# A QUALITATIVE RISK SEVERITY ASSESSMENT FOR AIRCRAFT ACCIDENT IN CIVIL AIRPORT

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## ABSTRACT

A practical problem in air transport is how to manage risk and safety. In recent years have developed special technical and managerial skills to the systematic, forward looking identification and control of hazards throughout the life cycle of a project, program, or activity. Safety Management System (SMS) involves the identifying, evaluating, and addressing of hazards or risk. Its sole purpose is to prevent accidents [1].

Once the safety risk of an unsafe event or condition has been assessed in terms of probability, the second step in the process of bringing the safety risks of the consequences of hazards under organizational control is the assessment of the severity of the consequences of the hazard if its damaging potential materializes during operations aimed at delivery of services. This is known as assessing the safety risk severity.

Safety risk severity is defined as the possible consequences of an unsafe event or condition, taking as reference the worst foreseeable situation.

This paper proposed a qualitative methodology for the risk severity assessment for different class of aircraft, which is based on historical data of the Aviation Safety Network database, from 1 January 1980 to 31 December 2010.

The accidents considered in this study are: overshoot; landing veer-off; take-off veer-off; landing overrun; take-off overrun; ground collision with other aircraft in landing; and ground collision with other aircraft in take-off.

The severity of the possible consequences of an unsafe event or condition, taking as reference the worst foreseeable situation, was be assessed using the FAA's Accident severity classification (2000).

**Keywords:** Risk assessment, accident severity, aircraft classification, historical data.

## INTRODUCTION

In November 2005, the International Civil Aviation Organization (ICAO) amended Annex 14, Volume I (Airport Design and Operations) to require member States to have certificated international airports establish an SMS. The fundamental element of an SMS is safety risk management process.

The significant concepts regarding safety risk management defined of the Safety Management Manual ICAO [2] can be summarized as follows:

a) There is no such thing as absolute safety — in aviation it is not possible to eliminate all safety risks.
b) Safety risks must be managed to a level "as low as reasonably practicable" (ALARP).
c) Safety risk mitigation must be balanced against:
   - time;
   - cost; and
   - the difficulty of taking measures to reduce or eliminate the safety risk (i.e. managed).
d) Effective safety risk management seeks to maximize the benefits of accepting a safety risk (most frequently, a reduction in either time and/or cost in the delivery of the service) while minimizing the safety risk itself.
e) The rationale for safety risk decisions must be communicated to the stakeholders affected by them, to gain their acceptance.

Figure 1 presents the ICAO safety risk management process in its entirety. After a safety concern has been perceived, hazards underlying the safety concern and potential consequences of the hazards are identified and the safety risks of the consequences are assessed in terms of probability and severity, to define the level of safety risk (safety risk index).

Once the safety risk of an unsafe event or condition has been assessed in terms of probability, the second step in the process of bringing the safety risks of the consequences of hazards under organizational control is the assessment of the severity of the consequences of the hazard if its damaging potential materializes during operations aimed at delivery of services. This is known as assessing the safety risk severity [2].

Safety risk severity is defined as the possible consequences of an unsafe event or condition, taking as reference the worst foreseeable situation. The assessment of the severity of the consequences of the hazard if its damaging potential materializes during operations aimed at delivery of services can be assisted by questions such as:

a) How many lives may be lost (crews, passengers, third-party)?

b) What is the likely extent of property or financial damage (direct property loss to the operator, damage to aviation infrastructure, third-party collateral damage, financial and economic impact for the State)?
c) What is the likelihood of environmental impact (spillage of fuel or other hazardous product, and physical disruption of the natural habitat)?
d) What are the likely political implications and/or media interest?

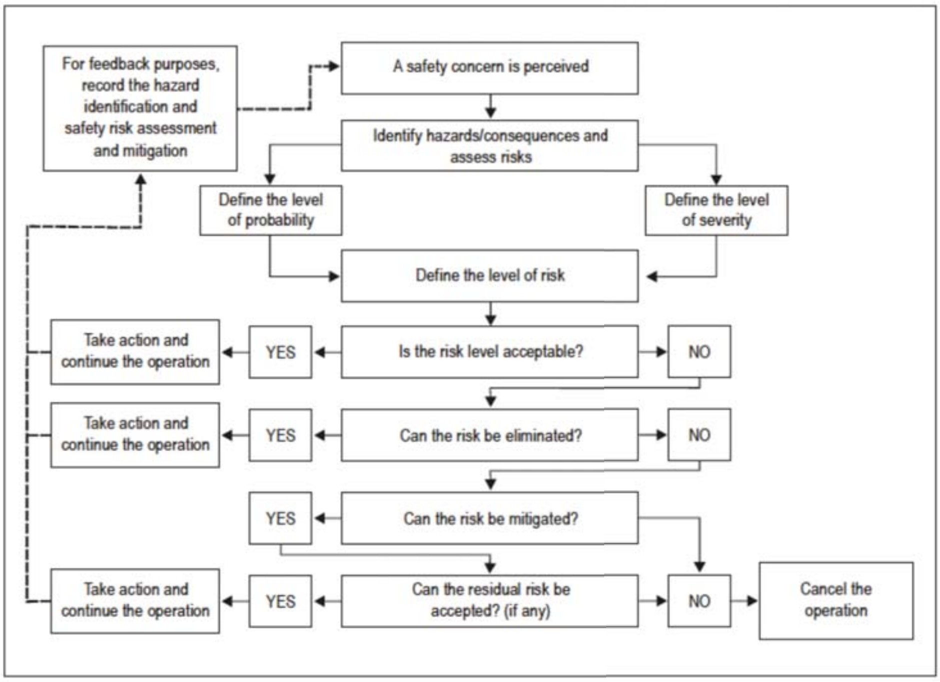



Figure 1 ICAO safety risk management process [2]

The original objective of this study was to collect historical data related to accident and serious incident to aircraft associated with airport operations to develop a comprehensive and organized database with editing and querying capabilities, containing critical parameters, including aircraft, airport, runway, phase of flight, and causal factor and consequence information that could assist the evaluation of runway safety areas. The authors believe that this database will be useful to define the parameters needed for the Risk Assessment procedure.

