Ministerie van Verkeer en Waterstaat

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Programmadirectie Ontwikkeling Nationale Luchthaven

Plots of crash locations

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National Air Traffic Services LTD London, in opdracht van Amsterdam Airport Schiphol

Summary

At the request of Amsterdam Airport Schiphol, plots of crash positions, crash densities, and areas based on 90% of crash probability were supplied using data from the NATS crash location database, and the NATS crash location model.

This study was carried under contract to Amsterdam Airport Schiphol. The contents of this paper reflect the views of the authors; they do not necessarily reflect the official view or policy of the Civil Aviation Authority or the National Air Traffic Services Ltd.

Inhoudsopgave

1 Background

The Department of Operational Research and Analysis (DORA), National Air Traffic Services (NATS) has developed an empirical approach for estimating third party risks near airports (Ref). The methodology is based on the estimation of three components: a suite of crash rates (crashes per movement) for different types of aircraft, a crash location model, and a crash consequence model. These three components are used in the calculation of the risk to third parties living near airports from aircraft crashes (see for example Refs: , , ,).

The above models were derived using statistical analyses of data from accident reports. In the course of developing the crash location and consequence models, accident data were entered into a simple relational database. The current version of the database contains data on 559 airport-related accidents from different parts of the world during the period 1970 to 1998.

The issue of public safety near airports is an area of current interest to the authorities in both the UK and The Netherlands. Amsterdam Airport Schiphol asked NATS to use the information in the NATS database to produce plots of the position of accidents near a runway end. In addition, they requested a plot of the area estimated to contain 90% of the potential accidents around an airport.

This report briefly outlines the basis on which these plots were produced and the underlying assumptions. Note that, although NATS has undertaken this work for Amsterdam Airport Schiphol on a commercial basis, NATS does not endorse a zoning approach based purely on percentages of crash probabilities, as our recommended approach is to base Public Safety Zones on levels of individual risk.

2 Crash location database and model

The information on accident locations entered into the NATS crash database was derived from official accident reports produced by organisations such as the UK Aircraft Accident Investigation Board or the National Transportation Safety Board (USA), supplemented by information from other sources such as reports produced for aircraft insurers.

Although the data collection was not restricted to accidents in particular regions of the world, accidents in 'First World' countries are more likely to be investigated and reported in detail (and the reports are more readily obtainable) than those in other parts of the world. For these reasons, the accident data set collected contains a 'disproportionately' high number of 'First World' accidents. Accidents occurring in North America, Western Europe, and Australia account for 65% of the data upon which the crash location model is based.

Since the aim of the data collection was to model accidents in the vicinity of airports, data collection was restricted to 'airport-related' accidents which were defined as follows:

- A take-off accident was deemed to be airport-related if it occurred at some stage between the aircraft beginning its take-off roll and completing its climbing phase of flight.
- A landing accident was deemed to be airport-related if it occurred at some stage between the aircraft starting descent to an airport and before completing its landing roll.

These definitions are deliberately very broad so that all accidents that might be considered to be airport-related are included.

The crash location model consists of distributions of wreckage and impact locations for four different types of crash:

- landing overruns (including veer-offs)
- landing crashes from flight (ie non-overruns)
- take-off overruns (including veer-offs)
- take-off crashes from flight (ie non-overruns)

An overrun accident is defined to occur when an aircraft departs from the paved surface of the runway, either over the end or the side. Taxiing accidents, although occurring at the airport, were not included.

The vast majority of accidents in the database involve aircraft with a Maximum Take-off Weight Authorised (MTWA) of 4 tonnes or greater. When using the data from the database, the value of 4 tonnes was chosen as the cut-off for the crash location model, as the vast majority of aircraft above this weight are used for commercial operations. Below this value, most types are predominantly used for non-commercial operations and might be expected to have different crash location distributions because of the different types of flying activities involved.

The location of each crash entered in the database is given in terms of both the initial ground impact and the final wreckage sites. The co-ordinate origin used for the position measurement depends on the phase of flight of the aircraft before the accident. For landing accidents, the origin is taken to be the centre of the landing runway end (threshold), while for take-off accidents the origin is the centre of the departure end of the runway.

The y co-ordinate of the initial impact and final wreckage sites is measured from the origin along the extended runway centreline in the direction of flight. The x co-ordinate is measured perpendicular to the centreline and the lateral distribution is taken to be symmetrical. The co-ordinate system is explained more fully in Ref 1.

Since the co-ordinate system is based on position relative to the runway, this implies that the effects of aircraft routes are not explicitly modelled. The effects of aircraft routes are handled in an 'average' way in the crash location model – in the case of the plotted accident locations, these are simply where the actual accident occurred in relation to the runway ends. No attempts were made to 'adjust' the crash locations to take account of the routes at Schiphol Airport.

As mentioned in Ref 2, adjusting crash locations to reflect routeing was considered to be inappropriate since there is no reliable way of relating the effects of intended route to eventual accident location. For example, on departure a serious problem (which ultimately causes a crash) may arise before the intended route of the aircraft deviates from a straight path. In this case, the pilot would not attempt to follow the intended curved route, and therefore the actual crash location would be independent of the intended route.

The crash location distributions are probability density functions in the form,

$$f(x,y) = f_y(y) \cdot f_{x|y}(x,y)$$

where $f_y(y)$ is a function representing the longitudinal location along the direction of the extended runway centreline, and $f_{x|y}(x,y)$ is the lateral distribution perpendicular to the centreline. The function $f_{x|y}(x,y)$is derived from |x| co-ordinate data, for which the corresponding y co-ordinate is also known. $f_{x|y}(x,y)$ is usually dependent on the y co-ordinate, although in one lateral distribution equation this is not the case.

