AN EVALUATION OF APPROACH AND LANDING FACTORS INFLUENCING AIRPORT SAFETY

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Abstract

This exploratory study examined some of the factors that influence approach and landing safety at principal international airports, especially as regards the influence on risk of fully-functioning precision terminal approach and guidance equipment. The objective was to quantify the degree to which these factors are associated with the risk of an accident. Accident and movement data for 557 ICAO Principal Airports for decade 1984-1993 were evaluated for the risk analysis. The accident sample comprised 132 hull loss occurrences. The study concludes that precision approaches confer a risk advantage of about five over non-precision approaches absent other factors on a world-wide basis. The study also concludes that, when stratified according to ICAO region, the risk increase associated with flying non-precision approaches compared with flying precision approaches varies from three-fold to nearly eight-fold. The lack of Terminal Approach Radar (TAR) increased risk among the study population three-fold compared to approaches with TAR present. However, this threefold increase in risk may potentially be attributed to the risk associated with non-precision approaches as in certain regions a correlation exists between the presence of radar and the presence of precision approach aids.

Abbreviations and Acronyms

ACI	Airports Council International
ADREP	Aviation Data Reporting Program (ICAO)
AFR	African Region of ICAO
AIP	Aeronautical Information Publication
APA	Asia-Pacific Region of ICAO
ARP	Aerodrome Reference Point
ATIS	Automatic Terminal Information Service
BASI	Bureau of Air Safety Investigation
CFIT	Controlled Flight Into Terrain
EEU	Eastern European Region of ICAO
EUR	European Region of ICAO
FAA	Federal Aviation Administration
FSF	Flight Safety Foundation
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
LAM	Latin American Region of ICAO
LOC	Localizer
MID	Middle Eastern Region of ICAO
NAM	North American Region of ICAO
NDB	Non-Directional Beacon
NLR	National Aerospace Laboratory
NM	Nautical mile
NOTAM	Notice To Airmen
NTSB	National Transportation Safety Board
PAPI	Precision Approach Path Indicator
PAR	Precision Approach Radar
RLD	Netherlands Department of Civil Aviation
RMS	Records Management Systems
RR	Risk Ratio
STAR	Standard Instrument Arrival Route
TAR	Terminal Approach Radar
VAG	Visual Approach Guidance
VASIS	Visual Approach Slope Indicator
VOLMET	Meteorology Information for Aircraft in Flight
VOR	VHF Omnidirectional Range

1 Introduction

Safety data from many studies show that approach and landing phase accidents account for a significant proportion of fatal air transport accidents. Approximately 50% of the world jet aircraft fleet accidents occurred in these flight phases and accounted for 43% of all fatalities(1). Not surprisingly one of the Flight Safety Foundation's (FSF) current priorities focuses on reduction of approach and landing accidents. As the majority of accidents occur in the vicinity of airports, public awareness is bound to increase. Attention to safety on and around airports increased substantially following the tragic El Al Airlines B-747 accident near Amsterdam's Schiphol Airport in October, 1992. The topic of this study is approach and landing safety and its interrelationship with airport terminal area guidance capabilities. The study was carried out by the FSF, its subcontractor, Records Management Systems (RMS) Incorporated, and partner National Aerospace Laboratory NLR.

The accident record and literature (e.g. Ref. 1-9) suggests, in general, that approach and landing accidents do not have a single cause; instead a series of contributory factors is nearly always involved. Such factors can be related to one or more of the following categories, including flight crew, environment, airport, ATC, aircraft, air carrier, organizational, and regulatory variables. Note that many of these factors are not directly controllable by the airport, since they are "owned" by another party. For example, the air carriers have control of the aircraft equipment inventory and its condition, as well as the quality and thoroughness of the selection, training and supervision of flight crews in appropriate procedures.

Recently there has been much industry debate about the risk factors allied to airport safety. Factors such as flying into airports surrounded by mountainous terrain, lack of radar coverage, absence of visual approach guidance, limited runway lighting, and non-precision approaches are sometimes associated with an increased operational risk(10). There has been much focus on the employment of *step down* approach paths in the case of non-precision approaches. The latter situation may inhibit the establishment of a desired stabilized final approach. Indeed some operators have been constructing non-precision approach procedures, where possible, in accordance with established stabilized approach criteria for many years. Some accidents have also involved pilots making errors concerning confusion about which altitude to maintain prior to passing a particular fix. Non-precision approach procedures with extremely shallow descents, as low as one and a half degrees, have also been implicated in some occurrences(3).

This investigation focuses on examining airport and approach factors that are postulated to be associated with an increased operational risk. As the degree to which these factors are associated with the risk of an accident has not necessarily been quantified elsewhere, this theme is central to the current study.

