NLR-TP-2000-400

External risk around airports
A model update

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Summary

Typical third party risk analysis methods consist of three submodels: an accident probability model, an accident location probability model and an accident consequence model. The results of these submodels are combined to calculate individual risk levels (local probability of death), which are usually presented as risk contours on a topographical map, and societal risk (probability of death of a group of N or more people).

In 1992 NLR developed a method for the calculation of third party risk levels around airports. The method is applied in many airport risk studies. With the experience gained over the years in application of the method, and due to the availability of improved historical data, the risk models were updated in 1999.

The improvements and extensions of the model consist of adaptations of model parameters and conceptual changes of the external risk models. They were made possible by the availability of much improved historical data on aircraft operations and accidents and by the extensive experience gained in the application of the model in a variety of risk assessment projects for several airports.

This report discusses the changes made to the models and a comparison of the result of calculations with the old model and the new model.

Contents

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Abbreviations

ADREP	Accident Data Report (ICAO)
ALPA	Air Line Pilot's Association
ATIS	Automatic Terminal Information Service
CAA-UK	Civil Aviation Authority of the United Kingdom
ICAO	International Civil Aviation Organization
IR	Individual Risk
JAA	Joint Aviation Authority
MTOW	Maximum Take-Off Weight
NLR	National Aerospace Laboratory
NTSB	National Transport Safety Board
OAG	Official Airline Guide
SR	Societal Risk
VOLMET	Meteorological Information for aircraft in flight

1 Introduction

The NLR External Risk model consists of three sub-models: an accident probability model, an accident location probability model and an accident consequence model. The results of these sub-models are combined to calculate individual risk levels (local probability of death) and societal risk (probability of death of a group of more than N people). The improvements and extensions of the model consist of an adaptation of model parameters and conceptual changes.

2 Accident Rate Model

The accident rate model provides separate crash probabilities per aircraft generation and flight phase and are based on historical data. Since safety levels differ considerably between airports a selection of data from the available worldwide data is required to make the accident rates airport specific. First a selection of airports similar to the airport under investigation is made, then a set of aircraft accidents is selected. With the selected accidents and the movements at the selected airports the accident rates can be determined. Accidents that occurred on the runway are not considered, because they do not contribute to external risk.

Airport selection criteria used for Amsterdam Airport Schiphol are:

1. Terminal Approach Radar present at the airport;

2. At least 70% of the approaches are made with precision approach equipment;

3. At least 90% of the operators are from JAA-countries and N-America;

4. Automatic Terminal Information System, ATIS, and Meteorological information for aircraft in flight, VOLMET, are present at the airport;

5. No obstacles higher than 2000 ft are present within 6NM, and no obstacles higher than 6000 ft are present within 25 NM; and

6. At least 150,000 commercial movements in any year within 1980-1997.

In addition, expert judgement on the selected airports is applied to exclude airports that are not comparable to Schiphol. The selection results in a set of 40 airports out of more than 5000 airports worldwide using the NLR airport database.

Accident data is obtained from various sources: Airclaims, ICAO ADREP, NTSB, Laurence Livermore database, Breiling and ALPA. The criteria for selection of accidents that occurred at the 40 selected airports is based on the following criteria:

1. The accident happened in the period 1980-1997;

2. No helicopters, military aircraft, test flight and air show accidents;

3. The maximum take-off mass of the aircraft is 5700 kg or more;

4. The accident happened during take-off, initial climb, initial approach, final approach, landing or go-around; and

5. Accidents caused by sabotage, terrorism or military actions are excluded.
The selection results in a list of 75 accidents.

Scheduled movement data are obtained from the Official Airline Guide (OAG) database of aircraft heavier than 5700 kg on all commercial airports worldwide. In cases the level of detail in the OAG database is insufficient, individual fleet data is used to distinguish between aircraft generations.

Table 1 shows the accident rates per generation for six accident types.

Table 1: Accident Rates per accident type and generation.

Accident type	Accident Rate (per million flights)		
	Generation 1	Generation 2	Generation 3
Landing overrun	0.251	0.200	0.062
Landing undershoot	0.753	0.145	0.124
Landing veer-off	0.879	0.181	0.093
Take-off overrun	0.377	0.109	0.062
Take-off overshoot	0.126	0.046[1]	
Take-off veer-off	0.377	0.034	

3 Accident Location Model

The accident location model gives the distribution of accident locations relative to runways and air traffic routes, assuming that an aircraft accident occurs. A selection of historical accident location data is taken from the NLR Air Safety Database, ADREP, ALPA, Airclaims, NTSB and CAA-UK databases and is divided into five categories: overshoot, take-off overrun, undershoot, landing overrun and veer-off.

