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ESTABLISHMENT CRITERIA FOR CATEGORY II INSTRUMENT LANDING SYSTEM (ILS)

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16. Abstract

This report develops revised establishment criteria for the Category II Instrument Landing System (ILS) with approach lights based upon benefit/cost analysis.

Revised criteria require 2,500 or more annual instrument approaches by certificated route air carrier aircraft. An existing Category II ILS at an airport recording fewer than 1,000 certificated route air carrier annual instrument approaches meets discontinuance criteria.

Benefits of an ILS include reduction of flight disruptions--delays, diversions, and cancellations due to lowered published approach and landing minimums--and safety, the reduced probability of approach accidents.

The primary impact of the criteria is to discourage future Category II ILS establishment at airports not served by trunk air carriers. In the short term, it is estimated that 25 airports now without a commissioned Category II ILS will qualify for a facility. Beyond the present time frame, only six additional airports are expected to qualify over the following ten years.

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EXECUTIVE SUMMARY

This report develops revised establishment criteria for the Category II Instrument Landing System (ILS) with approach lights based on benefit/cost analysis.

Previous Category II ILS criteria specified facility establishments at those primary air commerce airports serving large hubs or which recorded 5,000 or more annual instrument approaches. Depending on the interpretation of the phrase "primary air commerce airport," as many as 90 candidate airports currently without Category II ILS could have been identified. There had been no Category II ILS discontinuance criteria.

Revised criteria state that a requirement of 2,500 or more certificated route air carrier annual instrument approaches is necessary for a Category II ILS facility. On the other hand, an existing Category II ILS facility at an airport recording fewer than 1,000 certificated route air carrier annual instrument approaches meets discontinuance criteria.

The primary impact of the revised criteria is to discourage future Category II ILS establishment at airports not served by trunk air carriers, as such aircraft are typically equipped for Category II operation. In the short term, it is estimated that 25 airports now without a commissioned Category II ILS will qualify for a facility. Beyond the present time frame, only six additional sites are expected to qualify over the following ten years. Combined with the 35 airports currently having at least one Category II runway, it is expected that 66 airports will have a Category II facility by 1986.

Principal benefits of an ILS--reduced frequency of flight disruptions for the destination airport--vary widely according to the distribution of instrument weather, average number of passengers, and system costs. Therefore, Category II ILS candidates identified by numeric criteria will be validated in FAA Headquarters using supporting data furnished by the regions with their responses to the annual Call for Estimates. Such validation will take the form of a benefit/cost ratio; only sites with a ratio of one or greater qualify for establishment.

INTRODUCTION

This report develops revised establishment criteria for the Category II Instrument Landing System (ILS) with approach lights. The revised criteria are based on an analysis of the costs and benefits of the ILS and expressed in terms of annual instrument approaches (AIA's) on the candidate runway.

A Category II ILS upgrades a Category I system through the addition of dual electronic equipment, an inner marker beacon, upgraded marking and lighting systems, and one or more additional runway visual ranges. Additionally, the glide slope may need to be relocated and the localizer performance improved in order to achieve FAA specified Category II authorization for a candidate runway. Once authorized, assuming no restrictions or obstructions, equipped aircraft can land in weather visibilities down to 1,200-foot runway visual range (RVR) and a decision height of 100 feet. This compares with 2,400-foot RVR and 200-foot decision height limitation for the Category I ILS without touchdown zone and centerline lighting (TDZ/CL), or 1,800 RVR with TDZ/CL lighting.

Principal benefits attributed to the Category II ILS are reductions in flight disruptions, i.e., delays, diversions, and cancellations, that are deemed preventable in weather below Category I minimums. A runway qualifies for Category II establishment if the dollar worth of attributable benefits equals or exceeds the cost of providing Category II service over and beyond Category I systems.

To facilitate field application, a simple numeric criterion (called Phase I criterion) has been empirically derived from the more detailed benefit/cost analysis (Phase II). This criterion of 2,500 air carrier AIA's per airport will be published in Airway Planning Standard Number One (APS-1). Airports satisfying the Phase I criterion are candidates for Category II ILS. FAA Headquarters, using supporting data furnished by the regions with their responses to the annual Call for Estimates, will validate all submitted candidates via the benefit/cost technique to ensure that all establishments are economically justified.

SECTION I - PREVIOUS ILS CRITERIA

Previous establishment criteria for Category II ILS with Approach Light System, Sequenced Flashing Lights (ALSF), as published in APS-1 (Reference 1), read as follows:

Category II ILS with Approach Lights. The primary air commerce airport(s) serving a large hub or which records 5,000 or more annual instrument approaches is a candidate for a Category II ILS with approach lights provided appropriate FAA standards and requirements, as outlined in applicable agency directives, are met.

(1) All new and modified approach lighting systems for Category II (and III) candidate runways shall be the ALSF-2 configuration. Such light lanes shall be 2,400 feet in length provided the glide slope angle is 2.75 degrees or higher. At locations with the glide slope angle less than 2.75 degrees, the light lane shall be 3,000 feet in length.

(2) Existing ALSF-1 configuration systems will continue to be acceptable for Category II authorization at locations where the installed light assemblies meet ALSF-2 standards unless the runway being served is at an international airport (as defined in paragraph 9a(3)(c) of APS-1), in which case the configuration shall be updated to the ALSF-2 when funds and equipment become available. Presently installed ALSF-1 systems at Category II locations which are acceptable for Category II authorization will not be updated to ALSF-2 until such time that frangible mountings are provided. If the glide slopes at such locations have a 2.75 degree or higher angle, the outer stations 25 through 30 shall be deactivated as early as practicable.

SECTION II - CURRENT ILS CRITERIA

Revised establishment and discontinuance criteria for Category II ILS are:

A. Establishment

An airport with 2,500 or more certificated route air carrier annual instrument approaches is a candidate for a Category II ILS with approach lights provided assurance that appropriate FAA standards and requirements, as outlined in Order 6750.7 (Category II ILS Program), Order 6850.9 (Revised Approach Lighting Criteria), and Advisory Circular 120-29 (Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators), can be met if the necessary funding was provided. No Category II ILS installation shall commence until: (1) the sponsor has expressed his willingness to participate in the program, and (2) regions can assure that there will be no violations of obstruction clearance criteria which would preclude reduction of minima to those of Category II.

Subparagraphs (1) and (2) of the current criteria on page 2 of this report are retained in this revision.

B. Discontinuance

A Category II ILS at an airport recording less than 1,000 certificated route air carrier annual instrument approaches is a candidate for decommissioning. No Category II ILS shall be decommissioned without prior concurrence of the Regional Director. A Category II ILS that has been decommissioned shall be recommissioned as a Category I system if it qualifies under the provisions of paragraph 9a or 9b of Airway Planning Standard Number One. Surplus components will be made available for use at other Category II eligible locations.

C. Benefit/Cost Validation

Category II ILS candidates for establishment or discontinuance identified by paragraph A or B above will be validated in FAA Headquarters using the benefit/cost technique described in this report. A benefit/cost staff study is required prior to multiple Category II ILS establishment in accordance with the methodology outined in this report. FAA regional offices shall submit data required for validation purposes with their responses to the annual Call for Estimates.

Specific parameters required for benefit/cost validation are frequency of Category II weather; number of Category II equipped air carrier aircraft; air carrier, air taxi, and general aviation AIA's; and average number of deplaning passengers per air carrier. In order to facilitate field application, a simple criterion of 2,500 airport air carrier AIA's (Phase I criterion) was empirically derived from the results of the detailed benefit/cost analysis (Phase II). Candidates identified by Phases I and II are compared in Section VIII, Impact Assessment. The Phase I criterion is designed to identify as many candidates as possible with benefit/cost ratios of 1.0 or greater and, at the same time, eliminate as many sites as possible with ratios less than 1.0. In this manner, a close correlation exists between those locations identified under both the simple numeric criterion and detailed benefit/cost analysis.