1.1 Study Objectives

The central research question of this exploratory study was to quantify the relative risks of approach and landing operations with or without precision guidance at typical international Principal Airports. An additional task, dependent on the quality of the available data, was to quantify the degree of association for some of the other factors that may influence the risk of an approach and landing accident. A more comprehensive account of the study is presented in Ref. 11.

2 Risk Ratio Estimation

It is not sufficient to conclude from accident data alone that if a certain factor occurs in a significant fraction of the accident sample that it must be an important element of the events leading to the accidents. The equivalent fraction for all *non-accident* flights should be determined to enable assessment of the significance of the fraction found in the accident sample. Ideally, the available data would enable a full comparison between the accident data and the movement data. This involves establishing, in both accident and non-accident flights, the occurrences of all the factors of interest.

An estimate of the risk of crashing with a particular factor present was accomplished through the development of a *risk ratio* (RR). This risk ratio is represented by the following expression

$$RR=\frac{a/A}{f/N}$$

where

a = numbers of occurrences of a factor in accidents
A = total number of accidents
f = number of occurrences of the factor in non-accident flights
N = total number of movements.

The risk ratio magnitude provides some insight on the relative *association* (NB not *causation*) of a particular factor on the risk of an accident. A risk ratio of 1 means there is no significant difference in risk with the risk factor present and with it absent. A value greater than one indicates a greater risk. The larger the value of the RR, the stronger the association between the risk factor and the accident risk. The value itself indicates the magnitude of that risk. These relationships can then be tested for statistical significance and 95% confidence intervals calculated for the risk estimates. The 95% confidence interval provides insight on what the range of that risk might be as the RR is not absolute since its estimation is based on a sample. If the 95% confidence interval does not include the value of one, then the risk ratio is deemed to be statistically significant at the 0.05 level. The statistical test conducted for the bivariate analyses was based on the Chi square test for 2x2 tables. ***It should be noted that a positive association between a risk factor and approach accidents does not prove causation. It means only that a demonstrated association exists.***

The calculation of the risk ratio could only be accomplished for those variables where data existed for the prevalence of the factor among all airports included in the study sample. Initially, this evaluation strived to include factors other than *approach* variables in recognition of the multiple factor paradigm of accident causation. Denominator information {f/N} for factors such as pilot experience, pilot to pilot communication, etc. is not readily available for the entire commercial aircraft fleet. Therefore, the data gathering focused on airport and approach data such as approach type (precision and non-precision), approach lighting, surrounding terrain, approach radar services, standard arrival procedures (STARs) and visual approach path guidance (VASIS/PAPI).

3 Methodology

The overall approach employed in this study was to:

(a) identify a sample of approach and landing accidents using world-wide sources;
(b) identify potential approach and landing accident factors using accident narratives and related literature;
(c) compile airport movement and necessary non-accident data demanded by the risk ratio evaluation; and
(d) analyze the information gathered from these tasks in the context of the central research question. This involved risk ratio estimation.

The following sections provide additional detail of the methodology used.

3.1 Accident Data Sources

Searches were conducted on the following databases/sources for accident data:

- AirClaims
- Allied Signal (formerly Sundstrand) CFIT database(4)
- Australian Bureau of Air Safety Investigation (BASI)
- U.K. Civil Aviation Authority (CAA)(12)
- Flight International(13)
- FSF/ICAO CFIT Task Force database
- Fokker Aircraft
- ICAO ADREP database
- Lawrence Livermore National Laboratory(14)
- NLR accident database
- U. S. National Transportation Safety Board (NTSB)
- Netherlands Aviation Safety Board
- Robert E. Breiling Associates, Inc.(15,16)
- Skandia International.

These sources provided sufficient data to enable compilation of a virtually complete listing of all reported accidents that fulfil the qualification criteria presented in Section 3.2. With the exception of a few U.S. and European complete accident reports, accident summaries/narratives provided by the referenced sources above were generally employed to compile specific data on each of these accidents.

3.2 Accident Sample and Inclusion Criteria

Several criteria were used to establish the accident sample analyzed in this investigation, namely

(a) the accidents occurred during initial and final approach, landing, flare, roll-out after touchdown, and go-around on a Principal Airport defined in Section 3.3.1.
(b) The accidents occurred during the period 1984 through 1993.
(c) The accident resulted in loss of the aircraft hull.
(d) The accidents involved fixed wing aircraft; turbojet, turboprop and piston engined aircraft; and aircraft in all weight categories.
(e) The accident flights had the following characteristics
    - engaged in public transport
    - world-wide - no geographical restriction
    - freight, passenger and positioning flights
    - scheduled and non-scheduled flights
    - international and domestic flights.

