Journal of Air Transport Management 12 (2006) 352–357

Journal of
AIR TRANSPORT
MANAGEMENT

www.elsevier.com/locate/jairtraman

Quantifying and characterising aviation accident risk factors

D.K.Y. Wong*, D.E. Pitfield, R.E. Caves, A.J. Appleyard

Transport Studies Group, Civil & Building Engineering Dept., Loughborough University, Loughborough LE11 3TU, UK

Abstract

This paper compares the exposure of normal flights to a number of meteorological factors that also exist for flights resulting in accidents. The factors examined include visibility, ceiling height, temperature, crosswind, tailwind and instrument or visual meteorological conditions. Differences in exposure to these factors are examined and a measure of accident propensity related to different levels of risk exposure is quantified based on relative accident involvement ratios. Four categories of aircraft accidents relevant to the assessment of airport safety areas are examined.

Keywords: Aviation accidents; Normal operations data; Risk exposure; Relative accident involvement ratio

1. Introduction

The Air France landing overrun accident at Toronto airport in August 2005 as well as the Southwest incident at Chicago Midway in December later that year once again brought the media's attention to the debate on the adequacy of airport safety areas (ASA). ASAs are developed by international as well as local aviation authorities to protect passengers as well as nearby communities at and near airports. Examples of ASAs include the runway strip, runway end safety area (RESA) and runway protection zone. They are intended to mitigate against the risks of landing overruns (LDOR), landing undershoots (LDUS), take-off overruns (TOOR) and crashes after take-off (TOC). These are the major types of accidents that occur during the take-off and landing phases of flight and account for 90% of aviation accidents (Ashford, 1998).

The application and dimensions of ASAs lack international agreement. They are often rigidly determined and insensitive to the risks and needs of specific airports. While insufficient safety areas may endanger lives in case of an accident, their overcautious use may equally limit the potential of the airport. Doubts over the effectiveness and necessity of such areas has been voiced by property developers and environmentalists.

2. Analysis with normal operations data

An important step in assessing the adequacy of ASAs is to evaluate the likelihood of accident occurrence under different airport environments. This involves studying the nature of risk factors and quantifying their criticality. Previous work on the subject has been handicapped by the lack of data on normal, incident-free flights' exposure to risk (Piers et al., 1993; Khatwa and Helmreich, 1998). In the absence of this information, even though the occurrence of a factor (e.g. contaminated runway) may be identified as a contributor to many accidents, it is impossible to know how critical the factor is since many other flights may have also experienced it without incident. With normal operations data (NOD), the number of operations that experience the factor could be taken into account so risk ratios can be generated and their importance quantified.

A previous attempt to use NOD to assess aviation accident risk by Enders et al. (1996) concerned approach and landing accidents and compared the presence of high terrain and the availability of various airport navigational aids between normal flights and accidents. Kirkland et al. (2004) modelled the occurrence of aircraft overruns based on the difference in weight and runway criticality between

*Corresponding author.
E-mail address: k.y.wong@lboro.ac.uk (D.K.Y. Wong).

0969-6997/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jairtraman.2006.09.002

normal and accident flights. While the two pieces of work contribute to a better understanding of the factors behind accident occurrence, both identified exposure to meteorological conditions as a prime area warranting further research.

Here we compare normal flights' exposure to meteorological conditions with the equivalent for accident flights. Specifically, we explore whether accident flights and normal flights are exposed to statistically different meteorological conditions, and if so, measure the accident propensity under different levels of exposure. The first objective is achieved by chi-square analysis and *t*-tests while accident propensity is calculated using the relative accident involvement ratios (RAIR). Key weather parameters are thus quantified and characterised as aviation accident risk factors. The analysis was carried out independently for the four accident types related to ASAs, such that their occurrence characteristics may be individually understood and contrasted. The specific results of this paper pertain to a preliminary analysis.

3. Data

A comprehensive database of four accident types since 1982 is constructed using data from the US National Transportation Safety Board (NTSB). Intuitively, not all accidents are influenced by meteorological conditions, e.g. a purely mechanically induced accident. Not all accidents, therefore, are relevant to understanding the nature and criticality of weather parameters as risk factors. If all accident cases were used in the analysis, the "redundant" cases would lead to inaccurate results and misleading conclusions on the criticality of weather-related risk factors. To identify cases relevant to this research, the NTSB list of accident causes and factors was used. The full list of causes and factors were reviewed to identify all meteorological events, including icing conditions. An accident that involves any of these events is considered as weather-related—283 such accidents were identified.

The US Federal Aviation Administration (FAA, 2002) Aviation System Performance Metrics (ASPM) database is used as a source of data on normal flights' exposure to weather conditions. ASPM records in 15-min segments the weather condition, the particular combination of runways used for take-offs and landings as well as the arrival and departure counts. Movements at nine airports, for selected months over two years, are used as the NOD sample. The months of February, May, August and November were used to represent the seasonal changes in weather and the airports selected also reflect regional meteorological differences. Table 1 lists the sample airports and their respective sampling periods. The sample includes 323,487 normal flight operations.

The metrological information provided by ASPM includes general weather, i.e. instrument meteorological condition (IMC) or visual meteorological condition (VMC), lowest ceiling height, visibility, temperature, wind direction and wind speed. Since the runway configuration is also available, the tailwind and crosswind factors are calculated. The same information was computed for accidents using data from the NTSB accident database.

Table 1
Airports and sample period

Airport code	Sample month
LGA	August 2004
MSP	February 2004
ATL	May 2004
TPA	November 2004
PHX	August 2003
SEA	Febebruary 2003
SFO	May 2003
SLC	November 2003
MCO	August 2002

To ensure accuracy, an accident was eliminated if its weather information is recorded from an observation facility that is more than 10 nautical miles from the accident site. Thirty accidents were removed as a result, with 253 remaining (93 LDUS, 28 TOCs, 19 TOORs and 113 LDORs). The accident and normal flights data were also reconfigured to ensure consistency and comparability.

4. Accident data versus nod analysis

4.1. Comparisons of means

As an initial investigation of the difference in exposure to weather parameters between normal and accident flights, chi-square and *t*-tests were performed on the two sets of data to detect significant differences in means and the related effect sizes. This analysis was conducted on each accident type independently. Take-off accidents are compared to normal take-off operations and landing accidents to normal landing operations (Table 2).

The chi-square analysis on instrument/visual meteorological conditions shows it to have a significant association with the occurrence of all accident types. The phi statistic, however, suggests a stronger relationship between general weather and landing accidents than their take-off counterparts. The odds ratios indicate that while an accident is approximately 5.4 times more likely under IMC than VMC for landing accidents, take-off accidents are only about 3 times more likely.

The *t*-test results show significant differences in the means of visibility, ceiling and temperature between accident and normal flights, suggesting that the two groups of flights are exposed to generally different meteorological conditions. For example, visibility was significantly lower for crashes after take-off than normal take-off operations. The strength of association is not uniform across parameters and accident types. Both visibility and ceiling have high *r*-values but while effect size appears fairly consistent across all accident types for ceiling, visibility's strength of