Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

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Review of Air Traffic Management-related accidents worldwide: 1980 - 2001

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Summary

The National Aerospace Laboratory NLR has conducted a study to obtain more insight into the historical safety performance of the Air Traffic Management (ATM) system. The research objective of the present study is to quantify the historical safety performance of a number of selected ATM-related accident types. The study was not limited to accidents in which ATM was a causal factor but also covered all accidents that can be related to the ATM system in general.

This paper presents an analysis of ATM-related accidents involving civil transport aircraft which occurred worldwide during the period 1980-2001. ATM-related accident rates by event type, flight phase and world region are estimated and presented in this report. The causal factors in the ATM-related accidents were also analysed.

The important findings of this study are that the majority of all ATM-related accidents occurred during the taxi flight phase, that the most frequently identified event was a collision of an aircraft with a vehicle on the ground, that the most frequently identified causal factors in the ATM-related accident sample belonged to the Flight Crew group, and that the most frequently identified causal factor in the ATM-related accident sample was “Low visibility” closely followed by “Lack of positional awareness of the flight crew on ground” and “Incorrect or inadequate instruction/advice given by ATC”.

Contents

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1 Introduction

1.1 Background

A large number of studies are available that provide historical data on aviation safety. So far, not much attention has been given specifically to Air Traffic Management (ATM) related accidents. A recent mid-air accident over Germany and a major runway incursion accident at Linate airport, Italy, have increased the concern to reduce the number of ATM-related accidents in Europe. In addition, elsewhere in the world initiatives have started to reduce the number of runway incursions. However, there is not much known about the overall historical safety performance of the ATM system. The National Aerospace Laboratory NLR has conducted a study to obtain more insight into the historical safety performance of the ATM system. The results of this study are presented in this paper.

1.2 Research Objectives

The research objective of the present study is to quantify the historical safety performance of a number of selected ATM-related accident types. The study was not limited to accidents in which ATM was a causal factor but also covered all accidents that can be related to the ATM system in general. Therefore, the results of the present study are more significant when considering the safety performance of the overall ATM system.

2 Methodology

2.1 Approach

The following approach was used:

- Compilation of a sample of Air Traffic Management related accidents,
- Compilation of exposure data (i.e. number of conducted flights),
- Analysis of the data.

2.2 Data Sources

Searches were conducted in the NLR Air Safety Database. This database consists of accident data from a large number of sources including, for instance, official international reporting systems (e.g. ICAO ADREP), accident investigation agencies, and insurance companies. These sources provided data for virtually all reported ATM-related accidents. Exposure data were also obtained from the NLR Air Safety Database. The database contains arrival and departure data for commercial aircraft at airports worldwide.

2.3 Accident Sample Inclusion Criteria

Several criteria were used to establish the final accident sample:

1) The selected accident must fulfil the definition given in ICAO ANNEX 13, which is as follows:

An occurrence associated with the operation of an aircraft which takes place between the time any person board the aircraft with the intention of flight until such time as all persons have disembarked, in which:

a) a person is fatally or seriously injured as a result of:

- being in the aircraft, or
- direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
- direct exposure to jet blast,

except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:

- adversely affects the structural strength, performance or flight characteristics of the aircraft, and
- would normally require major repair or replacement of the affected component,

except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or

c) the aircraft is missing or is completely inaccessible.

Note 1: For statistical uniformity only, an injury resulting in death within thirty days of the date of the accident is classified as a fatal accident by ICAO.

Note 2: An aircraft is considered to be missing when the official search has been terminated and the wreckage has not been found.

Note 3: According to ICAO, one collision is counted as *two* accidents (one for each aircraft involved), which implies that the probability of the occurrence of an accident could be twice the probability of the occurrence of a collision. The word "*could*" is used here because it is possible that one of the aircraft involved in the collision does not comply with the accident inclusion criteria (e.g. one aircraft could be a small general aviation aircraft). In that case the collision is counted in this study as *one* accident[1].

2) The accidents involved aircraft operated by commercial operators, including and limited to:
- Freight operators and air carriers involved in public transport,
- Scheduled and non-scheduled flights,
- Freight, passenger, training and positioning flights,
- International and domestic flights,
- Turbojet, turboprop and piston-engine fixed-wing aircraft,
- Aircraft in the takeoff weight category of 5,670 kg or higher.

but excluding:

- Experimental/test flights,
- Accidents with helicopters.

3) Accidents caused by sabotage, terrorism and military actions were excluded.

4) Russian-built and business jet aircraft were excluded.

5) The accidents occurred during 1980 through 2001. This time frame was considered large enough to provide a statistically acceptable number of accidents. The available data for 2002 were incomplete and therefore not selected.

6) Accidents of the following type only were considered in the analysis:

- Wake vortex induced accidents[2],
- Accidents involving two or more aircraft,
- Accidents involving one aircraft and one or more ground vehicles,
- Accidents involving problems with landing aids[3].

[1] For this reason *collision* rates cannot be obtained by simply dividing the *accident collision* rates (presented in this study) by a factor two.
[2] Wake vortex = A disturbance caused by a pair of counter rotating vortices trailing from the wing tips of an aircraft.