The layout of traffic routes and runways may play an important role in the impact location of accidents and hence must be taken into account while calculating risk for an airport. It is however known from historical data that in some accidents aircraft impacted the ground while following a route to/from the airport, while in other accidents no particular route was being followed due to the difficulties encountered by the accident flight. Therefore the accident location model is split into a route dependent part and a route independent part (both parts are runway location dependent).

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[1] Difference between accident rates is statistically not significant.

A large number of datapoints are reported to be located on the extended runway centerline, while in reality they are likely to have been located close to but not at the extended centerline (especially for accident locations at great distances from the airport).

NLR has chosen to consider all accidents reported on the extended centerline as route dependent. It is not possible to derive a lateral distribution (i.e. perpendicular to the route) from the accident location data set. Alternatively, the lateral distribution of route dependent accident locations is derived from the operational distribution relative to intended routes of actual traffic. The allocation of datapoints to the route dependent and the route independent part is made on pragmatic grounds for the time being. A more elaborate division will be developed in 2000.

Undershoots, overshoots and overruns are modeled with similar functions. For undershoots and overshoots these functions are split into a route dependent and a runway dependent (route independent) part. Take-off and landing overruns are modeled using similar distribution functions with different parameters. Overrun accidents are assumed to be route independent. Veer-off data have been gathered but has not been modeled yet.

4 Accident Consequence Model

The accident consequence model (which only considers people on the ground, not passengers and crew on board of the accident aircraft) defines the consequences of an aircraft accident at a particular location in terms of the consequence area size and lethality. The consequence area together with population density information determines the number of people on the ground exposed to the accident. Accident reports and supporting information are used to determine the size of a consequence area and the lethality of actual accidents.

The size of the consequence area has been estimated for 71 datapoints. The consequence area is estimated from the distribution of the larger pieces of the aircraft. If no additional information was available the size of the consequence area was calculated by multiplying the plane's wingspan with the reported skid distance. The maximum take-off weight (MTOW) is used as measure of the aircraft's size. Using the 71 datapoints a crash area equal to 83 m^2/ton MTOW is found.

Lethality is defined as the ratio of the number of third party fatalities and the total number of people present in the consequence area. Although the sources are clear about the number of fatalities, they normally do not provide the number of people who were within the consequence area at the time of the crash. To estimate the number of people present at a crash site engineering judgements are made, based on information from the accident report, such as photos and drawings showing the density of houses and offices. Population within the consequence area is estimated for 115 crash areas. Of these 115 datapoints the unpopulated consequence areas (84 datapoints) provide no information on the lethality and are therefore ignored. Consequently, the lethality estimation is based on 31 datapoints. The

lethality is found to be equal to 0.28.

5 Comparison of the old model with the new model

In the new model accident ratios are derived for three aircraft generations and for six flight phases. The ratio for Schiphol calculated for the new model for 1990 is less than 50% of the ratio for 1990, calculated for the old model. The new value for 1997 is only 30% of the old 1990 ratio. The fact that the newly determined accident rates are much lower than the rates of the former model is mainly caused by the distinction in aircraft generations in the updated model. This distinction was not made in the former model. As a result of this, a relatively large amount of first and second generation aircraft, as observed in the average traffic of the selected airports, contribute to the higher accident rate in the former model. The updated model is capable of taking into account the fast replacement in the Schiphol traffic of older first and second generation of aircraft by modern third generation aircraft.
The changes made to the location model, i.e. modeling a route dependent part and a route independent part for overshoots and undershoots and incorporating operational traffic, result in shorter and wider risk contours for departure routes in the new model.
The dimensions of the consequence areas are based on more accurate data. This has resulted in a reduction of the crash area of 45 to 65% of those in the former model and crash areas which are independent of the terrain type. Lethality is determined to be about 7% less than in the former model.

