

## An Approach on Take-off and Landing Related Aircraft Accidents Involving New Considerations

Hamed Sheikhpour<sup>1</sup>, Gholamreza Shirazian<sup>2</sup> and Ebrahim Safa<sup>3</sup>

<sup>1</sup> M.Sc. Student of transportation engineering, Islamic Azad University, South Branch of Tehran, Iran

<sup>2</sup> Assistant Professor, Shomal Science and Technology University of Amol, Iran

<sup>3</sup> Assistant Professor, Islamic Azad University South Branch of Tehran, Iran

**Abstract.** This paper presents a new approach on take-off and landing related aircraft accident risk assessment methodology considering particular issues. In the first place, it considers the significance level of some contributing risk factors in face of various aircrafts involved-that has been separated in this study according to maximum gross weights from light to heavy aircrafts-. Such a consideration can help airport authorities implementing the most effective risk mitigation measures with regard to the airport fleet composition using cost-benefit analysis.

In addition, in this study, the new factor 'airframe hours', that is the total number of operating hours on the aircraft airframe, brought into account in the evaluation of accident risk factors. This factor, seems not to be considered in the previous studies. With respect to the large extent of airframe hours of aircrafts in use worldwide, and the number of aircrafts with the relatively high airframe hours within some developing countries operating fleets, it can be useful for aircraft manufactures as well as aviation safety auditors establishing criterions to improve the safety level.

**Keywords:** Aircraft accidents, Airframe hours, Maximum gross weight, Logistic regression.

### 1. Introduction

It is obvious that the aim of all risk assessment programs is to identify affecting risk factors, and find their relevant impact scale in prioritizing risk mitigation measures to improving safety levels.

Around 80 percent of jet aircraft accidents occur during take-off and landing phases of flight and hence close to an airport. Passengers, as well as nearby communities are, therefore at a heightened risk of death or serious injury. (1)

In the occurrence of any take-off and landing aircraft accident, there are different influencing parameters such as airport infrastructures, type of aircraft involved, meteorological conditions, as well as human factors differ from one situation to another that make the analysis of aircraft accident probabilities much complicated. In this regard, there has been continues efforts obtaining more realistic and applicable risk assessment methodologies better address safety issues implementing risk mitigation measures.

Aviation authorities whether local or international, have responded landing and take-off related accidents probability in the content of airport safety area (ASA) requirements to protect passengers as well as people on the ground in the vicinity of airports.

In terms of aero design ASAs, there is an internationally agreed framework on airport design in annex 14 of international civil aviation organization (ICAO, annex14 5th edition, 2009). FAA advisory circular 150/5300-13 on airport design is a parallel framework (FAA, 2004). As in UK, there is civil aviation publication CAP (CAP 168, 2006; CAP 642, 2011). The scope of ASA may differ from country to country and even place to place. In case of national jurisdiction, the best known paradigms that have instituted land use planning ASA include the Netherlands and United Kingdom-in term of public safety zones (PSZs) - and certain states in the US such as California. The regulations concerned are often formed from the concept of

risk counters and prohibiting developments within. Having a good estimate of near airport aircraft accidents probability is an unavoidable part of ASA regulatory process and would affect significantly in the effectiveness level of imposed constraints.

Wong et al. (2008) have developed an accident frequency model building on a single database of all relevant accident types with collection and use of normal operation data, not including airframe hours factor. There are also some previous studies that focused on a specific type of accident, such as approach-and-landing accidents (Enders et al., 1996; Khatwa and Helmreich., 1998). Kinderland's work (Kinderland et al., 2003) considered landing overruns but not any other types of accidents. The Britain department for transport circular (Dft) considered third party risk accidents. Dft has updated its circular on its control of development in airport public safety zone (Dft, 2010), but it's also not about the aircraft specifications such as airframe hours. This regulation has included all types of aircraft together not concerned about type of aircraft involved.