These accident types were considered to be ATM related. ATM *related* does not necessarily mean that ATM was a causal factor in the accident.

7) Accidents in the flight phase *standing*[4] were excluded.

There is no restriction to the geographical location at which the accident occurred. Selection criteria 2, 4, and 5 were also applied to the exposure data.

2.4 Accident taxonomy

A taxonomy was used to record all accidents fulfilling the inclusion criteria. This taxonomy consists of the following items:

- Accident date,
- Aircraft type (including manufacturer),
- Accident location,
- Region in which the accident occurred,
- Operator name,
- Flight phase,
- Event type,
- Onboard fatalities,
- Causal factor(s).

The following event types were considered in this study:

- Aircraft encountered vortex/wake turbulence,
- Collision/near collision with aircraft – both airborne[5],
- Collision with aircraft – one airborne,
- Collision with moving aircraft on ground,
- Collision with standing aircraft on ground[6],
- Collision with vehicle,
- Landing aids related accident[7].

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[3] Landing aids such as (but not limited to) ILS, MLS, PAR, PAPI, VASI and approach lights.

[4] STANDING: After the first person boards the aircraft with the intention of flight until pushback or, if pushback does not apply, until taxiing from the gate or parking position. Subsequently, from engine shut down upon reaching the gate or parking position after flight until the last person exits the aircraft.

[5] Near mid-air collisions can result in damage to the aircraft and/or fatal injuries to the occupants resulting from an evasive manoeuvre conducted to avoid the collision. Also note that mid-air collisions *do not* necessarily result in fatalities among the occupants of the involved aircraft.

[6] This should NOT be confused with the flight phase *standing* which is excluded in this study.

[7] Accident that was related to e.g. the failure or incorrect functioning of landing aids.

3 Results

3.1 Exposure data

Queries were made in the NLR Air Safety Database for the period 1980-2001. Selection criteria 2 and 4 from section 2.3 were also applied to the query. The relative distribution of the number of flights conducted in each world region is shown in Figure 1. It is clearly shown that the majority of all flights were conducted in North America and Western Europe.

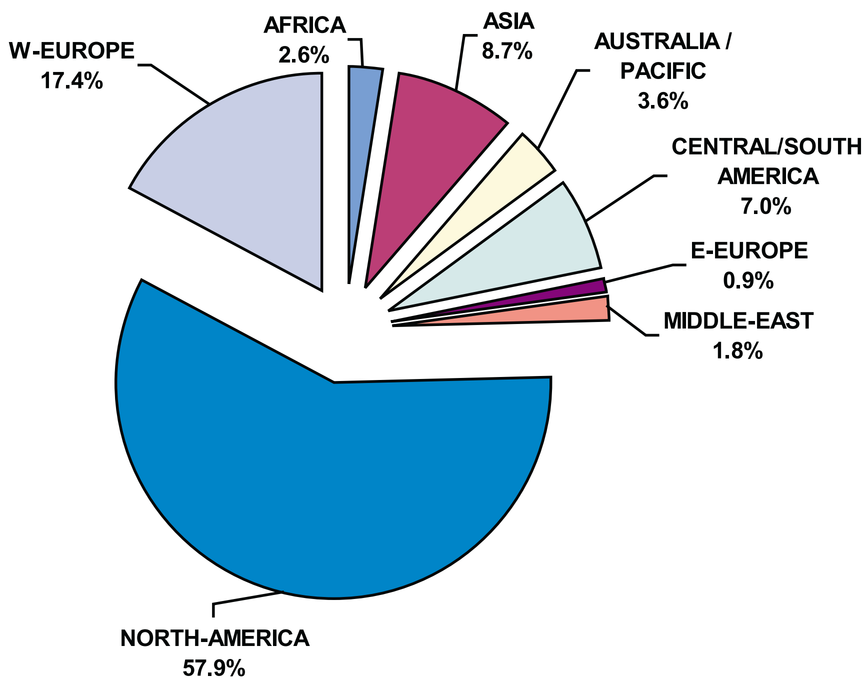

Figure 1: Distribution of flight exposure by world region

3.2 Accident data

A total of 213 ATM-related accidents were found that fulfilled the accident inclusion criteria of section 2.3. There were in total 2,600 accidents that fulfilled all criteria of section 2.3 but were not limited to the events listed under criterion 6. Hence, 8% of this total are considered ATM related. A number of different frequency distributions of the accident sample are discussed in the following sections.

3.2.1 Accidents by flight phase

In Figure 2 the distribution of the 213 ATM-related accidents by flight phase is shown. The majority of all ATM-related accidents in the sample took place in the taxi phase.