6 Results

A result of third party risk analysis is Individual Risk (IR). IR is defined as the probability per year that a person permanently residing at a particular location in the area around the airport is killed as a direct consequence of an aircraft accident. IR is presented as risk contours on a geographical map. The highest risk levels occur close to the runway thresholds. Figure 1 shows a Schiphol scenario calculated using the old (former) model and the revised (updated) model.
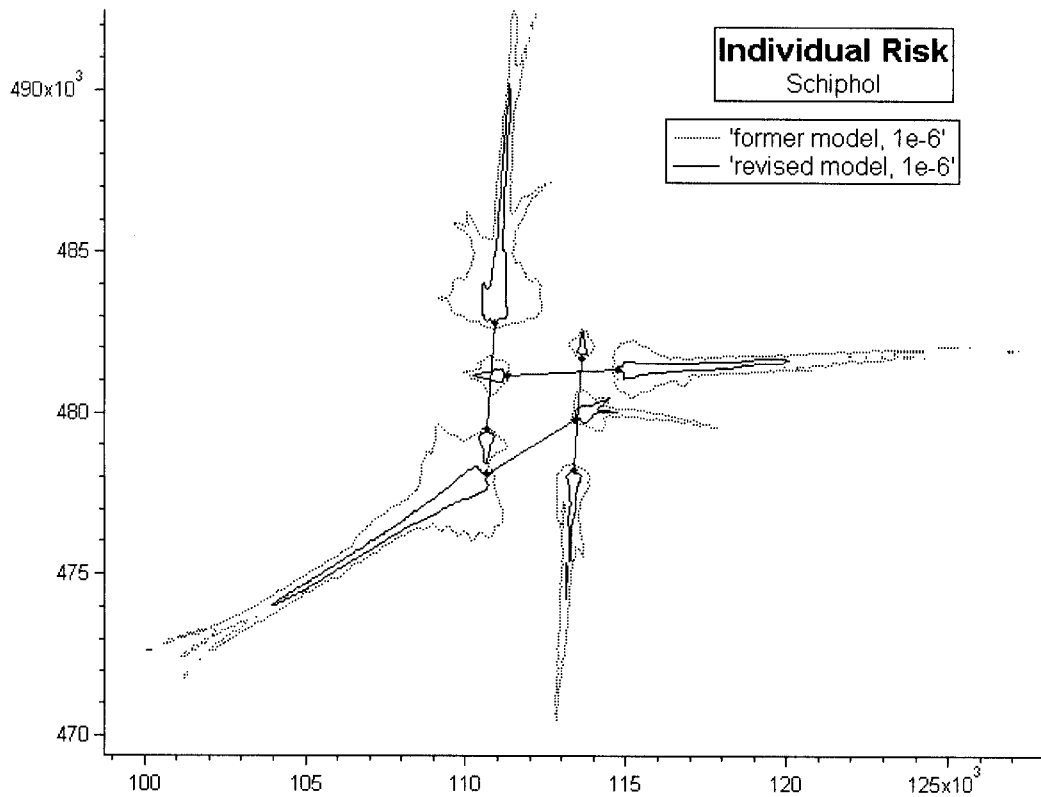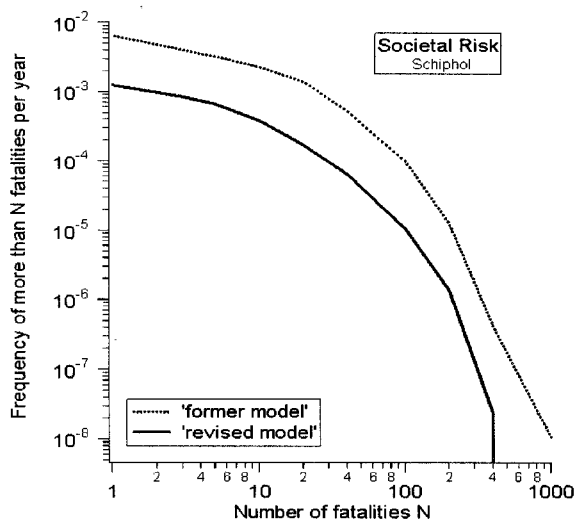
Figure 1: Individual Risk of Schiphol, level 1e-6, with the revised and the former model.

Another result of external risk analysis is Societal Risk (SR). SR is the probability per year of more than N third party victims due to an aircraft accident somewhere in the area around the airport. SR is presented in a diagram on logarithmic scale. Figure 2 shows such a diagram for the same Schiphol scenario as the IR contours presented above. The population density of the area around the airport is used to calculate SR.

Figure 2: Societal Risk of Schiphol with the revised and the former model.

7 Conclusions

The revised model incorporates improvements in all three sub-models. The accident probability model is improved by using new accident data to expand the statistical basis of the model and by using more accurate data on air traffic movements. Furthermore, the increase of data has made it possible to determine accident rates for different generations of aircraft and for different types of accidents. The accident location probability sub-model is improved by using new accident location data to determine location models for different types of accidents. The model has been split into a route dependent and a route independent part and the lateral distribution of the actual traffic is used. The accident consequence model is made more accurate using (new) accident data to model the consequence areas more accurately. The average consequence area is made independent of the type of terrain the aircraft crashes into and also the lethality is based on more accurate data.