    Excluded were training flights, experimental/test flights, aerial application/survey flights and construction work flights
(f) Accidents due to sabotage, terrorism and military actions were excluded.

After application of these criteria, the final accident sample consists of 132 accidents, see Appendix A.

3.3 Airport Data

A sample group of airports for which accident, airport specific, and movement data could be collected was required. Details are given below.

3.3.1 Principal Airports

The airport sample employed consists of the world's most important international airports, and is based primarily on *ICAO Principal International Airports*. The sample was augmented to include major U.S. and European airports not fully meeting the ICAO inclusion criteria. The final *Principal Airports* sample consists of 557 airports, see Ref. 11 for full details.

Movement data (i.e. number of take-offs and landings) for the principal airports were collected from ICAO, Airports Council International (ACI) and the FAA. Missing data entries were supplemented by interpolation and extrapolation techniques(17).

3.3.2 Airport Specific Data

Data sources were principally the Jeppesen Airways Manual, national Aeronautical Information Publications (AIP) and navigational documentation published by some major airlines.

The data is considered biased in the sense that it represents a July 1995 snapshot of available resources at the principal airports and it is assumed that this adequately describes the situation throughout the 1984-93 time span. This assumption seems plausible when the time and investments required to significantly upgrade airport facilities is considered.

Note also that possible unserviceability of technical facilities in the 1984-1993 time frame is not accounted for in the data. On an average day it was verified by checking NOTAMs for the principal airports that less than two percent of the approaches were compromised by the unserviceability of approach aids. It is assumed that any variations would not significantly influence the conclusions of the study.

3.3.3 Airport and Runway Variables

In this study ILS, MLS and PAR are considered precision approaches, whereas approaches with lateral guidance from LOC, VOR, NDB or GPS are considered non-precision.

Airport variables describe the airport as a whole and hold true for all runway-ends at that particular airport, whereas runway variables describe the (approach to the) individual runway-end.

Airport data collected were:

(a) The presence of significant terrain features in the vicinity of the airfield. Significant terrain in this context is defined as any spot elevation or obstacle more than 2000 feet above the aerodrome reference point (ARP) elevation within a circle of 6 NM around the ARP or 6000 feet within a circle of 25 NM around the ARP. A similar definition is also used by Jeppesen to determine whether or not to include colored contours on its approach plates(18).
(b) The availability of the latest weather observations to the pilot via ATIS or VOLMET.
(c) The presence of Terminal Approach Radar (TAR).
(d) The presence of published arrival routes from the airways to the final approach fixes of the instrument approaches at the airfield.
(e) Number of movements per annum, averaged over the 1984-1993 time frame.

For every runway-end, data collected were:

(f) The presence of an approach lighting system.
(g) The presence of any visual glidepath indicating system like PAPI or VASIS.
(h) The most precise published instrument approach procedure to the runway-end.
(i) The absolute number of landings on the runway-end. This is derived from the number of movements to the airfield, distributed over the runway-ends at that airfield where actual operational experience, prevailing winds, published preferential runway usage and runway-end approach facilities were used to determine this distribution.

4 Results and Discussion

4.1 Univariate Analysis

Table 1 presents the distribution of the accidents rates among the major ICAO regions. The average rate was slightly more than 10 accidents per million movements. The highest rates were for Latin America (LAM) and (AFR). North America (NAM) and Europe (EUR) had lowest accident rates.

Table 1 Accident Distribution by ICAO Region

ICAO REGION	No.	ACCIDENTS/1 MILLION MOVEMENTS
AFR	17	30.21
APA	19	18.28
EEU	5	20.55
EUR	26	9.51
LAM	34	32.36
MID	3	11.40
NAM	28	4.08
TOTAL	132	10.35

Table 2 Type of Approach Flown

TYPE APPROACH	No.	%
Non-Precision	27	20.5
Precision	35	26.5
Unknown	57	43.2
Visual	13	9.8

Table 2 displays the distribution of the type of approach flown for the accident sample. The data was unknown in 43% of the cases. Among those where approach status is known the distribution of precision and non-precision is quite similar.

Table 3 displays the distribution of the presence or absence of airport related factors deemed to be potentially important in these approach accidents. Approach lights were present for at least 58 (44%) of the accidents, while 61 of the accidents (46%) occurred while approaching runways with visual approach guidance systems in place. It should be noted that the presence of approach lights could not be determined for 51 of the accidents (39%), and the presence of VASI/PAPI could not be determined for 39 of the accidents (30%). This limitation should be considered when interpreting these results.