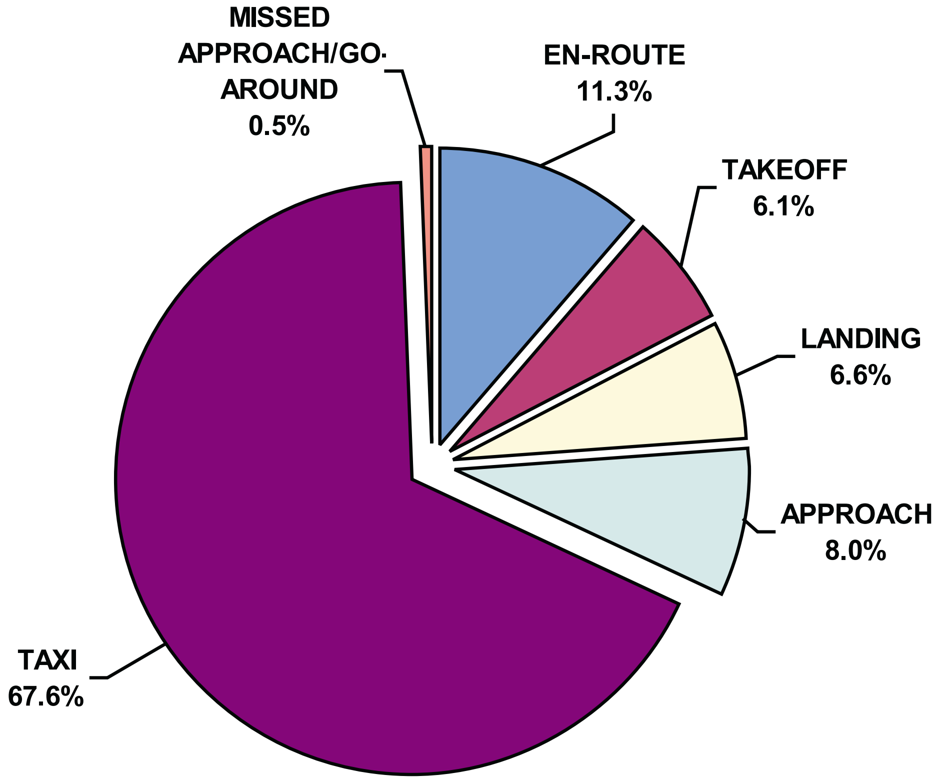

Figure 2: Distribution by flight phase

3.2.2 Accidents by event types

The relative distribution of the event types in the accident sample is shown in Figure 3. The majority of all events in the accident sample concerned collisions with vehicles on the ground (33%), followed by collisions with standing (22%) and moving (21%) aircraft on the ground.

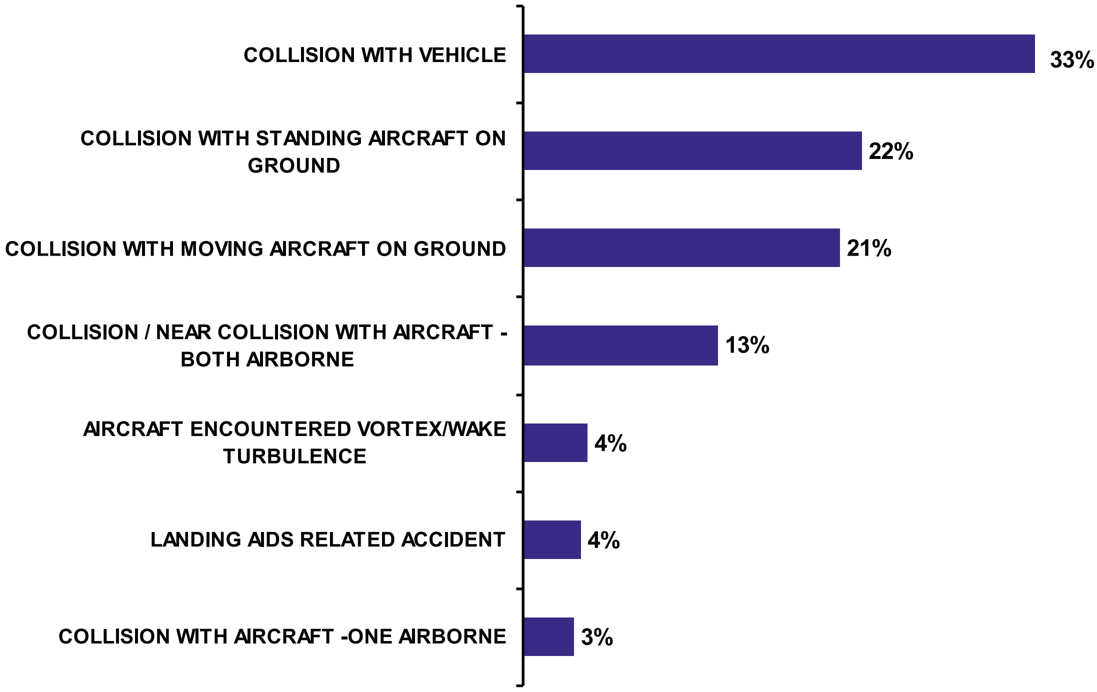

Figure 3: Relative distribution of event types in the accident sample.

3.2.3 Fatalities

There were 29 (14%) fatal ATM-related accidents recorded in the sample with 984 fatalities. In total, 664 fatal accidents fulfilled all criteria of section 2.3 except criterion 6. This results in a share of ATM-related fatal accidents of 4.4%.

Figure 4 shows the number of fatal ATM-related accidents by event type. The distribution of fatalities by event type is shown in Figure 5. The majority of the fatalities are caused by mid-airs (63 %). The wake vortex encounter event type is the only one in which there were no fatalities reported[8].