SECTION III - SCOPE

Benefits of Category II ILS systems include: (1) the prevention of weather-caused flight disruptions; (2) economic community benefits from improved transportation; (3) increased demand for air travel due to greater reliability of service; (4) enhanced military preparedness brought about by the ability to operate with fewer weather restrictions; and (5) greater safety since more precise approach guidance is available in all kinds of weather. Although all of the above are in part attributable to a Category II system, a substantial portion of the accrued benefits occur during Category I weather. On a national average, Category I (CAT I) weather conditions occur about 12 percent of the airports' hours of operation, while CAT II conditions occur less than 1 percent of the time (Reference 2). It seems logical, therefore, to attribute most of the above benefits to Category I ILS operation. The remaining benefits apply to those aircraft making approaches and landings during CAT II weather conditions. These are quantified as Category II ILS benefits.

While economic community benefits may merit consideration when examining a site for Category II ILS, these benefits are determined to be relatively minor when addressing issues of safety and prevention of weather-caused flight disruptions. Also, considering the subjectivity involved in the quantification and the predicted negligible contribution to total benefits, it is concluded that community benefits should be deleted from this study.

Benefits accruing from air traffic growth, although not explicitly addressed, are considered when discounting benefits over time. As explained in the following section, forecasted growth factors of Instrument Flight Rules (IFR) traffic are applied to each candidate site over a projected 15-year period. These factors, when multiplied by current annual benefits, determine 15-year discounted Category II ILS benefits.

Concerning enhanced military preparedness, each approach by military aircraft occurring during CAT II weather is assigned a dollar value of benefit, as are civil aircraft. At joint-use fields not meeting establishment criteria or where criteria do not apply, Category II ILS will be considered in accordance with existing FAA/DOD policies at the time of the request. In such situations an essential military requirement is presumed to exist prior to ILS consideration.

Safety of flight is of prime importance when evaluating requirements for an instrument approach system. The precision afforded by a Category II ILS capability undoubtedly will lead to safer landings in IFR as well as Visual Flight Rules (VFR) weather. On the other hand, landing minima are established to assure a level of safety compatible with the navigation aids and airborne equipment used during approaches. The problem then is, what safety comparisons can be made between a runway with a precision approach Category I or II ILS system with reduced landing minima for equipped aircraft and one without the ground facility but with compensating higher minima? Appendix D outlines the safety benefits for air carrier, air taxi, and general aviation aircraft. Each instrument approach performed is assigned a specific dollar value. It should be noted, however, that safety benefits comprise a minor share of the total Category II ILS benefits.

Category I ILS systems provide a first-level precision approach capability to suitably equipped aircraft. Such aircraft are provided both lateral and vertical guidance. Because of greater approach guidance afforded, aircraft can land down to weather minima of 2,400-foot RVR and a decision height (DH) of 200 feet (1,800 RVR with centerline and touchdone zone lighting). In the absence of RVR, equivalent minima of 1/2-mile visibility with a 200-foot ceiling are specified. Runways with less than the standard ILS can only provide non-precision approach guidance--usually only lateral guidance in the case of a partial ILS without the glide slope. The rate of descent information provided by the glide slope also offers an additional measure of safety to equipped aircraft under all weather conditions. For these reasons, most safety benefits are quantified in the Category I ILS benefit/cost analysis (Reference 9).

Category II ILS's also provide lateral and vertical guidance information but do so under tighter tolerances than Category I systems. Landing minima, because of the greater approach guidance afforded arriving aircraft, can be reduced down to 1,200-foot RVR with a decision height of 100 feet (Reference 3). Although greater system reliability and precision information are available through the Category II ILS for all ILS-equipped aircraft, only those arriving during CAT II weather conditions stand to achieve the maximum benefits. However, the more precise ILS beam of the Category II system plus the visual aids required for a Category II runway provide operational benefits to the pilot over the Category I system at comparable weather minima. A more detailed discussion regarding safety is included in Appendix C.

The Category II ILS analysis assigns dollar values for avertable flight disruptions which include reductions in delays, diversions, and cancellations. As stated above, benefits are quantified for aircraft making instrument approaches under Category II weather conditions--below 2,400 RVR 200-foot decision height but above 1,200 RVR 100-foot decision height. Those receiving benefits from a Category II ILS will be primarily certificated route air carriers since many are presently equipped and approved for Category II ILS operation. Military aircraft are being provided precision approach capability but they will not ordinarily operate into large commercial airfields. Virtually no air taxi and general aviation operators are equipped to fly Category II ILS approaches. Therefore, efficiency benefits based on averted air carrier flight disruptions are considered in the methodology.

SECTION IV - COSTS OF CATEGORY II ILS

Airborne Costs

Airborne equipment necessary for Category II operation includes, in addition to the instruments and radio equipment required by the Federal Aviation Regulations (FAR's), dual ILS localizer and glide slope receivers, flight control guidance systems, equipment for decision height identification and missed approach altitude guidance, plus an instrument failure warning system. Also, Advisory Circular 120-29 prescribes an extensive pilot training and proficiency program which must be included in each air carrier's approved training program (Reference 3).

The FAA, as of October 1975, has 38 Category II commissioned ILS facilities (including two at Andrews AFB and Category IIIA systems at Dulles and Atlanta) (Reference 4). These are located at 35 airports, with 27 more facilities installed but not yet commissioned at other sites. The existence of these installations appears to give sufficient incentive for all airlines, who will be the principal users of the system, to install a Category II capability in their jet aircraft. Aircraft so equipped are capable of making Category II ILS approaches during reduced weather minima at the Category II ILS runway. Category II airborne equipment is also fully compatible with Category I ground equipment and vice versa.

Ground System Costs

A full Category I ILS ground system consists of a localizer, glide slope, outer and middle marker beacons, possibly an RVR and ceilometer, and a medium-intensity approach light system with sequenced flashing lights (MALSR). (RVR's and ceilometers are not usually included in the "standard" ILS installation; however, they frequently appear at those sites busy enough to qualify for Category II ILS.)

Upgrading a full Category I ILS installation to Category II requires (Reference 5):

a. Assuring that localizer and glide slope performs within specified tolerances. In order to achieve the required improvement on localizer performance, an antenna suitable for providing improved localizer performance will be required. Capture effect glide slope or sideband reference glide slope may be required and, in addition, some site preparation needed for necessary glide slope path and course improvements. In many cases it also is necessary to relocate the glide slope to meet threshold crossing height requirements;

b. Installation of an inner marker beacon;

c. Retrofitting existing approach light system to Category II standards (This is not a requirement if an ALSF-1 is available and meets the gradient standards);

d. Installation of touchdown zone and centerline lighting systems;

e. Installation of hold signs and critical area markings;

f. Installation of a second RVR (A third RVR is required for runways longer than 8,000 feet);

g. Installation of dual equipment for localizer and glide slope components.

Costs of installing a Category II ILS from scratch would be somewhat less than the total cost of installing and improving a Category I facility because the requisite electronic components would be selected and properly located initially. In either case, actual implementation of the benefit-versus-cost analysis requires on-site cost information for the particular candidate runway. Cost estimates presented here are considered typical for purposes of analysis and are not to be used for validating actual Category II ILS candidates.

Typical FY 1975 establishment costs of Category I and II major ground system components and their difference are as follows:

Cost Item	Category I	Category II	Difference
Investment (000)			
ILS Establishment	222.4	417.4	195.0
RVR	56.6*	56.6**	0.0
Touchdown Zone/ Centerline Lighting	0.0	300.0	300.0
Approach Lighting	80.0	300.0	220.0
Site Preparation	75.0	100.0	25.0
Total	434.0	1,174.0	740.0
Annual O&M (000)			
Maintenance	52.8	127.9	75.1
Stocks and Stores	10.0	10.0	0.0
Flight Inspection	9.7	26.0	16.3
Total	72.5	163.9	91.4

*One RVR for Category I ILS

**Category II ILS establishment cost includes 2 RVR's; however, a third is required ($56,600) for runways over 8,000 feet

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Detailed investment costs were obtained from ASP-210, AAS-550, and AAF-130. In addition to system hardware, investment costs include test equipment, training, installation, initial flight inspection, regional supplies, construction material, and freight. Site preparation costs were derived from a survey of 64 Category I and 13 Category II sites (Reference 6). O&M costs were obtained from AAF-250.