The functions were chosen from two families, the gamma and Weibull distributions. Between them, these distributions combine the benefits of a broad range of applicability with a sensitivity to the behaviour of the tails of distributions. The expressions for the individual probability density functions are given in Ref 1.

3 Crash position and crash density plots

Plots have been produced giving a) the crash location points and b) the colour-coded crash density. As requested by Schiphol Airport, all plots are based on a runway length of 3450m which corresponds to the length of their longest runway. Two plots on two different scales (1 in 100,000 and 1 in 20,000) for both a) and b) were originally supplied separately (Ref), but only plots of 1 in 250,000 scale are shown in this report in Figures 3.1 and 3.2 for reasons of practically – the original plots were on A0 size paper.

In these plots, many of the crash locations appear exactly on the intended runway centreline. This is because, in many cases, the co-ordinates were derived from textual descriptions in accident reports. If the actual location was reasonably close to the centreline, the position may be reported as being on the centreline.

As noted earlier, in the case of a crash from flight, the crash location database may contain the co-ordinates of either the impact or final wreckage locations or both when these locations are available from accident reports. Both impact and wreckage locations were plotted in crash location and crash density plots produced in this study. This means those accidents in which both locations are in the database will appear twice on these plots. This is not the case for the 90% contours described in Chapter 4, since the statistical model is based on impact locations for crashes from flight and wreckage locations for overruns and therefore each accident will only 'count' once in these fitted models.

3.1 Crash location points

The 1 in 20,000 scale plot originally supplied (Ref 6) showed crash location data points plotted around half the runway length. This corresponds to the locations 'reflected' about a line drawn at the mid-point of the runway and perpendicular to it – this effectively brings all locations (takeoffs and landings) over to one runway end. A mirror image of these crashes was produced on the opposite side of the runway centreline. This plot corresponds to a pattern of crashes which is symmetric about the extended centreline, but located along only half the length of the runway and the area off one end. However, due to plotting restrictions, a small number of the points furthest from the runway end could not be shown. Figure 3.1 shows a smaller scale version (1 in 250,000) of this plot, but without showing the mirror image about the runway centreline.

In order to show all the relevant location points contained in the database, a 1 in 100,000 scale plot was also originally supplied (Ref 6). This showed all these points, again reflected about a line drawn at the mid-point of the runway and perpendicular to it. For this plot, no mirror image about the runway centreline was included.

3.2 Crash Density plots

The corresponding crash density plots were also originally supplied using the above two scales (Ref 6), but shown in Figure 3.2 on scale 1 in 250,000. The crash location density has been calculated by summing the number of crashes within each 1 km square. Therefore the units of crash density on the diagrams are crashes per square km. The range of density in each colour band has been calculated with a 'natural breaks' method using a Geographical Information System (GIS) software package (Arcview) (Ref). This method identifies breakpoints by looking for groupings and patterns inherent in the data. The statistical method used in Arcview for this process is Jenk's Optimisation, which minimises the variation in the values within each colour band.

It should be noted that both the crash location and the crash density plots provide only a relative measure of the probability of a crash at a given location (since location points or location density are shown rather than normalised probability values). This is because the crash location database only contains a proportion of all the accidents which actually occurred in the world in the period January 1970 to February 1998, and also because the data has been reflected as described above.

4 90% crash probability areas

To produce the 90% crash probability plot the standard proportions obtained from earlier work by NATS (Ref 2) were used for the percentages of take-off and landing crashes (72% landings and 28% take-offs), and for overruns and crashes from flight (30% overruns and 70% crashes from flight). It was assumed that the runway operates 50% in each direction in order to produce areas that are symmetrical about a perpendicular line through the mid-point of the runway; these 'half areas' are shown in the plot. As it was possible to show this on a 1 in 20,000 scale, only one plot was supplied (Ref 6), and this is reproduced on a scale of 100,000 in Figure 4.1.

The 90% cumulative crash probability contours were calculated using the NATS individual risk contour package using a grid of 50m x 50m squares to perform the calculation. The contours correspond to lines of equal crash probability, but given the 'spikiness' of the crash location equations along the runway centreline, and also the finite sampling rate in the calculation, there will still be some uncertainty in the location of this contour.

Although these contours will tend to represent a similar pattern of crash location probability to the plots described in the previous chapter, there are a number of differences which should also be noted. In Chapter 3, the ratio of take-off to landing accidents, and overruns to crashes from flight will necessarily correspond to that of the accident locations in the crash location database. In the case of the 90% contour, this ratio corresponds to the standard proportions used by NATS in the individual risk calculations (which are derived from the proportions in reported airport-related accidents resulting in a total loss in the period 1970 to 1995). Also in fitting the crash location equations to the distribution of data points, a small number of points (3 landing accidents) were excluded as they were considered outliers.

5 Conclusions and discussion

At the request of Amsterdam Airport Schiphol, plots of crash positions, crash densities, and areas based on 90% of crash probability were supplied using information in the NATS crash location database, and the NATS crash location model (a statistical model fitted to the crash location data).

The use of 90% crash probability contours will result in substantially larger Public Safety Zones, than the individual risk based approach recommended by NATS, and adopted by the UK Department for Environment, Transport and the Regions for airports in the UK. Basing a zone on a fixed percentage of accidents will also make it independent of the number of movements at the airport, whereas if zones are based on a particular risk contour (as is the policy in the UK), then other factors being equal, airports with greater movement numbers will have larger Public Safety Zones.

6 References

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