[8] During the time frame considered (1980-2001) three wake vortex related accidents have been recorded with fatal injuries to the occupants. Two of these accidents occurred with a B757 as leading aircraft and business jets as following aircraft. These accidents occurred in 1992 and 1993. In the present study accidents with business jets were excluded from the analysis. Note that in 1996 the Federal Aviation Administration (FAA) implemented new aircraft separation standards for the B757 following these accidents. In the third fatal accident due to a wake vortex, a Yakolev YAK-40 was involved. This is a Russian-built aircraft. These type of aircraft were excluded from the present analysis (see section 2.3). The fatal accident with an American Airlines A300-600 that occurred in Belle Harbour, USA in 2001, is sometimes classified as a wake vortex related accident. However, since the official investigation of this accident was not finalized during the present study, it was not considered a wake vortex related accident in this study.

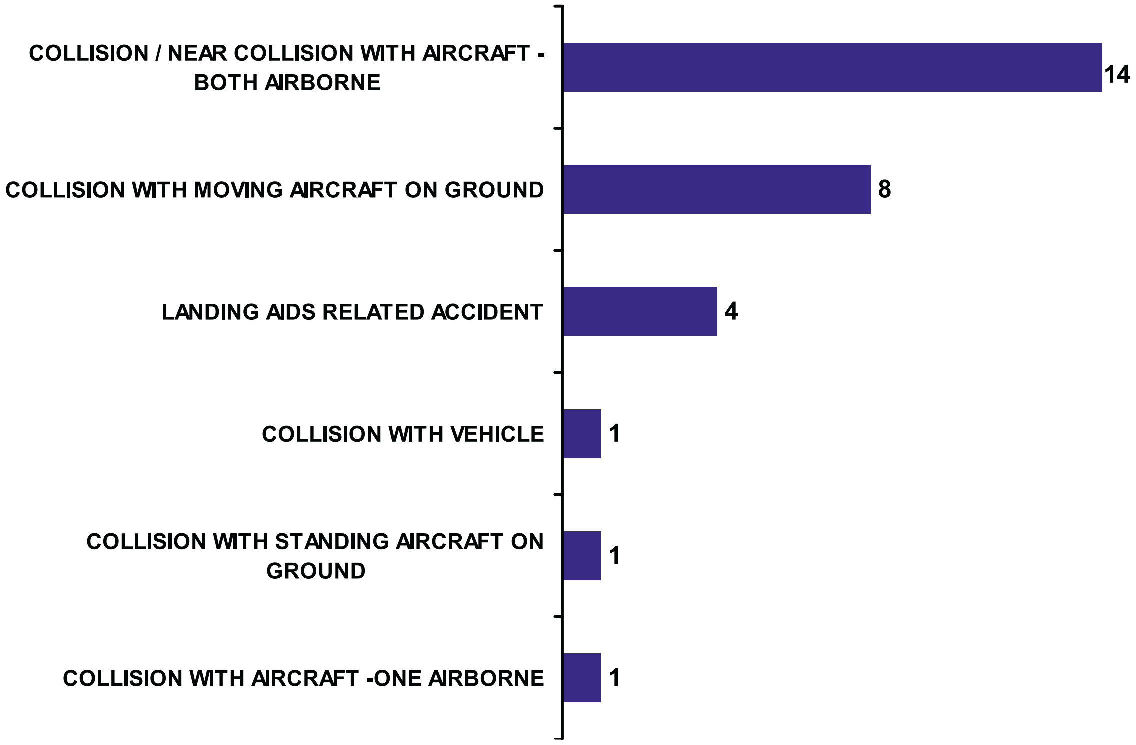

Figure 4: Number of fatal ATM-related accidents by event type.