Differences between total Category I and II ILS establishment costs or, alternatively, the cost of upgrading Category I to Category II ILS represent the expenditure required to further reduce the approach and landing runway minima. When comparing this marginal cost to incremental benefits of reduced flight disruptions under Category II conditions, a Category II ILS is considered economically justified if benefits equal or exceed costs. A procedure for discounting both costs and benefits is presented in the next section.

SECTION V - METHODOLOGY--ESTABLISHMENT CANDIDATES

This segment outlines the approach taken in the benefit/cost analysis based on ground rules identified in the previous section.

Type of Aircraft

Only instrument approaches by Category II approved air carriers will be considered as input to the analysis. A list of FAA approved Category II ILS aircraft by airline as of March 1975 is presented in Table 1. Dates of approval and minimum allowable RVR levels are also available for each aircraft type. Practically all approved aircraft are turbojets, a trend which is expected to continue as new Category II approvals are added. Additionally, almost all the identified airlines are operated by certificated route air carriers. It would probably be just as equitable to consider all currently approved aircraft to be certificated route air carriers. It is also expected that the number of airlines and Category II equipped aircraft will continue to increase. In the investigative stages of analysis, therefore, it may prove beneficial to include those carriers and aircraft that are anticipated to be approved, within a reasonable time frame, for Category II ILS operation at potential candidate airports.

As part of the analysis, numbers of Category II approved aircraft operating at specific airports are derived from the Airport Activity Statics of Certificated Route Air Carriers (Reference 7). This semiannual publication is prepared jointly by the Civil Aeronautics Board and FAA. Tables 6 and 7 of the publication contain a presentation by aircraft type of total departures performed (by scheduled plus nonscheduled service) along with the number of enplaned passengers by airport. By cross-referencing each air carrier and aircraft type with Table 1 of this report, numbers of applicable Category II approved aircraft are determined. In order to give candidate airports the benefit of the doubt, it is assumed that crews are checked out for Category II operation if they are operating approved aircraft. It is further assumed that, on the average, the number of enplaning passengers equals deplaning passengers and total departures performed equal total arrivals at candidate airports.

By dividing the number of Category II approved departures by total departures listed in Table 7 of Reference 7 or, alternatively, dividing Category II arrivals by total arrivals, that

TABLE 1

Summary of Category II Approvals

Airline	Type Aircraft	Airline	Type Aircraft
AAL	B-707	PAI	B-737
	B-727		YS-11
	BAC-111		
		PSA	B-727
BNF	B-727		L-1011
DAL	B-727	SBWX	DC-8
	B-747		
	CV-880		
	DC-8-50-51-61	TWA	B-707
	DC-9		B-727
	DC-10		B-747
	L-1011		CV-880
			DC-9
			L-1011
EAL	B-727		
	DC-8-61-63		
	DC-9-14-31	UAL	B-720
			B-727
			B-737
NAL	B-727		B-747
	B-747		DC-8-61-62
			DC-10
PAA	B-707		
	B-727		
	DC-8		

fraction of Category II equipped arrivals out of the total is found. Multiplying this fraction by total air carrier annual instrument approaches (AIA's) yields an estimate of the number of Category II air carrier AIA's at the candidate airport. Total air carrier AIA data is listed in Table 13 of FAA Air Traffic Activity (Reference 8), a semiannual publication of the FAA.

The product of the number of Category II air carrier AIA's and fraction of CAT II weather at the airport will provide the number of additional annual air carrier instrument approaches permitted by a Category II ILS. Furthermore, the number of deplaning passengers aboard such approaching aircraft will contribute in determining the dollar benefits of averted flight disruptions.

Weather Data

Category II approved aircraft executing instrument approaches may do so in weather meeting published airport minima or better. Benefits accruing during Category I or better approaches, however, have already been accounted for in the Category I ILS establishment criteria and associated benefit/cost analysis, Report FAA-ASP-75-1 (Reference 9). To avoid double counting, economic benefits of averted flight disruptions will accrue only to approved aircraft executing instrument approaches during CAT II weather conditions, i.e., weather below CAT I minima down to CAT II limitations.

Advisory Circular 120-29, "Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators" (Reference 3), states "When an applicant has complied with the provisions of the criteria (in the circular), operations specifications authorizing 1,600 RVR with a 150-foot decision height will be issued... When the first six months of operation have been analyzed and found acceptable, the operator will be authorized to operate at 1,200 RVR with a decision height of 100 feet."

Percentages of hourly weather observations falling within specified ceiling visibility categories have been tabulated for the FAA by the National Climatic Center (NCC) at Asheville, North Carolina, for all major U.S. airports (Reference 2). Data for any of these airports will be furnished by ASP-110 on request.

Data for these airports have been grouped by the NCC in three 8-hour intervals: 0700-1300, 1400-2100, and 2200-0600. Since airport activity is minimal during the last time interval, weather observations during this period, at the risk of adversely biasing the data, were omitted from the analysis. To further simplify matters, as differences in air carrier traffic during the first two periods are minor, weather data for these two intervals is merged.

The FAA currently counts all AIA's at all major airports. This count is used as an indicator of aircraft arrival rates during low ceiling and/or low visibility conditions consistent with the following definition: An instrument approach is an approach made to an airport by an aircraft having an IFR flight plan, when the visibility is less than three miles and/or the ceiling is at or below minimum initial approach altitude.

Data presented by the National Climatic Center is used to calculate "system enhancement factors" for each documented airport. These are applied to estimate the percentage of time that various instrument systems (VOR, Category I ILS, and Category II ILS) will be of assistance to an aircraft on an instrument approach. The following assumptions have been made in developing these factors:

1. AIA's are equally distributed through the time period for which the factor was developed;

2. AIA's are recorded when the ceiling is below 1,500 feet and/or the visibility is less than 3 miles;

3. The normal expectation is that:

    a. VOR approaches permit landings to minimum ceiling-visibility conditions of 400 feet and/or 1 mile;

    b. Category I ILS (with approach lights) permits ceiling-visibility minima of 200 feet and/or 1/2 mile;

    c. Category II ILS permits ceiling-visibility minima of 100 feet and/or 1/4 mile.

A Category II ILS enhancement factor can now be defined as the frequency of ceiling-visibility less than 200 feet and/or 1/2 mile, but greater than or equal to 100 feet and/or 1/4 mile divided by the frequency of ceiling-visibilities below 1,500 feet and/or 3 miles but greater than 200 feet and/or 1/2 mile. Simply stated, this represents the odds of encountering CAT II weather under IFR conditions. When this percentage of CAT II weather is multiplied by the number of Category II equipped air carrier AIA's, the number of additional approaches provided by Category II ILS is determined, i.e.,

$$\frac{\text{Total air carrier AIA's} \times \text{\% CAT II Wx}}{\text{\% CAT I or better IFR Wx}} = \text{Number of Additional AIA's}$$

Determination of Category II ILS Averted Flight Disruption Benefits

To determine the annual dollar value of averted flight disruptions, multiply the average cost of a flight disruption (outlined in Appendix B) by the number of additional AIA's given by the formula above.

Safety Benefits

To determine the dollar benefits of Category II ILS preventable accidents, multiply annual air carrier instrument approaches (AIA) by the dollar value of the potential benefit per approach ($2.75 per air carrier AIA). Add to this the air taxi AIA's multiplied by $7.09 and the general aviation (and military) AIA's by $2.24. The total is the Category II ILS safety benefit.

Total Benefits

Add dollar values of safety benefits to benefits of averted flight disruptions.

Note: If an existing Category I system includes TDZ/CL lighting, differences between Category I and II minima are 1,800 RVR versus 1,200 RVR. The computed number of additional AIA's, above, should be adjusted downward by substituting these revised requirements in the equation. Revised Category II costs would then exclude TDZ/CL lighting.