In this study, authors considering certain parameters such as the new factor 'airframe hours' with respect to type of aircraft involved in occurrence of take-off and landing accidents, suggest to estimate accident probability with respect to any specific event conditions.

For the aircrafts, with different airframe hours, determining the percentage of occurrences having a risk higher than a selected level can help aircraft manufactures and local airport authorities obtaining criteria in evaluating the level of subjected risk in certain aircrafts and emerging constraints to old operating aircrafts in deal with cost-benefit analysis.

An overview on the main contributing risk factors due to type of aircrafts with different specifications, such as maximum gross weight seems to be useful at least for the following reasons:

1. since some airport characteristics such as: number and orientation of runways, navigational aids, fleet composition as well as meteorological conditions, may widely vary from airport to airport; it can be useful in prioritizing risk mitigation measures, based on the most effective parameters involved in certain circumstances.

2. One of the products of such researches is a summary of factors or anomalies frequently present during aircraft Take off and Landing. Some of these factors may greatly help pilots making good decisions about attempts to go around if the information and risk processing capabilities are provided in real-time.

3. In considering the different types of aircraft defects with distinct maximum gross weight in the face of one or a combination of different risk factors, which can lead to effective improvements in aircraft performance.

## **2. Materials, Data, Method**

Aviation risks' modelling always has been a challenge. Accident investigation reports seldom contain the comprehensive information required to improve modelling. Even when there are standard forms and reports, many of the existing fields are not filled by the reporter. In addition, some important parameters associated with events relevant to risk studies are not available in the standard forms, or the investigator is not aware of their importance for modelling risks. The large quantity of causal factors and the scarceness of reliable data limit the accuracy of models developed. Modelling also depends on some judgment from the analyst. The assumptions made in the modelling can also influence the results. Therefore, it is important to develop more comprehensive guidance related to the parameters required to improve risk modelling in the future.

The model developed offers a new approach to accident frequency modelling addressing effective factors and role of involved aircraft in the most probable types of accident. These advances were made possible using multidimensional quantitative models that take into account the most significant relevant risk factors.

This model incorporates several risk factors identified for all types of during take-off and landing aircraft accidents. These include a range of meteorological conditions, operational parameters, and existing features and obstacles present in the runway safety area (RSA), and its surroundings due to type of aircraft involved.

### **2.1. Accident Database**

The US represents the largest national aviation system in the world in terms of air traffic, aircraft and airfields. The US NTSB is also the largest aviation accident investigator with an established database of

accidents that have been investigated in a relatively systematic and consistent manner. The preference for studying US aviation safety data has been echoed by other studies (2).

From this source all available relevant information due to take-off and landing related accidents, was extracted, with respect to the two containing parameters: phase of flight and occurrence code. Certain variables required additional calculation based on available data. For instance, crosswind strength was computed from data on wind direction, wind velocity and true runway orientation. The database therefore consists of all relevant cases that took place in the US between 1982 and 2010.

A number of other criteria were used to filter the NTSB accident database to identify the accidents of interest. These filters, in essence, involve accidents with minimal consequences. They were developed considering data availability and quality, the need for statistical significance, relevance to large and small airports as well as the criteria used by previous airport risk assessment studies (2). The final database encompassed 1397 cases, classifying in three categories, of which 736 are light aircrafts with maximum gross weight less than 34500lb, 407 medium aircrafts with maximum gross weight between 34000lb and 162000lb and 254 heavy aircrafts with maximum gross weight more than 162000lbs.

Instead of focusing on a specific type of accident, all accident types that are implicated by ASAs are included in this study. This facilitates the assessment of all accident types in a coherent manner, rather than being based on multiple databases with different inclusion criteria. Having a small number of categories also helps to increase the statistical significance of subsequent analyses and models. All accident types are sampled from the same period and for the same parameters. More definitive conclusions could therefore be drawn. This facilitates the analysis by cause rather than consequence.