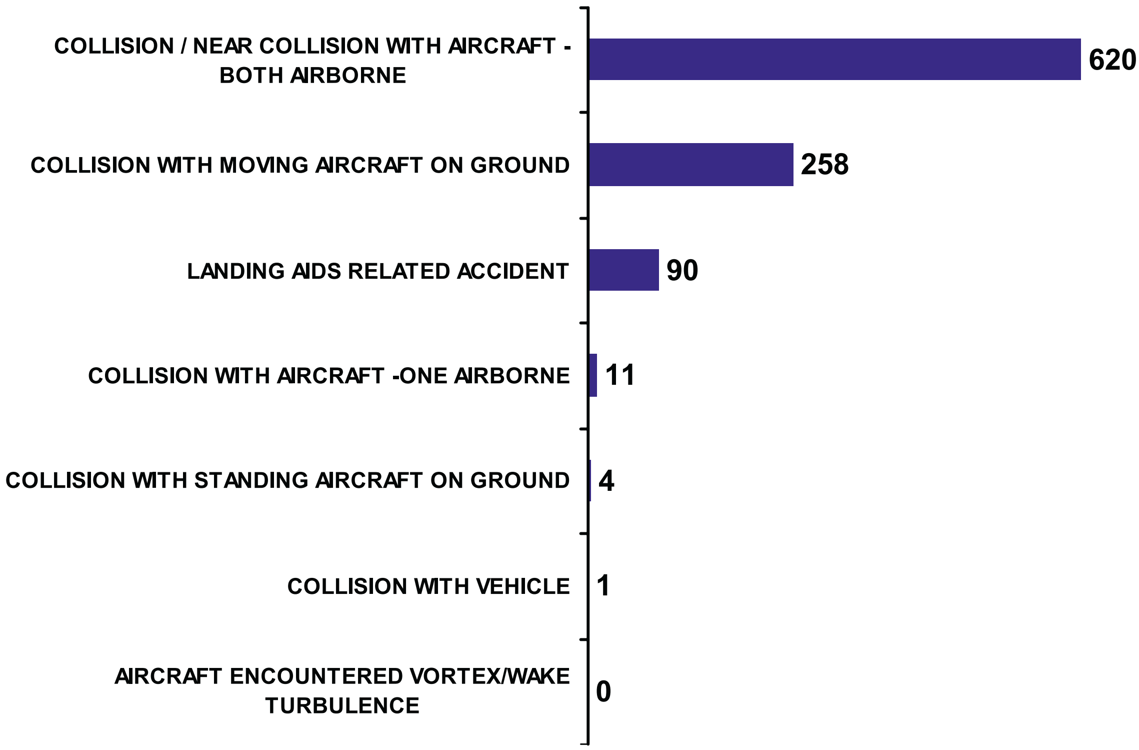

Figure 5: Distribution of total number of fatalities by event type.

3.3 Estimation of accident rates

In the next few sections, several accident rates are presented and discussed.

3.3.1 Accident rates by world regions

It is known from statistical data that North American and Western European operators have a better safety performance than operators from other regions. However, since the present study is concerned with ATM-related accidents, a sub-division by operator region is not useful. Instead, a sub-division is made by world region itself because of the differences in ATM standards and quality in the different world regions. The accident rate is then estimated by dividing the number of accidents that occurred in a region by the number of flights conducted in the same region. The accident rate per region for all flight phases and event types is given in Figure 6, including the 95% confidence intervals. The overall ATM-related accident rate of 0.44 per million flights for all regions is also shown in this figure for comparison. From Figure 6 it appears that there is not much difference among the regions. Except for the Australia/Pacific region all ATM-related accident rates are comparable. Tentatively it was expected that regions with poor ATM infrastructures (e.g. Africa) would have higher ATM-related accident rates than for instance the North America of Western Europe regions. A number of explanations can be given why the accident rates appear to be the same for each region[9].

First, a large number of the ATM-related accidents that occurred in the North America and Western Europe regions involved collisions in the “taxiing to/from runway” flight phase. Such occurrences are more likely to take place at large complex airports with significant number of ground movements. Such airports can especially be found in North America and Western Europe. Secondly, the 95% confidence intervals of the accident rates for North America and Western Europe are relatively much smaller than those of other regions. This means that the statistical accuracy of the estimated accident rates is lower for the other regions compared to the accident rates estimated for North America and Western Europe.

In the remainder of this paper, ATM-related accident rates will be calculated for the regions North America and Western Europe combined. These regions have a comparable ATM infrastructure, complexity of airports, airport activity and the same mix of operators. Accident rates for other regions will be presented for completeness and not necessarily for comparison.

[9] Reporting bias in safety related events is a known factor in some countries. However, the type of occurrences analysed in this study are believed to be less influenced by reporting biases than for instance minor incident type of events.