Multiple ILS

As the typical Category II ILS airport will only have a single equipped runway, 100 percent of potential Category II AIA's are expected to occur on this single runway. For these cases, the above methodology stands. For multiple Category II ILS candidate sites, benefits should be adjusted by multiplying total airport benefits by the expected percentage increase of

Category II traffic exceeding capacity on the existing Category II ILS runway. Regions will be encouraged to conduct on-site surveys of marginal IFR traffic growth in these circumstances. Candidates for multiple Category II ILS must first demonstrate a requirement on the basis of Category II air carrier arrivals exceeding current capacity limitations. It should be noted that only minor demand for multiple Category II ILS's is anticipated. In most cases airports experience less than 300 annual avertable air carrier flight disruptions. (See Table 4, page 24.) These can easily be handled by a single equipped runway. On the other hand, airports with existing multiple Category II ILS's, e.g., Chicago O'Hare and Atlanta International, have 800 and 1,900 annual avertable air carrier flight disruptions, respectively.

It is also important to note that the above methodology is based on average cost computations, published weather data, and operations data obtained from References 7 and 8. In actual application of the benefit/cost analysis, regions are encouraged to supply an estimate of percentage of air carrier AIA's performed on candidate runways for multiple Category II ILS. The benefit/cost analysis will be performed using the estimated air carrier traffic count for these runways.

Discounted Costs and Benefits

The Office of Management and Budget has prescribed a standard 10 percent discount rate to be used in evaluating the measurable costs and/or benefits of programs or projects when they are distributed over time (Circular A-94, Revised) (Reference 10). Over 15 years, the discount factor is 7.605. As O&M costs are assumed to be constant over time, the discounted operating and maintenance costs are 7.605 times the annual cost.

Category II ILS benefits are primarily a function of instrument air carrier traffic activity. Since air traffic is expected to increase throughout the next 15 years, a net discount factor was developed and illustrated in Table 2 by multiplying OMB's discount factors by FAA's median forecast factors for 1976-87 (extrapolated to 1990) (Reference 11). The net discount factor summed over the next 15 years is 9.951. As the benefits are computed on an annual basis, instead of discounting them by year, lifetime efficiency benefits are calculated by multiplying the present annual benefits by 9.951.

TABLE 2

Discount Factors

Year After Funding	10% Discount Factor	x	Air Carrier IFR Growth Factors 1976-90	=	Net Discount Factors for Air Carrier Benefits
1	.909		1.087		.988
2	.826		1.130		.933
3	.751		1.152		.865
4	.683		1.196		.817
5	.621		1.239		.769
6	.564		1.283		.724
7	.513		1.348		.692
8	.467		1.391		.650
9	.424		1.434		.608
10	.386		1.477		.570
11	.350		1.520		.532
12	.319		1.563		.499
13	.290		1.606		.466
14	.263		1.649		.434
15	.239		1.692		.404
TOTAL	7.605				9.951

Discount IFR growth factors for air taxi and general aviation aircraft are 15.346 and 12.123, respectively (Reference 9). As in the case of air carriers, these were developed using national forecast data. In order to obtain discounted safety benefits, multiply the benefit of each aircraft type by the corresponding factor. Thus, the equation for discounted Category II ILS safety benefits reads:

A/C AIA's x \$2.75 x 9.951 + A/T AIA's x \$7.09 x 15.346 +

G/A AIA's x \$2.24 x 12.123

At present, IFR growth factors are not available by aircraft type for specific airports. It is anticipated, however, that such forecasts will be available in the near future. When this revision occurs, growth data specific to the candidate site will be used in lieu of national forecast data.

Discounted incremental marginal costs of Category II versus Category I ILS are:

Cost Item	Cost (000)	Discount Factor	Discounted 15-Year Cost (000)
Investment	\$740.0	1.000	\$ 740.0
Annual O&M	91.4	7.605	695.1
Total			\$1,435.1

Dividing discounted benefits by discounted costs, the benefit/cost ratio for Category II ILS is calculated.

A summary of the above procedure is presented in Table 3.

SECTION III - SCOPE

Benefits of Category II ILS systems include: (1) the prevention of weather-caused flight disruptions; (2) economic community benefits from improved transportation; (3) increased demand for air travel due to greater reliability of service; (4) enhanced military preparedness brought about by the ability to operate with fewer weather restrictions; and (5) greater safety since more precise approach guidance is available in all kinds of weather. Although all of the above are in part attributable to a Category II system, a substantial portion of the accrued benefits occur during Category I weather. On a national average, Category I (CAT I) weather conditions occur about 12 percent of the airports' hours of operation, while CAT II conditions occur less than 1 percent of the time (Reference 2). It seems logical, therefore, to attribute most of the above benefits to Category I ILS operation. The remaining benefits apply to those aircraft making approaches and landings during CAT II weather conditions. These are quantified as Category II ILS benefits.

While economic community benefits may merit consideration when examining a site for Category II ILS, these benefits are determined to be relatively minor when addressing issues of safety and prevention of weather-caused flight disruptions. Also, considering the subjectivity involved in the quantification and the predicted negligible contribution to total benefits, it is concluded that community benefits should be deleted from this study.

Benefits accruing from air traffic growth, although not explicitly addressed, are considered when discounting benefits over time. As explained in the following section, forecasted growth factors of Instrument Flight Rules (IFR) traffic are applied to each candidate site over a projected 15-year period. These factors, when multiplied by current annual benefits, determine 15-year discounted Category II ILS benefits.

Concerning enhanced military preparedness, each approach by military aircraft occurring during CAT II weather is assigned a dollar value of benefit, as are civil aircraft. At joint-use fields not meeting establishment criteria or where criteria do not apply, Category II ILS will be considered in accordance with existing FAA/DOD policies at the time of the request. In such situations an essential military requirement is presumed to exist prior to ILS consideration.

SECTION VI - ILLUSTRATION OF BENEFIT/COST TECHNIQUE

The benefit versus cost methodology developed in this study is applied for Tampa International Airport, Tampa, Florida. The airport currently is served by two Category I ILS's on runways 18L and 36L. This example determines if 36L qualifies for a Category II ILS.

Airport: Tampa, Florida

Runway 36L - 150 feet wide; 8,000 feet long

Step Number		
1	CY 1974 air carrier AIA's	3,737
2	Percent Category II equipped air carriers	95%
3	CY 1974 Category II equipped air carrier AIA's (Step 1 x Step 2)	3,550
4	Average number of deplaning passengers (n) per Category II equipped air carrier	52
5	Percent weather equal to or above CAT II but less than CAT I minima	0.30%
6	Percent IFR weather equal to or above CAT I minima	5.25%
7	Number of additional AIA's (Step 3 x [Step 5 ÷ Step 6])	203
8	Benefit/additional AIA ($44n + $502)	$2,790
9	Efficiency benefits (Step 7 x Step 8 x 9.951)	$5,635,948
10	Air carrier AIA's (3,737) x $2.75 x 9.951 + air taxi AIA's (511) x $7.09 x 15.346 + general aviation AIA's (1,060) x $2.24 x 12.123	$186,647
11	Total discounted benefits (Step 9 + Step 10)	$5,822,595

Step Number		
12	Discounted 15-year marginal costs	$1,435,100
13	Benefit/cost ratio (Step 11 ÷ Step 12)	4.1

SECTION VII - METHODOLOGY - DISCONTINUANCE CANDIDATES

Category II ILS's may be decommissioned if the operating and maintenance costs of providing the service exceed the benefits derived. Normally, facilities so qualified are at airports that experience a severe reduction in service by the major air carriers. Aside from air carrier landings, light passenger loads will contribute to discontinuance decisions. In any event, Category II ILS's, if discontinued, will revert to a Category I system. If activity levels drop below Category I decommissioning criteria, the facility would be completely decommissioned.