Table 3 Airport Related Factors

Airport-Related Factors	% YES	% NO	% UKN
Approach Lights	43.9	17.4	38.6
STAR	73.5	25.8	0.8
Approach Radar	67.4	31.8	0.8
High Terrain	28.0	71.2	0.8
VASI/PAPI	46.2	24.2	29.5
ATIS/VOLMET	81.4	21.2	0.8

4.2 Bivariate Analysis

Table 4 presents the findings from the evaluation of the association of airport related risk factors and approach accidents adjusted for the number of movements involving that particular risk factor. Recall from Section 2 that a *RR larger than one indicates a greater accident risk with the factor under consideration present. However, the lower limit of the 95% confidence interval must be greater than one for the risk to be considered statistically significant.* The movement ratio (number of non-risk movements divided by risk factor movements) provides some insight to the ratio of movements with the risk factor present compared to those without the risk factor present. A high value denotes a large difference while a lower value denotes that the number of movements with the risk factor present and not present are more similar.

It should be recognized that the results presented below treat the TAR, approach status, and ATIS/VOLMET variables as independent factors. It is likely, however, that these factors are closely related and not independent since many large airports provide all these services. The reader should keep these limitations in mind when reviewing the results.

Table 4 shows that the risk of crashing while flying a non-precision approach is five times greater than that associated with flying a precision approach. If TAR is not available, the associated risk of crashing is three times greater than that when it is present. If there is no standardized approach routing, the risk is about one and a half times that when STARs are available. If there is no ATIS or VOLMET, the associated risk of crashing is almost four fold that if current airport weather information is available. When interpreting the latter finding it should be considered that correlations may exist with other factors. The presence of high terrain, the lack of VASIS or PAPI, and the lack of approach lights were not associated with a greater risk of crashing within this population.

Table 5 looks at the risk associated with non-precision approaches stratified by each ICAO region. All the regions had a greater positive association between non-precision approaches and the risk of crashing while on approach than for aircraft flying precision approaches - ranging from a threefold increase in risk to almost an eightfold increase of risk depending on the region. Note also the movement ratio which gives some indication of the relative frequency of non-precision approaches compared to precision approaches. Europe (EUR) had the highest movement ratio of 16.6 while Latin America (LAM) had the lowest with a value of 3.2.

Table 6 shows the percentage of ILS approaches made with the assistance of approach radar, stratified by region. From Table 6 it can be concluded that in the North America (NAM) region, virtually no ILS approach is made without the presence of a TAR. The Africa (AFR) and LAM regions show that a significant number of airports offer a precision approach facility but do not have a TAR. In developed regions of the world (Europe and North America) an ILS installation in most cases is associated with a TAR.

Table 7 provides the risk ratio of the association between TAR and accidents. Europe and Asia-Pacific (APA) show a statistically significant no TAR risk ratio of three. As noted above in these latter regions, the presence of a TAR is often combined with the presence of an ILS (Table 6) while in the regions with low correlation between ILS and TAR, namely Africa and Latin America, the TAR risk ratio is considerably lower. It seems likely that the risk ratio for no TAR is correlated to some extent with the risk ratio associated with a non-precision approach.

Both AFR and LAM have no demonstrated increase of risk when TAR is not present. It is interesting to note that both of these regions have TAR movement ratios which indicate an equal number of TAR and none TAR movements during the study period.

It is also interesting to note that the North America region has a very high TAR movement ratio of 44 which indicates that vast majority of approaches in the NAM region are flown with TAR guidance.

Table 4 Risk Ratio for Airport Related Risk Factors, All ICAO Regions

Airport-Related Risk Factor	Risk Ratio	95% Confidence Intervals	Risk Factor Accidents	Non Risk Factor Accidents	Risk Factor Movement	Non Risk Factor Movement	Movement Ratio
Non Precision Approach	5.2	$3.9<RR<6.9$	27	35	1,037,947	11,403,061	11
No Term. Appr. Radar	3.1	$2.4<RR<4.0$	42	89	1,322,944	11,429,765	8.6
High Terrain	1.2*	$0.9<RR<1.6$	37	94	2,852,450	9,588,652	3.4
No STAR	1.6	$1.2<RR<2.1$	34	97	2,122,025	10,630,685	5.0
No ATIS/ VOLMET	3.9	$2.8<RR<5.5$	28	103	693,875	12,058,835	17.4
No Approach Lights	1.4	$1.0<RR<2.0$	23	58	2,559,278	10,191,932	4.0
No VASIS/PAPI	0.8*	$0.6<RR<1.1$	32	61	5,294,677	7,458,033	1.4

Note: * denotes that the risk ratio value was not statistically significant at the 5% level.