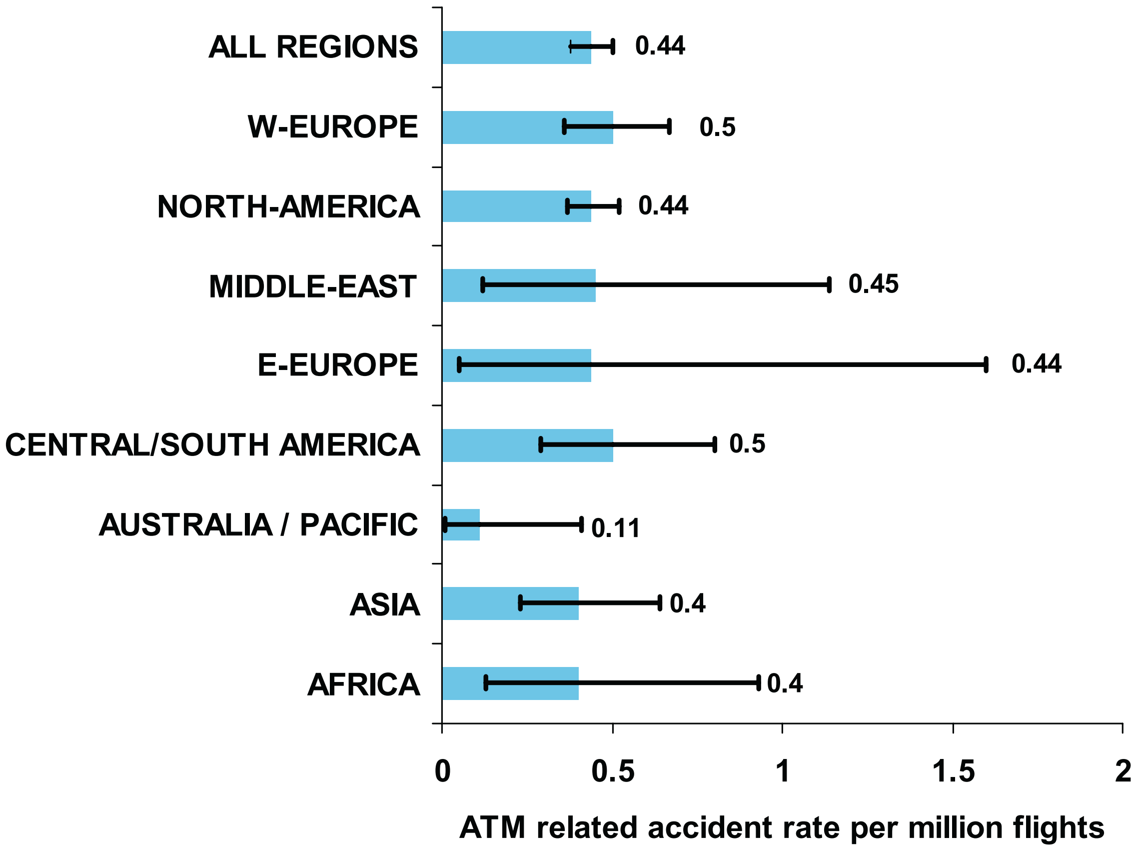

Figure 6: ATM-related accident rates by region (all flight phases and event types).

3.3.2 Accident rates by event type

Figure 7 shows the accident rate per event type, including the 95% confidence intervals, for the North America - Western Europe combined region and the all other regions combined. The "collision with vehicle" has the highest rate for the North America - Western Europe region. The landing aids related accident rate for the North America - Western Europe region is low and significantly less than for the other regions. This could be an indication of the quality and reliability of the landing aids equipment at the airports located in North America and Western Europe. The fact that the North America -Western Europe region has a higher wake vortex accident rate is likely caused by the high traffic density on the airports and the associated minimum spacing used to obtain sufficient capacity.

3.3.3 Accident rates by flight phase

In Figure 8 the accident rate by general flight phase for the North America - Western Europe combined region is compared to the other regions. The taxi phase is by far the most critical for both sub-regions. However, for the North America - Western Europe combined region it is significantly higher than for all other regions. This is due to the presence of large complex airports with significant number of ground movements in the North America - Western Europe region.

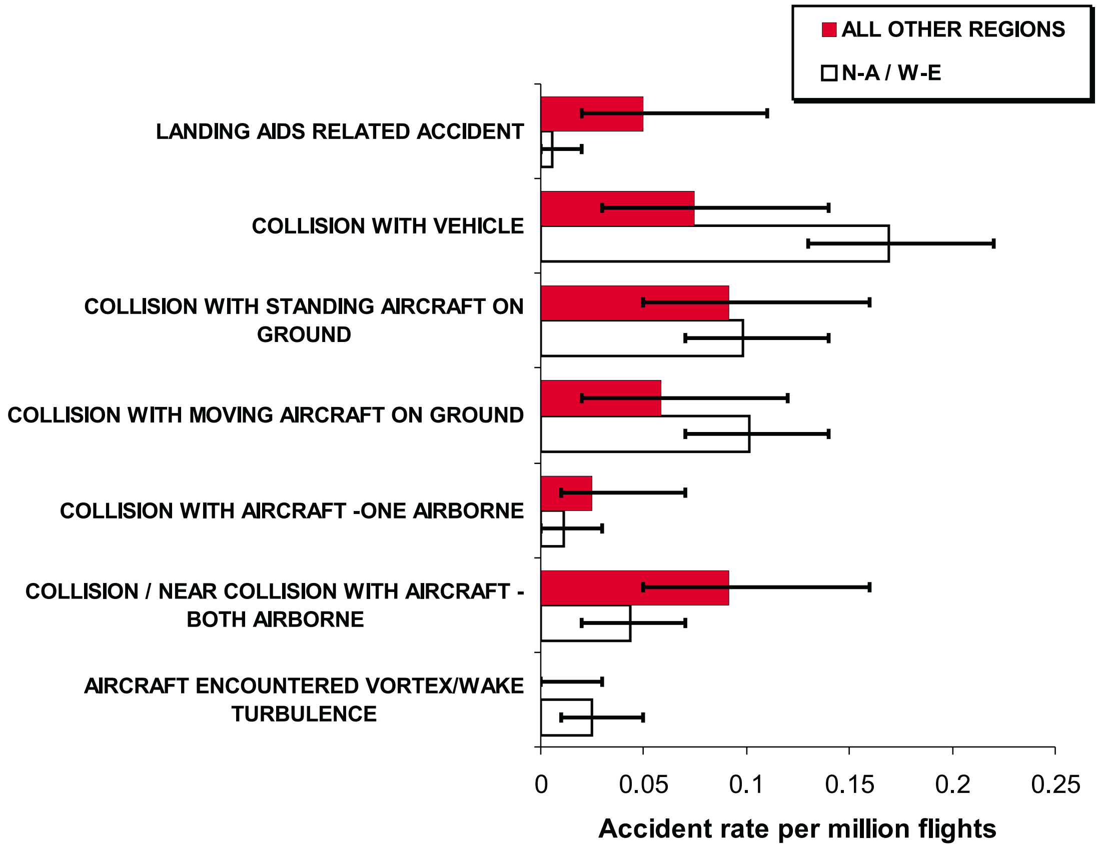

Figure 7: ATM-related accident rate by event type and regions.