Since a Category II facility would revert to a Category I system upon initial discontinuance, differences in 15-year discounted O&M costs between the two are compared with marginal benefits over the same time period--just as in the validation procedure of candidates for establishment. Category II ILS runways will qualify to be downgraded to Category I status only if these marginal costs exceed marginal benefits. Using cost data in this report, the marginal discounted O&M cost is 48 percent of total establishment costs. (See Section V.) Candidates for establishment with benefit/cost ratios of .48 or more would have O&M costs at least equal to benefits. Sites with ratios less than .48 would have costs exceeding benefits--qualifying them for downgrading to Category I systems. Airports having less than 1,000 air carrier AIA's normally fall into this category.

Category II runways at airports having less than 1,000 air carrier AIA's will be screened by the benefit/cost procedure, comparing operating and maintenance costs to benefits according to the methodology presented in this report. At present, no airport has a Category II ILS runway qualifying for discontinuance. Additionally, no discontinuance candidates are forecast for the next decade.

SECTION VIII - IMPACT ASSESSMENT

The initial screening criteria (2,500 air carrier AIA's) and benefit/cost procedure were applied to airports without commissioned Category II ILS runways as of October 1975 in order to assess the impact of proposed criteria. Table 4 documents the results for airports having 1,000 or more Category II approved air carrier AIA's. This is considered more than adequate to include all possible qualifiers. Airports are listed in order of total AIA's. Airport and air carrier AIA data was obtained from Reference 8. Actual weather data (Reference 2), percentage of Category II approved air carrier aircraft (Reference 7), and average numbers of deplaning passengers by airport (Reference 7) were used in determining the number of additional AIA's achievable with the ILS. Cost data in Section IV was applied to all sites.

Unless otherwise indicated, the year of first qualification under revised establishment criteria is CY 1974. (See remarks column in Table 4.) Planned ILS facilities are indicated by "P," and airports with Category II designated (programmed) runways by "D." Forecasted facilities qualifying by FY 1986 are indicated by "F." Airports qualify for a facility when the benefit/cost ratio equals or exceeds 1.0.

In CY 1974 there were 61 airports with 2,500 or more air carrier AIA's. Of these, 35 currently have at least one Category II ILS (with 32 having benefit/cost ratios of 1.0 or more). Of the remaining 26 airports without a commissioned facility, 20 have benefit/cost ratios of 1.0 or more.

Under benefit/cost analysis, approximately 23 percent of the potential candidates identified by 2,500 AIA's (Phase I criterion) are expected to drop out. This is due either to low passenger deplanements, low frequency of CAT II weather, or both.

TABLE 4

Airport Survey - Impact Assessment

Airport	CY 1974 AIA's Total (000)	CY 1974 AIA's A/C (000)	Additional A/C	Criteria Satisfied Initial	Criteria Satisfied B/C	Remarks
Cleveland	22.9	16.8	257	X	5.24	D
San Diego	19.6	10.6	77	X	2.17	
Boston	19.5	14.0	452	X	9.90	D
Santa Ana	19.3	4.4	123	X	2.60	
Rochester	19.0	10.5	180	X	2.98	D
Miami	18.8	12.8	281	X	5.91	
St. Louis	17.7	11.8	160	X	2.97	
Columbus	14.3	6.8	96	X	1.68	D
Charlotte	13.3	7.1	261	X	4.35	P
Nashville	11.9	5.5	70	X	1.18	D
San Jose	11.1	5.1	58	X	1.00	
Buffalo	10.9	7.2	197	X	3.26	D
Bristol	8.4	4.0	114	X	1.23	D
Albany	8.4	3.6	99	X	1.69	D
Raleigh	8.4	2.9	92	X	1.60	
Tulsa	8.3	3.5	58	X	0.93	D,F
Denver	7.9	5.7	88	X	1.95	D
Richmond	7.2	1.9	47		0.80	D,F
Birmingham	7.2	3.6	10	X	0.26	
Chatanooga	6.9	2.3	74		1.01	D
Wichita	6.4	1.8	44		0.73	F
Greensboro	6.4	2.6	117	X	1.74	
Allentown	6.4	1.2	47		1.00	
Fort Wayne	6.3	1.3	31		0.56	
Binghamton	6.2	1.5	39		0.58	
Omaha	6.1	3.2	36	X	0.65	
Charleston	6.1	2.4	109		1.40	
Honolulu	6.0	4.1	0	X	0.10	
Roanoke	5.9	3.7	168	X	1.93	

TABLE 4 (continued)

Airport	CY 1974 AIA's Total (000)	A/C (000)	Additional A/C	Criteria Satisfied Initial	B/C	Remarks
Madison	5.7	2.8	28	X	0.38	
Lexington	5.4	1.9	27		0.42	
Tampa	5.3	3.7	203	X	4.06	D
Toledo	5.3	1.4	36		0.58	D
Des Moines	5.3	1.8	31		0.54	
Norfolk	5.2	2.8	62	X	1.09	
Akron/Canton	5.2	1.4	33		0.59	
Little Rock	5.1	2.0	51		0.78	F
Shreveport	5.0	2.9	65	X	0.84	D,F
Baton Rouge	5.0	2.4	29		0.39	
Columbia	4.8	1.8	38		0.67	D
Jackson	4.6	2.4	55		0.69	D,F
Knoxville	4.4	2.0	29		0.43	D
Middleton	4.2	1.4	46		0.90	
Bangor	3.3	1.0	63		0.93	
Erie	3.3	1.2	28		0.40	
Wilmington	3.2	1.3	21		0.22	
Asheville	3.0	1.5	22		1.26	
Evansville	2.8	1.0	16		0.29	
Huntington	2.7	1.2	61		0.60	
Augusta	2.5	1.4	40		0.48	D
Orlando	1.5	1.4	51		1.02	P

NOTES: "X" denotes Phase I numeric establishment criterion satisfied.
"D" denotes that a site is designated (but not yet commissioned) for Category II ILS.
"P" denotes a Category II ILS is planned but not yet established.
"F" denotes sites that are expected to qualify for establishment by FY 1986.

SECTION IX - SENSITIVITY ANALYSIS

The equation for determining annual ILS benefits can be written as:

$$\frac{\%\ \text{CAT II Wx}}{\%\ \text{CAT I or better}} \times \begin{matrix}\text{No. of AIA's by}\\ \text{approved Cat. II A/C}\end{matrix} \times (\$44n + \$502) +$$

$$(\text{A/C AIA's} \times \$2.75 + \text{A/T AIA's} \times \$7.09 + \text{G/A AIA's} \times \$2.24)$$

where n is the average number of deplaning passengers per Category II approved air carrier.

When factoring appropriate discount growth factors into the equation and dividing by discounted costs, the benefit/cost ratio is obtained. (See Section V.)

This section provides a brief look into the effects of changing the above parameters on identified numbers of candidates. As prevailing Category II weather increases for example, the benefit/cost ratio will also increase. The net effect is an increase in the number of qualified airports--those with benefit/cost ratios of 1.0 or greater. Similarly, the number of airports qualifying is dependent on air carrier AIA's, average number of deplaning passengers per air carrier, and system costs. These are examined individually here.

Table 5 lists those locations with 1,000 Category II air carrier AIA's or more. These are the same airports evaluated for the impact analysis in the previous section. This table, however, lists the weather factor, Category II approved air carrier AIA's, and deplaning passengers on these aircraft.

Table 6 presents a summary of changes in number of qualified locations resulting from varying the analysis parameters.