Table 5 Risk Ratio for Non Precision Approaches Stratified by ICAO Region

ICAO Region	Non Precision Risk Ratio	95% Confidence Intervals	Precision Accidents	Non-Precision Accidents	Precision Movements	Non-Precision Movement	Movement Ratio
All Regions Combined	5.2	$3.9<RR<6.9$	35	27	11,403,061	1,037,947	11
AFR	3.6	$2.1<RR<41.7$	3	5	438,193	92,031	4.8
EEU	n/a	n/a	2	0	222,743	20,080	11.1
APA	7.7	$4.5<RR<13.1$	3	5	938,480	83,062	11.3
EUR	4.1	$1.8<RR<9.8$	13	4	2,552,976	153,408	16.6
MID	n/a	n/a	1	0	235,666	22,730	10.4
LAM	3	$2.0<RR<4.4$	3	7	765,238	236,313	3.2
NAM	5.8	$3.0<RR<11.0$	10	6	6,249,763	430,321	14.5

Note: Risk ratio values for EEU and MID regions were not included in this listing since they did not have any non-precision accidents that were identified in this study. They were included in the aggregate calculation for all regions.

Table 6 Percentage of ILS approaches conducted with TAR assistance

REGION	EUR	EEU	NAM	AFR	MID	LAM	APA	Total
%	82%	91%	97%	36%	78%	53%	82%	82%

Table 7 Risk Ratio for Terminal Approach Radar Stratified by ICAO Region

ICAO Region	No TAR Risk Ratio	95% Confidence Intervals	No TAR Accidents	TAR Present Accidents	No TAR Movements	TAR Present Movement	Movement Ratio
All Regions Combined	3.1	2.4<RR<4.0	42	89	1,322,944	11,429,765	8.6
AFR	1.2*	0.8<RR<1.7	11	6	298,844	263,890	1.1
EEU	n/a	n/a	0	5	28,100	215,200	7.6
APA	3.0	1.7<RR<5.5	7	12	126,400	912,980	7.2
EUR	3.5	1.4<RR<8.5	4	21	144,700	2,988,080	17.9
MID	1.3*	0.3<RR<6.5	1	2	66,400	196,783	3.0
LAM	1.2*	0.9<RR<1.6	19	14	505,680	544,982	1.1
NAM	n/a	n/a	n/a	28	152,850	6,707,850	43.9

Note: Risk ratio values for EEU,MID and NAM regions were not included in this listing since they did not have any non-TAR radar that were identified in this study. They were included in the aggregate calculation for all regions.
* denotes that the risk ratio value was not statistically significant at the 5% level.

Table 8 Risk Ratio of High Terrain Around Accident Airport, Stratified by ICAO Region

ICAO Region	High Terrain Risk Ratio	95% Confidence Intervals	High Terrain Accidents	No Terrain Accidents	High Terrain Movements	No Terrain Movement	Movement Ratio
All Regions Combined	1.2*	0.9<RR<1.6	37	94	2,852,450	9,588,652	3.4
AFR	0.4*	0.1<RR<1.5	2	15	165,570	397,164	2.4
EEU	n/a	n/a	1	4	21,050	222,250	10.6
APA	1.0*	0.6<RR<1.9	7	12	367,300	672,080	1.8
EUR	0.9*	0.4<RR<2.1	5	20	581,300	2,151,480	3.7
MID	n/a	n/a	1	2	58,650	204,533	3.5
LAM	0.8*	0.5<RR<1.3	10	23	415,500	635,132	1.5
NAM	1.1*	0.5<RR<2.1	6	22	1,387,850	5,472,850	3.9

Note: Risk ratio values for EEU,and MID regions were not included in this listing since the number of accidents in one or more categories was too small to calculate. They were included in the aggregate calculation for all regions.
* denotes that the risk ratio value was not statistically significant at the 5% level.

Presence of high terrain around an airport did not appear to have a significant impact on risk of crashing compared to airports without high terrain (Table 8). The finding that high terrain is not a risk factor for aircraft approaching airports does not mean it is not an important consideration. It just means that no association between high terrain and increased risk of an accident was shown, based on the data available for this study.

Table 9 lists the risk ratios associated with the absence of STARs at airports where the approach accidents occurred. Only the AFR and NAM regions had risk ratios that were statistically significantly greater than 1 for the absence of STARs.

Table 10 displays the results of the evaluation of the association of visual approach guidance (VAG) and risk of an accident stratified by ICAO region. There were no significant increases in risk associated with an absence of VAG. These results should not be interpreted to mean that VAG is not needed. It means that in this study, no demonstrated association was shown between accident risk and the presence or absence of VAG. The lack of association may be due to the fact that most of these accident aircraft were conducting instrument approaches. The main value of VAG may be for aircraft that are conducting visual approaches. Other correlations may exist, for example if stratified across approach type.