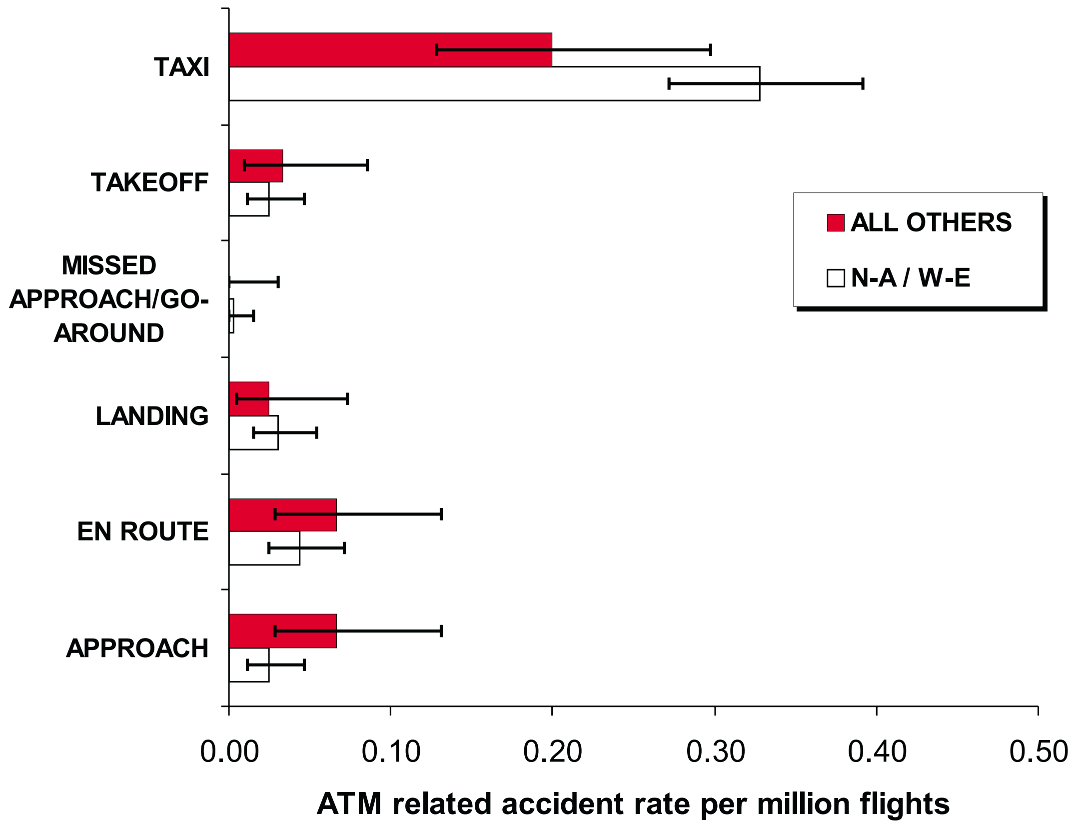

Figure 8: ATM-related accident rate by flight phase and regions.

4 Causal factors in ATM-related accidents

The results in the previous sections did not address the factors attributed to the ATM-related accidents. In this section the causal factors in the ATM-related accidents are discussed.

The classification of factors in aircraft accidents is subjective. Therefore in this study no distinction was made between causal, circumstantial, or contributing factors as has been done in many other safety studies. This approach is in line with recommendations given by ICAO on the classification of accidents. The taxonomy for causal factors developed by the CAA-UK was used in the present study. A causal factor is defined as an item, that was judged to be instrumental in the causal chain of events leading to the accident. The causal factors were listed in four groups; Flight Crew, ATC, Environmental, and Aircraft System and divided further into specificfactors. An accident may have been allocated any number of causal factors from any one group, and any combination of groups. The causal factors were identified using the official findings of an accident investigation agency. Also the narrative was used to identify the causal factors. However for 70 accidents (33% of total sample) there was insufficient information to identify the causal factors.

In Figure 9 an overview is given of the distribution of causal factor groups in the ATM-related accident sample (not including those with insufficient information). It is interesting to note that the most frequently identified causal factors belonged to the Flight Crew group and not to the ATC group. The flight crew is apparently more important as a causal factor in ATM-related accidents than ATC is.

The ten most frequently identified causal factors in the ATM-related accident sample are listed in Table 1. Low visibility is the most frequently identified causal factor followed by lack of positional awareness of the flight crew on ground and incorrect or inadequate instruction/advice given by ATC.

Table 1: Top ten most frequently identified causal factors.