TABLE 5

Airports Examined in Sensitivity Analysis

Airport	% CAT II Wx ÷ % IFR Wx or Better	No. Category II Approved A/C AIA's	Deplaning Passengers per A/C	B/C ≥ 1
Cleveland	.017	15,100	49	X
San Diego	.012	6,400	64	X
Boston	.034	13,300	57	X
Santa Ana	.028	4.200	48	X
Rochester	.018	10,000	36	X
Miami	.023	12,200	53	X
St. Louis	.018	8,900	42	X
Columbus	.015	6,400	36	X
Charlotte	.039	6,700	40	X
Nashville	.016	4,400	33	X
San Jose	.025	2,300	32	X
Buffalo	.029	6,800	39	X
Bristol	.044	2,600	19	X
Albany	.029	3,400	38	X
Raleigh	.033	2.800	40	X
Tulsa	.023	2,500	32	
Denver	.026	3,400	55	X
Richmond	.026	1,800	35	
Birmingham	.004	2,500	29	
Chattanooga	.037	2,000	28	X
Wichita	.037	1,200	33	
Greensboro	.053	2,200	34	X
Allentown	.039	1,200	46	X
Fort Wayne	.026	1,200	35	
Binghamton	.035	1,100	21	
Omaha	.020	1,900	36	
Charleston	.052	2,100	27	X
Honolulu	.000	1,200	93	
Roanoke	.051	3,300	24	X
Madison	.028	1,000	21	

TABLE 5 (continued)

Airport	% CAT II Wx ÷ % IFR Wx or Better	No. Category II Approved A/C AIA's	Deplaning Passengers per A/C	B/C ≥ 1
Lexington	.021	1,300	27	
Tampa	.057	3,600	52	X
Toledo	.030	1,300	33	
Des Moines	.031	1,000	34	
Norfolk	.024	2,600	41	X
Akron/Canton	.025	1,300	36	
Little Rock	.034	1,500	32	
Shreveport	.025	2,600	26	
Baton Rouge	.024	1,200	23	
Columbia	.025	1,500	39	
Jackson	.026	2,100	25	
Knoxville	.035	1,700	29	
Middleton	.036	1,300	45	
Bangor	.063	1,000	37	
Erie	.028	1,000	28	
Wilmington	.021	1,000	15	
Asheville	.091	1,300	22	X
Evansville	.016	1,000	38	
Huntington	.061	1,000	18	
Augusta	.031	1,300	24	
Orlando	.046	1,100	52	X

TABLE 6

Summary of Sensitivity Analysis

Weather Factor	Net Change in Qualified Airports
Increase 10%	+ 2
20%	+ 3
Decrease 10%	- 3
20%	- 5

Category II Approved A/C AIA's	Net Change
Increase 250	+ 2
500	+ 3
1,000	+ 8
1,500	+15
2,000	+18
Decrease 250	- 5
500	- 7
1,000	-11
1,500	-12
2,000	-13

Number of Deplaning Passengers per A/C	Net Change
Increase 5	+ 1
10	+ 3
Decrease 5	- 4
10	- 5

15-Year Discounted Cost	Net Change
Increase $ 50,000	- 1
$100,000	- 2
$200,000	- 3
Decrease $ 50,000	0
$100,000	+ 2
$200,000	+ 3

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APPENDIX A

Benefits of Reduced Flight Disruptions*

Weather-caused flight disruptions--delays, diversions, and cancellations--impose economic penalties on both aircraft operators and users. Delays and diversions increase aircraft operating costs. Cancellations result in loss of revenue. All three types of disruptions create extra passenger-handling expense for the airlines. However, most of the costs of flight disruptions are borne by the passengers, who suffer inconvenience and delay. Since airports vary widely with respect to the numbers of passengers they handle, average number of enplaned passengers is a variable in the flight disruption cost estimating equations developed below. The approach taken in this analysis is similar to that adopted for Category I ILS (Reference 9).

In long-haul operations, airlines seldom cancel because the destination airport is forecast to be closed. If on arrival the destination airport is open or is forecast to be open within an hour or so, the aircraft will proceed to its destination and either land or hold. As CAT II weather can be forecast relatively accurately, controllers can reliably inform aircraft of holding time duration. If holding times are expected to exceed one hour, aircraft will divert to another airport.

Short- and medium-haul flights (500 and 1,000 miles or less, respectively) tend to take delays on the ground at the departure airport to conserve fuel and operating costs as well as easing congestion problems at the arrival airport. Short-haul flights may cancel if weather at the destination airport is forecast to be below minimums. If the airport is an intermediate stop along a route, it may be overflown, creating a diversion for passengers intending to land and a cancellation for those expecting to board the aircraft. If forecasted weather does not materialize, however, flights may be diverted or cancelled needlessly.

Relative Frequency of Flight Disruptions

CAB statistics show that 1.9 percent of air carrier departures at hub airports in CY 1974 were cancelled (Reference 7):

*Appendix A principally taken from Reference 9.

Hub Classification	CY 1974 Departures Scheduled	Scheduled Completed Number	Percent
Large	2,430,647	2,385,410	98.1
Medium	889,498	872,453	98.1
Small	632,410	620,095	98.1
Total	3,952,555	3,877,958	

Average percentage of CY 1973 cancellations was slightly higher with a 2.6 percent cancellation rate. Differences, however, are not significant to affect projected numbers of flight disruptions.

Fromm (Reference 14) determined several years ago that about two-thirds of air carrier cancellations, on an annual basis, were due to weather causes. He also found that air carrier diversions were about one-sixth as frequent as cancellations and that five-sixths of these diversions were caused by weather. These figures seem reasonable today and have been used here to estimate the proportions of cancellations and diversions of air carriers as follows:

weather-caused cancellations = 1.9% x 2/3

= 1.3% of all flights

weather-caused diversions = 1.9% x 1/6 x 5/6

= .3% of all flights

Air Transport World magazine (Reference 15) has for a number of years published CAB data on the on-time arrival performance of the trunk air carriers. Averages for CY 1972, CY 1973, and CY 1974, weighed by numbers of scheduled departures per carrier, were as follows:

Performance Measure	CY 1972 (Percent)	CY 1973 (Percent)	CY 1974 (Percent)
On time or within 15 minutes	74.1	70.1	73.6
Over 15 minutes late	24.2	27.7	24.9
Cancelled flight	1.7	2.2	1.5
Total Percent, Trunk Air Carriers	100.0	100.0	100.0

This data indicates that trunk air carrier delays (over 15 minutes) average 26 percent of scheduled departures over the three-year period. No information is available about the breakdown of these delays by cause, i.e., below-minimum weather, mechanical problems, late equipment, airport congestion. However, delay data submitted by airlines to FAA over a six-year period, 1964-1969, indicates that about 25 percent of delayed arrivals were because of weather (Reference 9). Thus, 26 percent of flights delayed times 25 percent of delays due to weather equals 6.5 percent of all flights delayed because of weather and associated congestion.

Recapitulating, we have for fairly busy air carrier airports:

Weather-Caused Flight Disruptions	Percent of All Flights	Normalized Distribution
Delays	6.5	80
Cancellations	1.3	16
Diversions	.3	4
	8.1	100%

Aircraft Delays (Primary)

An average delay of 45 minutes waiting for the weather to improve was applied to delayed aircraft. Prevailing CAT II weather conditions, usually fog, often persist for several hours, causing rather lengthy delays. After the weather improves (usually to low visibility IFR), the queue which has built up must be reduced, and subsequent flights must take their turn in line. The net effect at a busy airport could easily be to more than double the average waiting time. In slow hours, or at less busy airports, the effect would be much smaller. For this analysis the average delay time is expected to be 1-1/4 hours (45 minutes waiting for the weather to improve plus 30 minutes wait in queue). It is further estimated that 50 percent of the time the aircraft spends waiting for improved weather is taken on the ground at the departure airport.

Aircraft Delays (Secondary)

When an aircraft is delayed for approximately an hour, the flight on which the equipment next goes out (or the next leg of a continued flight) will also be delayed. Equipment turn-around time, however, normally includes slack time, estimated at 15 minutes. By foregoing scheduled slack time at intermediate stops, delayed flights are able to make up some lost time during subsequent flights between city pairs. Nevertheless, passengers boarding later flights would still have waited for the delayed flight to arrive. Passengers waiting at airports on the next one or two legs of the delayed flight would experience practically as much delay as those on the preceding legs. If many intermediate stops are made, only enplaning passengers at later legs will experience minor delays.

There are, however, mitigating factors which influence the cumulative effect of delays. For one thing, delays will sometimes occur in the evening when an aircraft is through flying for the day or has but one or two more trips to make. More important than the foregoing, airlines do not generally schedule flights for the tight turn-arounds suggested above. Typically, departing flights are scheduled on the hour or half-hour for customer convenience. Customer demand also leads airlines to allow aircraft to sit on the ground for extended periods during the day and late evening. The very existence of air carrier morning and early evening traffic peaks attests to the fact that airlines behave in this manner. Finally, at the largest airports airlines can use other aircraft to back up a flight that is delayed. Such reshuffling of aircraft is one of a dispatcher's key functions; he will often dead-head equipment that is temporarily idle to close a gap on a delayed flight.