4.3 Data and Study Limitations

This study is subject to limitations that need to be considered when interpreting the results. While some have already been addressed, it is important to summarise the main points.

(a) *Limited Sample Size* - While the 132 accidents analyzed represent the majority of commercial aircraft accidents that occurred on approach and landing on Principal Airports during the period under consideration, the small number of events limited the analysis to very simple single- and two-factor analysis.

(b) *Missing Data* - Many accidents had factors that were coded as unknown since the details were not available in the summary report. Missing data not only escalated problem (a) above, but may represent a serious problem since its influence on the results of the study is unknown. However, this study was exploratory in nature.

(c) *Accident Analysis* - An effort was made to assess the influence of factors other than type of approach on accident risk in recognition of the multiple factor paradigm of accident causation. This evaluation, however, was limited by both the limited size of the accident sample and the paucity of data for some more important factors that past experience show are significant in accident causation.

5 Conclusions

For the accident sample analyzed herein, the following conclusions can be drawn:

(a) Latin America and Africa ICAO regions demonstrated the highest approach and landing accident rates, followed by Eastern Europe. Western Europe and North America had the lowest rates, the rate for North America being 7 times lower than that in Latin America.

(b) On a world-wide basis, there appears to be a five-fold increase in accident risk among commercial aircraft flying non-precision approaches compared with those flying precision approaches.

(c) When stratified by ICAO region, the risk increase associated with flying non-precision approaches compared with those flying precision approaches ranges from three-fold to almost eight-fold, depending on the region.

(d) The lack of TAR increased risk among the study population three-fold compared to approaches with TAR present. To some extent this threefold increase in risk may be attributed to the risk associated with non-precision approaches as in certain regions a correlation exists between the presence of radar and the presence of precision approach aids.

(e) World-wide, presence of high terrain around an airport did not appear to have a significant influence on accident risk compared to airports without terrain. This implies that terrain is not necessarily a prerequisite for the approach accidents to occur: however, this does not mean that high terrain is not an important consideration for aircraft approaching high terrain airports.

(f) Absence of charted procedures for initial arrival to an airport area in the ICAO North American and African regions showed a 1.5 increase in risk of an accident, compared to airports that had STARs.

(g) Though visual approach guidance is deemed an important landing aid, no *association* was demonstrated between the presence or absence of VAG and accident risk for the accident sample considered herein.

6 Recommendations

Based on this study, the following recommendations are considered appropriate, namely

(a) the risk value of flying precision approaches vs non-precision approaches should be conveyed to all operators and airport authorities.

Table 9 Risk Ratio of Absence of STARs, Stratified by ICAO Region

ICAO Region	STAR Risk Ratio	95% Confidence Intervals	NO STAR Present Accidents	STAR Present Accidents	No STAR Movements	STAR Present Movement	Movement Ratio
All Regions Combined	1.6	1.2<RR<2.1	34	97	2,122,025	10,630,685	5.0
AFR	1.6	1.1<RR<2.3	11	6	224,775	337,959	1.5
EEU	n/a	n/a	0	5	20,950	222,350	10.6
APA	1.8*	0.5<RR<6.8	2	17	60,050	979,330	16.3
EUR	1.8*	0.3<RR<4.5	2	23	184,700	2,548,080	13.8
MID	n/a	n/a	0	3	110,600	152,583	1.4
LAM	0.9*	0.5<RR<1.5	10	23	361,400	689,232	1.9
NAM	1.9	1.1<RR<3.3	9	19	1,159,550	5,701,150	4.9

Note: Risk ratio values for EEU,and MID regions were not included in this listing since the number of accidents in one or more categories was too small to calculate. They were included in the aggregate calculation for all regions.

* denotes that the risk ratio value was not statistically significant at the 5% level.

Table 10 Risk Ratio of Absence of VASI or PAPI, Stratified by ICAO Region

ICAO Region	VASI Risk Ratio	95% Confidence Intervals	NO VASI Present Accidents	VASI Present Accidents	No VASI Movements	VASI Present Movement	Movement Ratio
All Regions Combined	0.8*	0.6<RR<1.1	32	61	5,294,677	7,458,033	1.4
AFR	1.5*	0.6<RR<3.7	3	6	125,954	436,780	3.5
EEU	n/a	n/a	3	0	125,919	117,381	0.9
APA	1.0*	0.2<RR<6.9	1	12	75,906	963,473	12.7
EUR	1.6*	0.9<RR<2.7	8	13	660,190	2,072,589	3.1
MID	n/a	n/a	0	3	26,371	236,811	9.0
LAM	1.3*	0.6<RR<2.7	5	17	189,273	861,359	4.6
NAM	0.9*	0.6<RR<1.3	12	10	4,091,062	2,769,637	0.7

Note: Risk ratio values for EEU,and MID regions were not included in this listing since the number of accidents in one or more categories was too small to calculate. They were included in the aggregate calculation for all regions.