The data fields of the accident database covered a multitude of parameters including aircraft, weather conditions, and flight as well as airport characteristics. Econometric models are a good approach to analyze the impact of certain variables on accident frequency. Multivariate logistic regression was the preferred statistical procedure for this study. This technique is suited to models with multiple predictor variables that include a mixture of continuous and categorical parameters.

Collecting a set of factors involved in the accidents, forward stepwise logistic regression using NLogit statistical software -starting with no variables in the model, trying out the variables one by one and including them if they are statistically significant- was used to calibrate the risk models. The predictor variables were entered by blocks, each consisting of related factors, such that the change in the model's significance could be observed as the variables were included. There were some correlations among some predictor variables in the primary groups of parameters. Removing non-significant variables along with incorporating related variables into single block resulted in an 8 block set of interested factors. Table 1, explains how each variable is measured or categorized for input into the logistic regression.

Table1: Blocks of Variables Involved in Accident Probability Modeling

Variable	Variable Type	Categorical Groupings/Measuring Unit
Ceiling Height	Continues	100ft
Visibility	Categorical	<4 statute miles (SM) 4-8 SM >8 SM
Precipitation	Categorical	Snow/Rain/Precipitation No Precipitation
Crosswind	Continues	Knots
Dawn/Dusk	Categorical	Dawn/Dusk Not Dawn/Dusk
Storm	Categorical	Storm No Storm
Airframe Hours	Continues	1000 Hours

Visibility was entered into the model as a three-level categorical variable having a more practical decision criterion. Airframe hours- that I the total number of operating hours on the aircraft airframe- derived in two-level variable after dividing true values by 1000. Besides, ceiling height certain numbers divided by 100 before including in the frequency model.

### 3. Results

Contributing table 1 variables in a multinomial discrete logistic regression iteration based on the log likelihood function using 'NLogit 4.0' statistical software, calibrated specific model coefficients were achieved. With model coefficients, the probability for accident occurrence could be obtained. For each accident type:

$$P(\text{Accident Occurrence}) = 1 / (1 + e^{-z})$$

The utility function from the multinomial logistic discrete choice modelling is:

$$U(\text{Light, Medium, Heavy}) = \langle a_0, a_1, 0 \rangle + \langle b_0, b_1, 0 \rangle * (\text{Visibility} < 4) + \langle 0, c_1, 0 \rangle * (4 < \text{Visibility} < 8) + \langle 0, 0, 0 \rangle * (\text{Visibility} > 8 \text{NM}) + \langle 0, d_1, d_2 \rangle * (\text{Airframe Hours}) + \langle 0, 0, e_2 \rangle * (\text{Ceiling Height}) + \langle 0, 0, f_2 \rangle * (\text{Precipitation}) + \langle 0, 0, 0 \rangle * (\text{Icing Condition}) + \langle g_0, 0, g_2 \rangle * (\text{Crosswind}) + \langle 0, h, 0 \rangle * (\text{Dawn/Dusk}) + \langle 0, 0, i_2 \rangle * (\text{Storm})$$

The backward stepwise regression procedure has not included parameters that are not significant for the particular risk models. All remaining parameters are significant at the 95% confidence interval.

Table 2 represents the obtained model coefficients of contributing risk factors for three categories of aircrafts and their relevant t-statistics and p-values indicated significance confidence level of incorporating parameters. Remembering that, the t-statistic is just the estimated coefficient divided by its own standard error. Thus, it measures "how many standard deviations from zero" the estimated coefficient is, and it is used to test the hypothesis that the true value of the coefficient is non-zero, in order to confirm that the independent variable really belongs in the model. If the p-value is greater than 0.05--which occurs roughly when the t-statistic is less than 2 in absolute value--this means that the coefficient may be only "accidentally" significant.