For all the foregoing reasons, it is an exaggeration to say that a flight delay at the initial leg of the trip will result in cumulative delays to subsequent passengers. In this analysis, it was assumed that 45 minutes of weather-caused delay at hub airports gives rise to 2 hours of passenger delay--45 minutes of weather delay plus 30 minutes in queue plus 45 minutes' delay to subsequent flights.

Diversions

If restrictive weather is forecast to persist for more than 1-1/2 hours, arriving long-haul aircraft usually will divert. Diverting an aircraft is a costly procedure--additional flying time in holding over the original destination airport, in flying to an alternate destination, and in the expense of passenger accommodations. After the weather improves, the aircraft usually must be ferried to another airport before it resumes normal scheduled operations. It is estimated that diversions average one hour extra flying time, including those flights that are diverted prior to entering the terminal area of the original destination airport but excluding overflights which merely proceed to the next destination. Repositioning aircraft required an estimated one-half hour ferry flight. Total additional flight time per diversion thus is 1-1/2 hours.

It is also necessary to consider lost passenger time in assessing diversion impacts. One hour is immediately lost 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 providing passengers meals and overnight lodging. If the return trip is by air, an extra hour of flight time is estimated plus three hours of waiting for the destination airport to open. If surface transportation is used, a similar amount of time is likely to be required to arrange for alternate transportation and for the actual travel time. Total time lost due to a flight disruption thus adds up to five hours per passenger.

Passenger costs to the airlines for flight diversions include the value of time lost and average $30 for extra passenger-handling expenses of food, housing, and return trip fare.

Cancellations

Airlines seldom cancel flights on account of weather unless the weather is extremely poor and is forecast to remain so for several hours.

Given a flight cancellation, the airline must arrange reservations for a future flight if the passenger still desires to go and issue new tickets. As in the case of flight diversions, instances may arise where meals and lodging may be provided if exceptionally long waits are anticipated. These handling expenses are averaged at $2 per passenger for all passengers whether continuing their trip at a later time or not.

As with diversions, aircraft sometimes must be repositioned after a cancellation. An average of one-half hour extra flying time for ferrying aircraft is assumed (the same for diverted aircraft) and it is estimated that one-third of cancelled aircraft must be repositioned. Averaged for all cancellations, this yields 10 minutes extra flying time per cancellation (one-half hour applied to one-third of the cancellations).

Airlines also are subject to losses of passenger revenue because some passengers may shift to other means of transportation and others may cancel their trip. The decision to cancel or not is influenced by many factors including trip length, whether the cancelled flight is the outbound or return trip, the expected duration of below-minimum weather, the availability of alternative means of transportation, and the purpose of the trip.

Domestic airline passenger trip lengths average about 700 miles (Reference 9). (International trips are seldom cancelled.) At 10 cents per passenger mile, revenue per trip averages $70. With revenue retention rate of 80 percent, the revenue loss attributed to a cancellation averages about $14 per passenger.

Revenue losses when flights are cancelled are offset by savings in direct aircraft operating costs of the potential flight. The average duration of a trunk air carrier aircraft flight in FY 1975 was 1.25 hours. At $840 an hour for typical airline operating costs, this equals $1,050 in operating costs saved.

Passengers waiting for flights that were later cancelled may have already spent two hours at the airport waiting for the weather to improve. After the weather improves, passengers continuing their trips by air must find another flight going their way and get reservations. This can easily add three hours of additional delay. Assuming a total of 5 hours on the average when flights are cancelled and applying this delay to 80 percent of cancelled passengers who elect to continue their trips by air gives an average of 4 hours of delay per cancelled passenger. These long delay times may seem excessive, but it should be noted that airlines ordinarily do not cancel flights unless the destination airport (or if the weather is bad enough, the departure airport) is forecast to be below minimums for a considerable period of time. If closures of shorter duration are forecast, they will usually delay on the ground at the departure airport.

Secondary Effects of Diversions and Cancellations

When an aircraft is diverted, it will frequently result in a cancellation of the following trip on which the aircraft was supposed to depart. In this study it was estimated that one-half of diversions result in subsequent cancellations. This estimate is consistent with the methodology in Reference 9 and reasonably close to estimates used in Reference 5. In both cases data was consistent with fragmentary information obtained from a couple of airlines. A similar assumption was made with respect to aircraft that cancel because of below-minimum forecasts for the destination airport.

APPENDIX B

Derivation of Flight Disruption Costs

Effects of weather-related flight disruptions cause aircraft to be delayed both on the ground and in flight. Repositioning aircraft because of flight diversions requires a ferry flight, and subsequently cancelled aircraft may spend some time waiting on the ground until final cancellation.

Aircraft operating costs, specifically air carrier expenses as they totally comprise the potential benefits, are quite diverse depending on aircraft type and whether these are air or ground costs. Cost and fleet size data (as of 4/1/75) have been updated from CAB data (Reference 16) to reflect increasingly higher operating costs. These are presented in Table B-1. Costs include crew, fuel, oil, insurance, and maintenance. Average costs are adjusted for airborne, ground, and weighted combination of the two. Operating costs will vary according to the type of flight disruption encountered--a delay, diversion, or cancellation--as each requires varying amounts of airborne and ground time.

Besides aircraft operating costs, the cost of passenger time lost must also be accounted for, estimated at $12.50 an hour. This estimate agrees with the value of passenger time used in similar benefit/cost studies for Category I ILS, Air Traffic Control Towers, and Airport Surveillance Radars by the Office of Aviation System Plans. All of these studies have been coordinated within FAA and with aviation industry organizations.

<u>Delay Costs</u>

Airline delay costs equal 50 percent of 45 minutes per delayed aircraft (one-half of $760) plus 30 minutes for queue reduction (one-half of $970).

Passenger delays, primary plus secondary effects, equal 2 hours per passenger (45 minutes of weather delay plus 30 minutes queue reduction plus 45 minutes secondary effects). At $12.50 per hour, this comes to $25 per passenger, which when multiplied by the number of deplaning passengers (n) yields the total costs of passenger delay. The total cost per delayed air carrier aircraft is estimated to be:

$$\$25n + \$865.00$$

TABLE B-1

Air Carrier Average Operating Cost/Hour

Type	No. Fleet	Cost/Hour Airborne	Ground	Combination
747	98	$2,475	$1,870	$2,000
DC-10	114	2,000	1,560	1,645
L-1011	68	2,000	1,560	1,645
DC-8/61/63	87	1,100	920	955
707/720	313	900	707	800
DC-8	124	900	707	800
727	759	900	707	800
990	6	900	707	800
737	151	690	565	600
DC-9	333	690	565	600
BAC-11	31	690	565	600
Turboprop	223	450	320	400
Weighted Average		$ 970	$ 760	$ 840

Air carrier cancellation and diversion costs are now developed in accordance with the assumptions in the previous section.

Cancellation Costs

Per Aircraft	
Repositioning aircraft (1/6 of $840)	$ 140.00
Less direct operating savings (1.25 hours at $840)	(1,050.00)
Total	($ 910.00)
Per Passenger	
Extra handling expense	$ 10.00
Revenue loss	70.00
Less revenue recovered (at 80%)	(56.00)
Lost time (4 hours at $12.50)	50.00
Total	$ 74.00

One-half of the cancellations level to subsequent cancellations so that the cost associated with an air carrier cancellation is:

$$1\tfrac{1}{2}(\$74.00n - \$910.00)$$

or

$$\$111n - \$1,365.00,$$

where n is the number of deplaning passengers.

Diversion Costs

Per Aircraft

In-flight delays (1 hour at $970)	$ 970.00
Repositioning aircraft (1/2 hour at $840)	420.00
Total	$1,390.00

Estimating that one-half of all diversions lead to subsequent cancellations, the cost of an air carrier diversion is:

$$\$92.50n + \$1,390.00 + \frac{1}{2}(\$111n - \$1,365.00)$$

or

$$\$148n + \$707.50,$$

where n is the number of deplaning passengers.

