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The development of a more risk-sensitive and flexible airport safety area strategy: Part I. The development of an improved accident frequency model

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ABSTRACT

This two-part paper presents the development of an improved airport risk assessment methodology aimed at assessing risks related to aircraft accidents at and in the vicinity of airports and managing airport safety areas (ASAs) as a risk mitigation measure. The improved methodology is more quantitative, risk-sensitive, flexible and transparent than standard risk assessment approaches. As such, it contributes to the implementation of Safety Management Systems at airports, as stipulated by the International Civil Aviation Organisation.

The first part of the paper presents the methodological advances made in the development of accident frequency models; namely the building of a single comprehensive database of all relevant accident types, the collection and use of normal operations data in quantifying the criticality of a series of risk factors, and modelling accident frequency using multivariate logistic regression. The resulting models have better goodness-of-fit, sensitivity and specificity than standard risk assessment methodologies.

1. Introduction

International as well as local aviation authorities have developed airport safety areas (ASA) at and around airports to protect passengers as well as nearby communities from accidents that occur during the take-off and landing phases of flight. ASAs could be grouped into two families – aerodrome design ASAs and land-use planning ASAs.

In terms of aerodrome design ASAs, there is an internationally agreed framework on airport design set out in Annex 14 to the Convention on International Civil Aviation (ICAO, 1999). National aviation authorities, however, may deviate from Annex 14 or develop different standards. For instance, the FAA's Advisory Circular 150/5300-13 on Airport Design is a parallel framework to Annex 14 (FAA, 2004), as is the UK's CAP 168. The notion of ASAs, therefore, tends to differ from country to country. Under ICAO Annex 14, safety areas relevant to take-off and landing accidents include the Runway End Safety Area and Runway Strip. The concepts of the Runway Strip and the RESA are combined under FAA rules, which define the Runway Safety Area. The FAA also specifies a Runway Protection Zone, which has no equivalent in ICAO Annex 14.

Land-use planning ASAs result from regulations and guidelines that govern the way land is used around runways. There are relatively few national regulations on land-use near airports, let alone an international framework. The most notable jurisdictions that have instituted land-use planning ASA include the Netherlands, the United Kingdom and certain states in the US such as California. The regulations concerned are often formed from the concept of risk contours and prohibiting development within.

Wong (2007) highlighted a number of fundamental deficiencies concerning airport safety area (ASA) regulations. These include the number of risk factors considered in the formulation of ASA policies; their rigid, prescriptive and compartmentalised nature; opacity in rule-making and the lack of review mechanisms; a piecemeal and reactive approach; a fragmented oversight regime; a "tick the box" compliance mentality on behalf of the regulated parties; and the overall regulatory rationale. Above all, current ASA requirements stipulate average levels of safety across vastly different airports, contributing to a significant mismatch between actual risk exposure and safety margin provision. The need for a more risk-sensitive, flexible and effective strategy of using and regulating ASAs is clear. As the first of a two-part paper, this paper presents the development of an accident frequency model that would be central to the improved utilisation and requirements of ASAs. The frequency model in an ASA-related risk assessment considers the probability of an accident occurring in the vicinity of an airport. This follows established practice of risk assessment in the field (Piers, 1996; DfT, 1997; Hale, 2002).

The following section puts forward the methodological advances made in this paper, namely an integrated approach, the building of a single comprehensive accident database, the expanded use of normal operations data (NOD) and the inclusion of new risk factors. The first two advances guided the way the

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accident database was developed (described in Section 3) and the use of new sources of NOD (described in Section 4) allowed the inclusion of the additional risk factors.

2. Advances in methodology

The model developed offers a new approach to accident frequency modelling addressing some key deficiencies of current risk mitigation measures and risk assessment methodologies. These advances were made possible by expanding the traditional scope of airport risk assessment studies, building comprehensive and compatible accident and normal operations databases and developing multi-dimensional quantitative models that explicitly take into account previously neglected risk factors. These are detailed below.

2.1. Integrated approach

This research takes an integrated approach to airport risk assessment rather than focusing on a single stakeholder or element of the aviation system. The study crosses existing regulatory boundaries and considers aircraft crash risk on both sides of the airport fence, reflecting the geographically continuous nature of accident risk. This facilitates complementary policies in aerodrome design, land-use planning and operational parameters to be developed in lieu of the current fragmented and compartmentalised risk control measures. It has never been done before and avoids the difficulties of drawing from studies with different objectives and assumptions. The need for such an approach is evidenced in the responses to the New Zealand Civil Aviation Authority's consultation on its Runway End Safety Area (RESA) policy where respondents suggested that more aerodrome physical requirements be assessed along with the RESA in a single coherent study (Watson, 2005).

