multi-Engine Turbojet/fan, Over 20,000 TOGW	.0017	2.3	.00
Rotary Piston	.0000	1.0	.00
Rotary Turbine	.0055	1.4	.01
Total	1.0000		5.0

1/ Number of "passengers," as opposed to "occupants," is relevant since crew costs are included in aircraft variable operating costs.

2/ Source: Reference F-3 based on References F-7 and F-8. Total does not add exactly to 1.0000 due to independent rounding.

3/ Sources: References F-6, F-8 and F-9.

TABLE F-8

General Aviation Aircraft Variable Operating Costs per Airborne Hour (1985 Dollars)

Aircraft Type	(A) Hourly Variable Operating Costs[1] Fuel & Oil	(B) Maintenance	(C) Total	(D) Distribution by IFR Hours[2]	(E) Extension (D) x (E)
Single-Engine Piston, 1-3 Seats	$ 21.31	$ 9.55	$ 30.86	.0094	$ 0.29
Single-Engine Piston, 4 + Seats	26.63	14.59	41.22	.4894	20.17
Twin-Engine Piston, Under 12,500 TOGW	53.55	62.80	116.35	.3112	36.21
Twin-Engine Turboprop Under 12,500 TOGW	125.12	118.42	243.54	.0935	22.77
Twin-Engine Turboprop Over 12,500 TOGW	454.22	276.04	730.26	.0122	8.91
Twin-Engine Turbojet/fan, Under 20,000 TOGW	577.48	248.45	825.93	.0460	37.99
Twin-Engine Turbojet/fan, Over 20,000 TOGW	811.29	311.95	1,123.24	.0322	36.17
Multi-Engine Turbojet/fan, Over 20,000 TOGW	889.56	706.12	1,595.68	.0052	8.30
Rotary Piston	29.27	38.57	67.84	.0000	.00
Rotary Turbine	51.41	85.41	136.82	.0000	.11
Total				1.000	$170.92 or $171

1/ Source: Reference F-5.

2/ Source: Reference F-3 based on References F-7 and F-8. Total does not add exactly to 1.000 due to independent rounding.

TABLE F-9

National Average Number Of Occupants[1/]
Per General Aviation Itinerant Flight

Aircraft Type	(A) Distribution By IFR Hours[2/]	(B) Number Of Occupants[3/]	(C) Extension (A) x (B)
Single-Engine Piston, 1-3 Seats	.0094	1.5	.01
Single-Engine Piston, 4 + Seats	.4894	2.4	1.17
Twin-Engine Piston, Under 12,500 TOGW	.3112	3.6	1.12
Twin-Engine Turboprop, Under 12,500 TOGW	.0935	5.6	.52
Twin-Engine Turboprop, Over 12,500 TOGW	.0122	5.6	.07
Twin-Engine Turbojet/fan, Under 20,000 TOGW	.0460	4.1	.19
Twin-Engine Turbojet/fan, Over 20,000 TOGW	.0322	4.1	.13
Multi-Engine Turbojet/fan, Over 20,000 TOGW	.0052	4.1	.02
Rotary Piston	.0000	2.1	.00
Rotary Turbine	.0008	2.5	.00
Total	1.0000		3.2

1/ Number of "occupants," as opposed to "passengers," is relevant since crew costs are not included in aircraft variable operating costs.

2/ Source: Reference F-3 based on References F-7 and F-8.

3/ Sources: References F-6 and F-8.

TABLE F-10

Military Aircraft Variable Operating Costs per Airborne Hour (1985 Dollars)

Aircraft Type	(A) Hourly Variable Operating Costs[1] Fuel & Oil	(B) Maintenance	(C) Total	(D) Distribution by Type[2]	(E) Extension (C) x (D)
Fixed Wing					
Turbojet/fan, Multi-Engine	$2,135	$432	$2,567	.0933	$ 239.50
Turbojet/fan, Twin-Engine	1,223	220	1,443	.4757	686.44
Turbojet/fan, Single-Engine	786	173	959	.1896	181.83
Turboprop	231	185	416	.1613	67.10
Piston	53	69	122	.0781	9.53
Rotary Wing					
Turbine	50	86	136	.0018	.24
Piston	30	38	68	.0000	.00
Total				1.000	$1,184.64 or $1,185

1/ Source: Reference F-5.

2/ Source: Reference F-3. Total does not add exactly to 1.0000 due to independent rounding.

TABLE F-11

National Average Number Of Occupants[1/]
Per Military Itinerant Flight

Aircraft Type	(A) Distribution By Type[2/]	(B) Number Of Occupants[3/]	(C) Extension (A) x (B)
Fixed Wing			
Turbojet/fan, Multi-Engine	.0933	6.0	.56
Turbojet/fan, Twin-Engine	.4757	6.0	2.85
Turbojet/fan, Single-Engine	.1896	6.0	1.14
Turboprop	.1613	5.0	.81
Piston	.0781	3.0	.23
Rotary Wing			
Turbine	.0018	2.0	.00
Piston	.0000	2.0	.00
Total	1.0000		5.6

1/ Number of "occupants," as opposed to "passengers," is relevant since crew costs are not included in aircraft variable operating costs.

2/ Source: Reference F-3. Total does not add exactly to 1.0000 due to independent rounding.

3/ Source: Reference F-6.

References for Appendix F

F-1 Economic Analysis of Investment and Regulatory Decisions - A Guide, Report Number FAA-APO-82-1, January 1982.

F-2 Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Report Number FAA-APO-81-3, September 1981. Updated by APO Bulletin Number FAA-APO-84-3, June 1984, same title. See also Reference F-5.

F-3 Establishment and Discontinuance Criteria for Precision Landing Systems, Report Number FAA-APO-82-10, June 1983.

F-4 Airport Activity Statistics of Certificated Route Air Carriers, 12 Months Ending December 31, 1980, Prepared jointly by the FAA and CAB.

F-5 Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Work program currently in process to update Reference F-2 (scheduled for publication as an APO bulletin in mid 1987).

F-6 Investment Criteria for Airport Surveillance Radar (ASR/ATCRBS/ARTS), Report Number FAA-APO-83-5, May 1983.

F-7 General Aviation Pilot and Aircraft Activity Survey, Report Number FAA-MS-81-1, January 1981.

F-8 General Aviation Pilot and Aircraft Activity Survey, Report Number FAA-MS-79-7, December 1979 (1978 data).

F-9 Commuter Air, "Inventory of Commuter Aircraft Fleet - September 1979," October 1979.