* denotes that the risk ratio value was not statistically significant at the 5% level.

(b) New technologies for providing approach and landing guidance (e.g. GPS) should be reviewed periodically by authorities and air carriers to equip airfields with precision guidance capability where present ground-based equipment is too costly or ineffective, due to siting and/or terrain problems.

(c) International support should be given to reducing the approach and landing risk variances between different ICAO Regions.

(d) The international sharing of accident and incident data should be encouraged, to facilitate addressing safety problems quickly and effectively.

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Appendix A Accident Sample Listing

DATE	AIRPORT	AIRCRAFT TYPE
03/13/84	Ernesto Cortissoz, Colombia	C-46
04/26/84	Bremen, Germany	B-727
06/16/84	Sanaa INTL, Yemen	IL-18
08/05/84	Zia Ul Hak, Bangladesh	F-27
09/18/84	Schwechat, Austria	Metro
10/17/84	Arlanda, Sweden	Metro
10/22/84	Kennedy INTL, Bolivia	CV-440
11/10/84	King, Virgin Islands	Lear 24
12/20/84	Dar es Salaam INTL, Tanzania	DHC-6
12/30/84	Bali INTL, Indonesia	DC-9
01/01/85	Kennedy INTL, Bolivia	B-727
01/09/85	Kansas City Downtown, USA	L-188
02/07/85	Le Bourget, France	CL-600
02/19/85	Bilbao, Spain	B-727
04/11/85	Salta, Argentina	HS-125
04/15/85	Phuket INTL, Thailand	B-737
08/02/85	Dallas Fort Worth INTL, USA, TX	L-1011
12/02/85	Rio de Janeiro Galeao, Brazil	B-747
01/27/86	Ezeiza INTL, Argentina	B-707
01/31/86	East Midlands, UK	SD-360
02/07/86	King Abdul Aziz INTL, Saudi Arabia	B-737
02/21/86	Erie INTL, USA, PA	DC-9