Total estimated costs associated with weather-caused disruptions of air carrier flights can now be determined by weighting the cost of each type of disruption by its proportional frequency of occurrence (above) and combining costs as follows:

Disruption	Cost Equation	Weight
Delay	$ 25n + $ 865.00	0.80
Cancellation	111n - 1,365.00	.16
Diversion	148n + 707.50	.04
All Disruptions	$43.68n + $ 501.90	1.00

The average cost of an air carrier flight disruption is estimated to be:

$$\$44n + \$502,$$

where n is the number of deplaning passengers.

APPENDIX C

Safety Benefits

The treatment of accrued safety benefits of aircraft operating under approach and landing aid (ALA) guidance always deserves paramount attention. Consideration for the necessity of an ALA, however, must be weighed in accordance with current air traffic control regulations. That is, in light of existing regulations, aircraft approaches and landings in the absence of facility aids are already deemed to be safe. The existence of ALA's, on the other hand, would maintain equivalent levels of safety but under reduced weather minimums. The net effect is to reduce aircraft delay and increase airport capacity without compromising safety. Although this is the approach taken here, it is not applicable in all situations.

For instance, only nonprecision approach guidance, such as a localizer and middle marker, is available on runways without ILS. In this case, highly precise approach guidance offered by an ILS would benefit all suitably equipped aircraft. Specifically, in the case of Category I systems, safety benefits accrue to all ILS-equipped aircraft including those executing approaches during nonprecision IFR and visual approach weather.

Although this reasoning is somewhat applicable to Category II ILS systems, incremental safety benefits for landing minimums below Category I operation are limited to that phase of approach having a ceiling of 200 feet and visibility of 1/2 mile, and a 100-foot DH and runway visual range of 1,200 feet--the difference in landing minimums ascribed to Category I and II ILS operations. As the components of each system are similar except for the addition of an inner marker and standby equipment capabilities of the Category II system, all Category II-equipped aircraft operating above minimums of 200-1/2 are assumed to realize similar benefits. Benefits provided by the inner marker would aid only those aircraft operating below CAT I minimums as they are about 1,000 feet from the end of the runway--well below the decision height for CAT I operations.

The FAA report, Preliminary Analysis of Civil Aviation Accidents January 1974-December 1972 (Draft) (Reference 13) prepared by MITRE Corporation, documents the results of a comprehensive study of civil aviation accidents that occurred within the United States during a nine-year period. In total, approximately 46,000 accidents were identified through National Transportation Safety Board accident reports throughout the study period, of which 29,000 occurred during normal operating conditions. Further analysis of the data identifies 18,600 landing accidents during normal operating conditions, of which 564 fatalities resulted from those public accidents involving 5 or more fatalities (19 air carrier and air taxi accidents). Examining the accident briefs, no conclusive Category II preventable accidents were identified involving appropriately equipped aircraft for Category II approaches and landings.

Nevertheless, a convincing argument for safety can be made on the basis of attributing Category II ILS to the prevention of accidents having indeterminable causes. Therefore, Appendix D derives quantifiable benefits for accidents that may be "ILS preventable."

APPENDIX D

Derivation of Safety Benefits

Simpson (Reference 13) recently completed a detailed analysis of civil aviation accidents occurring between January 1964 and December 1972. One section of his report describes landing accidents that may have been prevented by a precision approach over this time period. Data was obtained by directly searching the entire NTSB data base for accidents which happened under circumstances where it would be hypothesized that at least some of the accidents might have been avoided if precision approach facilities had been available and used. A number of crashes in IFR weather were also identified as having taken place during precision approaches (41 accidents). The report, however, is inconclusive as to whether these accidents could have been avoided through the use of improved ATC facilities. The benefits of landing accidents developed in this appendix are based on Simpson's statistics.

Landing accidents occurring from January 1964 to December 1972 that may have been prevented by a precision approach are presented in Table D-1.

TABLE D-1

Landing Accidents That May Have Been Prevented
by a Precision Approach
January 1964 through December 1972

	Accidents/Fatalities		
	Nonprecision Approach	Visual Approach	Total
Air Carrier	8/152	2/143	10/295
Small Air Taxi	20/43	5/6	25/49
Corporate/Executive	13/29	1/1	14/30
Small General Aviation	42/50	61/31	103/81
Total	83/274	69/181	152/455

According to Simpson, about 10 percent of the preventable landing accidents occurred in weather below CAT I but above CAT II weather minimums. Taking a conservative approach, we attribute all preventable accidents occurring in CAT II weather to be preventable by Category II ILS. Benefits for preventable accidents from Category I ILS have already been accounted for in the Category I ILS criteria study (Reference 9). Therefore, by taking 10 percent of the total landing accidents, above, we obtain the number of preventable accidents and fatalities below (Table D-2):

TABLE D-2

Number of Preventable Accidents and Fatalities

User Group	Average Preventable Accidents	Average Preventable Fatalities	Fatalities per Accident
Air Carrier	1	29.5	29.5
Air Taxi	3.9	7.9	2.0
General Aviation	10.3	8.1	.8

According to Reference 9, 73 percent of air carrier instrument approaches are precision approaches as compared to 53 percent for air taxi and 38 percent for general aviation. Applying these percentages to the total number of instrument approaches performed by each aircraft category from 1964-72, we ascertain the number of precision approaches for each during the period. As there is no explicit data on preventable precision approach accidents, it is assumed that they occur with the same frequency as preventable nonprecision approach accidents.

TABLE D-3

Preventable Precision Approach Accident Rates
by User Group
1964-72

User Group	Precision Approaches	Instrument Approaches	Number of Precision Approaches	Preventable Approach Accidents*	Approaches per Accident
Air Carrier	73%	7,094,000	5,179,000	1	5,179,000
Air Taxi	53%	810,000	429,000	3.9	110,000
General Aviation	38%	3,454,000	1,313,000	10.3	127,000

*from Table D-2

Accident costs include loss or damage to property and loss or injury to human life. Aircraft replacement costs average about $6 million for air carrier aircraft, $200,000 for air taxi aircraft, and $50,000 for general aviation aircraft. As approach accidents often result in total destruction of the aircraft, it is estimated that loss or damage to aircraft averages 90 percent of replacement cost in these instances.

Aircraft accident fatalities have been costed at $300,000 each. This estimate is consistent with other benefit/cost analyses conducted by FAA. The basic data was obtained from the Civil Aeronautics Board and is based on non-Warsaw payments during the period 1966 to 1970 projected from the base period to 1975.

Estimated approach accident costs are shown in Table D-4. The value of lives lost was determined by multiplying the value of a life ($300,000) by the average fatalities per accident given in Table D-2. As data on number of injuries in accidents of this kind is not readily available, this factor has been omitted; accident costs are underestimated to this extent.

TABLE D-4

Preventable Precision Approach Accidents
by User Group

User Group	Aircraft Losses	Value of Lives Lost	Average Cost per Accident
Air Carrier	$5,400,000	$8,850,000	$14,250,000
Air Taxi	180,000	600,000	7,800,000
General Aviation	45,000	240,000	285,000

Dividing accident costs from Table D-4 by average number of precision approaches between accidents from Table D-3 gives the average "risk cost" per precision approach. This cost is a measure of the benefit that a Category II ILS could provide by preventing accidents of this type. These benefits are given in Table D-5.

TABLE D-5

Benefits of Preventing Precision Approach Accidents
by User Group

User Group	Approaches per Accident	Average Cost per Accident	Potential $ Benefits per Approach
Air Carrier	5,179,000	$14,250,000	$2.75
Air Taxi	110,000	780,000	7.09
General Aviation	127,000	285,000	2.24

Taking $2.75 for each air carrier instrument approach, $7.09 for each air taxi instrument approach, and $2.24 for each general aviation instrument approach, we can estimate the annual dollar value of potential safety benefits.