Causal Factor	**Number of accidents**	
1. Environmental - Low visibility	23	(16%)
2. Flight Crew - Lack of positional awareness - on ground	22	(15%)
3. ATC - Incorrect or inadequate instruction/advice	20	(14%)
4. Flight Crew - Failure in look-out	17	(12%)
5. Flight Crew - Non-adherence to procedures	17	(12%)
6. Flight Crew - Omission of action / inappropriate action	14	(10%)
7. ATC - Failure to provide separation - ground	12	(8%)
8. Aircraft System - System failure affecting controllability	9	(6%)
9. Flight Crew - Failure in CRM (cross-check / co-ordinate)	8	(6%)
10. ATC - Ground aid malfunction or unavailable	7	(5%)

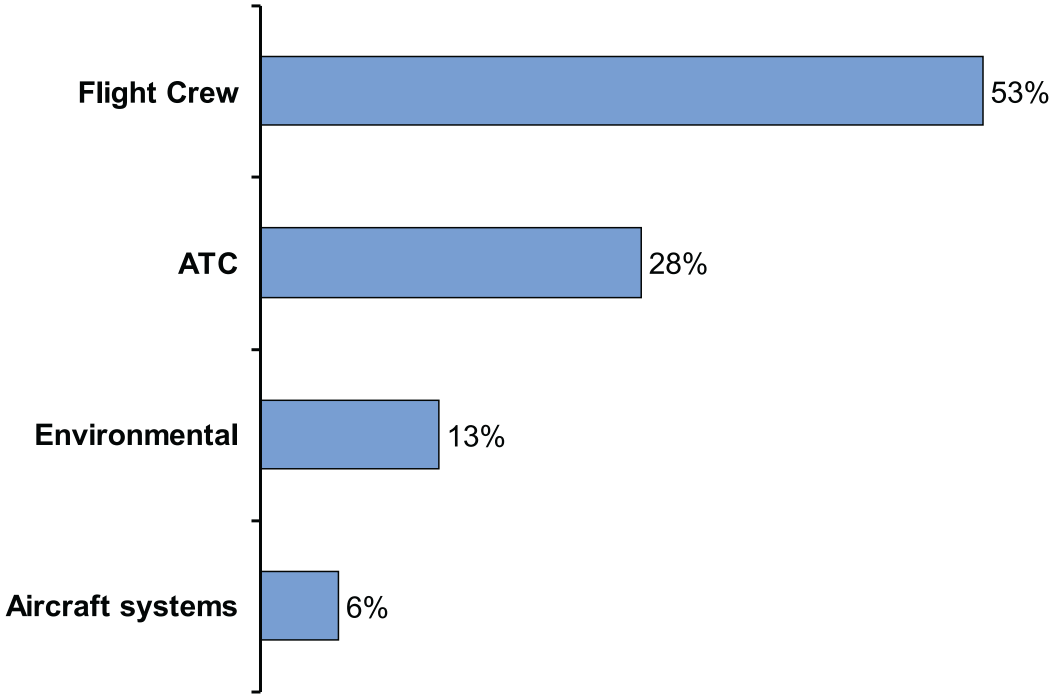

Figure 9: Distribution of causal factors groups.

The most frequently identified causal factors by event type are summarised in Table 2. For the wake vortex encounter events there was insufficient data to give the most frequently identified causal factors.

A comparison between the causal factors identified for the different world regions did not show significant differences except for the “low visibility” factor. The causal factor “low visibility” was identified more often for accidents that occurred in North America and Western Europe than in the other regions. The local climatological circumstances in North America and Western Europe could be an explanation for this finding.

Table 2: Most frequently identified causal factors by event type.

Event type	**Most frequently identified causal factors**
AIRCRAFT ENCOUNTERED VORTEX/WAKE TURBULENCE	• *Insufficient data*
COLLISION / NEAR COLLISION WITH AIRCRAFT -BOTH AIRBORNE	• ATC - Failure to provide separation - air • Flight Crew - Lack of positional awareness - in air
COLLISION WITH AIRCRAFT - ONE AIRBORNE	• ATC - Incorrect or inadequate instruction/advice
COLLISION WITH MOVING AIRCRAFT ON GROUND	• Environmental - Low visibility • ATC - Incorrect or inadequate instruction/advice
COLLISION WITH STANDING AIRCRAFT ON GROUND	• Flight Crew - Lack of positional awareness - on ground • Aircraft System - System failure - affecting controllability • Flight Crew - Failure in look-out
COLLISION WITH VEHICLE	• Environmental - Low visibility • Flight Crew - Lack of positional awareness - on ground
LANDING AIDS RELATED ACCIDENT	• Flight Crew - Non-adherence to procedures • ATC - Ground aid malfunction or unavailable

5 Conclusions

- ATM-related accidents have a share of 8% in all accidents,
- ATM-related accidents have a share of 4.4% in all fatal accidents,
- The majority of all ATM-related accidents occurred during the taxi flight phase,
- The most frequently identified event was a collision of an aircraft with a vehicle on the ground,
- Collisions and near collisions between two airborne aircraft caused the majority of the number of onboard fatalities in ATM-related accidents,
- The overall worldwide ATM-related accident rate is 0.44 per million flights,
- The most frequently identified causal factors in the ATM-related accident sample belonged to the Flight Crew group,
- The most frequently identified causal factor in the ATM-related accident sample was “Low visibility” closely followed by “Lack of positional awareness of the flight crew on ground” and “Incorrect or inadequate instruction/advice given by ATC”.