2.2. Single comprehensive database

Another advance made by this study is the comprehensive accident database developed. Unlike previous studies that focused on a specific type of accident, such as approach-and-landing accidents (Enders et al., 1996; Khatwa and Helmreich, 1998), third-party accidents (DfT, 1997) or overruns (CAA, 1998), all accident types that are implicated by ASAs are included in this study – take-off and landing overruns, undershoots, veer-offs as well as crashes after take-off. This facilitates the assessment of all accident types in a coherent manner, rather than being based on multiple databases with different inclusion criteria. All accident types are sampled from the same period and for the same parameters using a set of standardised rules. More definitive conclusions on ASA policies could therefore be drawn. For example, Kirkland's work (Kirkland et al., 2003) considered overruns but not undershoots or crashes after take-off. Having included the latter two types of accidents for modelling, the current study provides the complete analysis of RESA and (Public Safety Zone) PSZ needs.

2.3. Normal operation risk exposure

Another methodological advance is the use of normal operations (i.e. non-accident flight) data for risk modelling, specifically data related to flight operations and meteorological conditions. Various studies have already identified the lack of normal operations data (NOD) as a major obstacle to the development of quantitative risk models (DOT, 1979; Piers et al., 1993; Khatwa et al., 1996; Khatwa and Helmreich, 1998; Eddowes et al., 2001; Li et al., 2001). For example, a NLR study on the impact of crosswind on aircraft operations noted that "the significance of [risk] factors can only be established when the number of non-accident flights, under identical circumstances is known" (Van Es et al., 2001). Enders et al., (1996) stated that the unavailability of NOD hampered the calculation of accident occurrence rates and the ICAO concurs that the absence of NOD "compromises the utility of safety analysis" (ICAO, 2006). Indeed, in the absence of information on risk exposure, even though the occurrence of a factor, e.g. contaminated runway, could 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 the factor without incident. With NOD, the number of operations that experience the factor singly and in combination with other factors could be calculated, so risk ratios could be generated and the importance of risk factors quantified. This would allow the allocation of resources for safety improvement to be prioritised (Enders et al., 1996).

This paper represents a step forward in the field of airport risk assessment in collecting a large and representative sample of disaggregate NOD covering a range of operational and meteorological risk factors, allowing their criticality to be quantified. Incorporating this risk exposure information into the accident frequency model enhances its predictive power and provides the basis for formulating more risk-sensitive and responsive ASA policies. Accident frequency models need no longer rely on simple crash rates based on just aircraft, engine or operation type. As discussed below, factors previously ignored by airport risk assessments and ASA regulations are accounted for using the models developed in this study. Moreover, this normal operations database is not only valuable for the current project but can also be used for future studies.

2.4. Factors considered

In addition to airline Flight Operational Quality Assurance (FOQA) or Flight Data Recorder (FDR) data through which airlines use to monitor aircraft performance, only in human factor and crew resource management analysis is the use of NOD relatively established. Khatwa and Helmreich (1998) used Line Operations Safety Audits (LOSA) to analyse crew errors during non-accident flights. Work at the University of Texas at Austin (Helmreich et al., 1999; Klinect et al., 1999) also used LOSAs to build conceptual models that represent the operating environment. Beyond human error analysis, the use of NOD in risk assessment is limited, especially for airport-related risks. Enders et al. (1996) and Roelen et al. (2000) used aggregate NOD to establish risk ratios for various risk factors such as the availability of Terminal Area Radar and other airport navigational aids. Many attempts to incorporate NOD in risk assessment failed because the available risk exposure data does not allow subdivision in movements based on the risk factors of interest (Piers 1994, 1998). Kirkland et al. (2003) broke new ground in the use of disaggregate NOD for assessing aircraft overrun risk. Using a limited sample of NOD, three overrun risk models were built. Two of them assessed overrun risk based on aircraft weight as a percentage of the maximum take-off and landing weight respectively and the third model considered landing overrun risk based on the distance of excess runway available. Although some insightful conclusions were drawn, the number of risk factors that could be modelled remained small.

One notable gap in research is the quantification and modelling of the criticality of meteorological risk factors to accident occurrence. The lack of data on flights' exposure to meteorological conditions meant traditional risk assessment had to rely on qualitative judgements (Eddowes et al., 2001) or simply ignore meteorological conditions as risk factors, as do most ASA policies. Although Enders et al. (1996) acknowledged that adverse weather conditions is one of the most regularly cited factors in accident reports, they were unable to include the terms in their analysis. Kirkland also cited