03/20/86	Sam Ratulangi, Indonesia	CASA-212
06/10/86	Cairo INTL, Egypt	F-27
08/31/86	Los Angeles INTL, USA, CA	DC-9
09/14/86	Schiphol, Netherlands	Islander
10/03/86	Sam Ratulangi, Indonesia	Skyvan
10/19/86	Maputo INTL, Mozambique	TU-134
10/25/86	Charlotte Douglas INTL, USA, NC	B-737
12/15/86	Mohamed V, Morocco	HS-125
01/03/87	Port Bouet, Ivory Coast	B-707
01/15/87	Salt Lake City INTL, USA, UT	Metro
03/04/87	Wayne County MET, USA, MI	CASA-212
03/31/87	Kansas City Downtown, USA, MO	PA-32
04/13/87	Kansas City INTL, USA, MO	B-707
05/08/87	Kennedy INTL, Bolivia	DC-6
05/08/87	Eugenio Mar de Hostos, Puerto Rico	CASA-212
05/19/87	Viru Viru INTL, Bolivia	DHC-6
07/31/87	La Aurora INTL, Guatemala	Lear 23
08/31/87	Phuket INTL, Thailand	B-737
09/30/87	La Palma, Canary Islands, Spain	Falcon 20
10/09/87	Memphis INTL, USA, TN	Beech 18
10/19/87	Leeds Bradford, UK	King Air
12/21/87	Merignac, France	EMB-120
01/02/88	Adnan Menderes, Turkey	B-737
01/18/88	William P. Hobby, USA, TX	HS-125
01/19/88	La Plata County, USA, CO	Metro
02/08/88	Hannover, Germany	Metro
02/08/88	4th of February, Angola	B-707
03/04/88	Orly, France	F-27
04/01/88	Kansas City Downtown, USA, MO	Beech 18
04/15/88	Tacoma INTL, USA, WA	DHC-8
05/26/88	Hannover, Germany	F-27
06/16/88	Soekarno Hatta INTL, Indonesia	Viscount
07/06/88	Ernesto Cortissoz, Colombia	CL-44
07/21/88	Murtala Muhammed, Nigeria	B-707
08/02/88	Reykjavik, Iceland	CASA-212
08/31/88	Hong Kong INTL, Hong Kong	Trident
09/09/88	Bangkok INTL, Thailand	TU-134
09/12/88	Welschap, Netherlands	MU-2B
10/17/88	Fiumicino, Italy	B-707
01/08/89	East Midlands, UK	B-737
01/30/89	Lisbon, Portugal	Lear 23
02/19/89	Kuala Lumpur INTL, Malaysia	B-747
02/24/89	Helsinki-Vantaa, Finland	Metro
02/25/89	Toncontin INTL, Honduras	DC-6
03/06/89	Ataturk, Turkey	Metro
03/21/89	Guarulhos INTL, Brazil	B-707
04/03/89	Coronel Fransisco Secada V, Peru	B-737
04/10/89	Chabeuil, France	F-27
06/07/89	Johan Adolf Pengel, Surinam	DC-8
07/11/89	Bole, Ethiopia	B-707
07/19/89	Sioux Gateway, USA, IA	DC-10
07/21/89	Ninoy Aquino INTL, Philippines	BAC 1-11
07/27/89	Tripoli INTL, Lybia	DC-10
08/10/89	Coronel Fransisco Secada V, Peru	DC-8
08/13/89	William P. Hobby, USA, TX	HS-125
09/07/89	Port Harcourt, Nigeria	BAC 1-11
10/21/89	Toncontin INTL, Honduras	B-727
12/26/89	Tri-Cities, USA, WA	JetStream
01/25/90	J.F. Kennedy INTL, USA, NY	B-707
03/21/90	Toncontin INTL, Honduras	L-188
03/27/90	Kabul, Afghanistan	IL-76
05/04/90	New Hanover INTL, USA, NC	Nomad
05/11/90	Cairns INTL, Australia	Citat-1
07/14/90	Khartoum, Sudan	B-707
08/13/90	Cozumel INTL, Mexico	Jet-Comd
08/24/90	Logan INTL, USA, MA	PA-31T
11/14/90	Zurich, Switzerland	DC-9
11/29/90	Des Moines INTL, USA, IA	PA-31T
12/04/90	Jomo Kenyatta INTL, Kenya	B-707
01/11/91	Tancredo Neves, Brazil	Lear 25
02/01/91	Los Angeles INTL, USA, CA	B-737
03/03/91	City of Colorado Springs M, USA,	B-737
03/15/91	Eduard Gomes INTL, Brazil	Lear 35
03/18/91	Brasilia INTL, Brazil	Lear 25
05/09/91	Sam Ratulangi, Indonesia	F-27
05/23/91	Pulkovo, Russia	TU-154
06/17/91	Oscar Machado Zuloaga INTL, Venezuela	G-II
07/11/91	King Abdul Aziz INTL, Saudi Arabia	DC-8
09/03/91	Gustavo Rojas Pinilla, Colombia	AC-690
09/04/91	Kota Kinabalu, Malaysia	G-II
09/14/91	Lic Benito Juarez INTL, Mexico	TU-154
09/16/91	Ernesto Cortissoz, Colombia	Herald
12/17/91	Okecie, Poland	DC-9
01/20/92	Entzheim AB, France	A-320
02/15/92	Mallam Aminu, Nigeria	DC-8
03/24/92	Athens, Greece	B-707
03/30/92	Granada, Spain	DC-9
06/07/92	Eugenio Mar de Hostos, Puerto Rico	CASA-212
06/22/92	Cruzeiro do Sul INTL, Brazil	B-737
07/27/92	Lic Benito Juarez INTL, Mexico	Viscount
07/31/92	Tribhuvan INTL, Nepal	A-310
09/28/92	Tribhuvan INTL, Nepal	A-300
10/04/92	Schiphol, Netherlands	B-747
11/07/92	Sky Harbor INTL, USA, AZ	Sabrejet
11/15/92	Puerto Plata INTL, Dominican Republic	IL-18
11/25/92	Mallam Aminu, Nigeria	B-707
12/10/92	Mariscal Sucre INTL, Ecuador	Sabrejet
12/21/92	Faro, Portugal	DC-10
01/06/93	Charles de Gaulle, France	DHC-8
01/09/93	Indira Gandhi INTL, India	TU-154
01/15/93	Port Bouet, Ivory Coast	B-707
02/27/93	Rio de Janeiro Galeao INTL, Brazil	Lear 31
04/06/93	Natrona County INTL, USA, WY	MU-2B
04/14/93	Dallas Fort Worth INTL, USA, TX	DC-10
07/18/93	Augusto Cesar Sandino, Nicaragua	B-737
08/07/93	Bush, USA, GA	King Air
09/14/93	Okecie, Poland	A-320
11/04/93	Hong Kong INTL, Hong Kong	B-747
12/12/93	Yoff, Senegal	DHC-6
01/09/93	Kansas City Downtown, USA, MO	L-188