Table 2: calibrated model Coefficients

Variable	Coefficient	Standard Error	Coefficient/ St. Err.	P[ z >z]
A0	4.80149	0.31111	15.434	0.0000
A1	1.88488	0.32725	5.760	0.0000
B0	-1.32177	0.29063	-4.548	0.0000
B1	-1.85061	0.30760	-6.016	0.0000
C1	0.99242	0.22967	4.321	0.0000
D1	0.12371	0.00943	13.124	0.0000
D2	0.12204	0.01009	12.091	0.0000
E2	0.00704	0.00224	3.140	0.0017
F2	0.52805	0.26255	2.011	0.0443
G0	-0.02870	0.00658	-4.361	0.0000
G2	0.01927	0.00676	2.849	0.0044
H1	1.50554	0.26625	5.655	0.0000
I2	1.68896	0.55326	3.053	0.0023

Model log likelihood at convergence = -677.2513

Log likelihood market share (Lc) = -977.3189

Adjusted R2 (ρ2) = 0.3026

Percent of correctly predicted cases = 51.18%

The numerical values above indicate goodness of fit confidence scale of the represented model. All the t-statistics absolute values are above 2 and p-values less than 0.05. The wide existence distance between the

market share log likelihood and the convergence one tells about the prediction power of incorporating variables.

From the calibrated coefficients in table 2, the z for the three nominated aircraft types are:

The z for light aircrafts probability formula is:

$$z = 4.80149 - 1.32177(\text{Visibility} < 8\text{NM}) - 0.02870(\text{Crosswind})$$

z for medium aircrafts is:

$$z = 1.88488 - 1.85061(\text{Visibility} < 8\text{NM}) + 0.99242(4 < \text{Visibility} < 8\text{NM}) + 0.12371(\text{Airframe Hours}) + 1.50554(\text{Dawn/Dusk})$$

And for heavy aircrafts:

$$z = 1.2204(\text{Airframe Hours}) + 0.00704(\text{Ceiling Height}) + 0.52805(\text{Precipitation}) - 0.02870(\text{Crosswind}) + 1.68896(\text{Storm})$$

Using the formulae above and the measurement details from Table 1, type of accident probability of any specific flight, in the case of an accident occurrence, can be assessed. For categorical variables, only multiply the relevant coefficients by 1 and the irrelevant ones by 0.

From the obtained formula, it is clear that the three cases do not contain identical parameters. For instance crosswind only features in the light aircrafts formula and heavy's, airframe hours also appears in the medium and heavy aircrafts, but not in the lights.

#### 4. conclusion

In the process of take-off and landing aircraft accidents risk assessment with respect to aircraft involved, as described in this study, there are distinct impact coefficients of different contributing parameters between aircrafts with different maximum gross weights. Such a consideration can help any particular airport -with the relevant fleet composition and different aircrafts using runways- implementing the most effective risk mitigation measures and safety improvement plans with respect to the associated risk factors.

The significant role of 'airframe hours' in the two of three aircraft categories obtained accident models (medium and heavy aircrafts), seems not to be negligible. Since there is a much more catastrophic consequence of a medium or heavy aircraft accident compared with light aircrafts, with maximum gross weight less than 34000lbs, airport authorities along with aircrafts manufactures can take this factor into account in the safety programs associated with safe-life of operating aircrafts.

#### 5. References

- [1] Airport watch briefing. Third party risk around airport. March 2009
- [2] D.K.Y. Wong, D.E. Pitfield, R.E. Caves, A.J. Appleyard. The Development of a more Risk- Sensitive and Flexible Airport Safety Area Strategy. Safety Science 47, 2009.
- [3] ACRP Report 3. Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas
- [4] Dft, 2010. Third party risk near airports and public safety zone policy. Department for transport, London.
- [5] ICAO, aerodromes. Annex 14 to the convention on international civil aviation. 15th edition, 2009.
- [6] [6] Proposed changes for civil aviation publication (CAP) 232- Aerodrome survey requirements. 14 October 2011.
- [7] Khatwa, R. Helmreich, R. Analysis of critical factors during approach and landing in accidents and normal flight. Final report, 1998.