The research team extended the study objective to include the estimation of severity of the aircraft accident associated with airport operations differentiated for class of aircraft, through a methodology based on historical data contained in database.

## THE DATA

The data used in this study were collected in a database. This database contains records of the ANS (Aviation Safety Network) database which according to the following criteria:

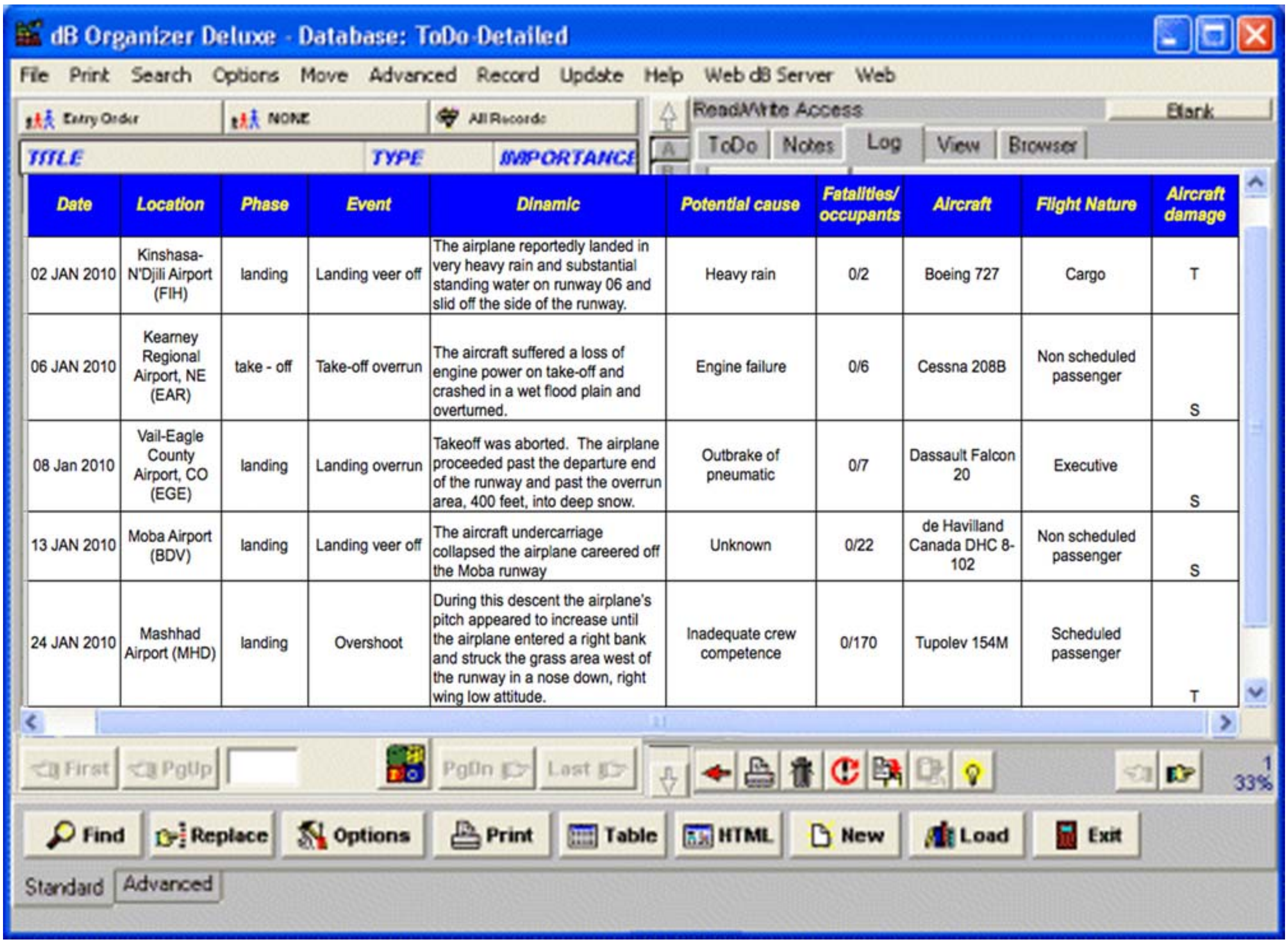
1. Occurrence in the period 2000-2010;
2. Only accident and serious incident are included;
3. Accidents to helicopters, military aircraft and tourist flights are excluded;
4. Accidents only during landing, go-around, take-off, taxi and parking are included; and
5. Sabotage, terrorism and military actions are excluded.

The Aviation Safety Network is a private, independent initiative founded in 1996. It covers accidents and safety issues with regards to airliners, military transport planes, and corporate jets, and contained descriptions of more than 10.700 incidents, hijackings, and accidents. Most of the information are from official sources (civil aviation authorities and safety boards), including aircraft production lists, ICAO ADREPs, and country’s accident investigation boards.

In ANS’s database for every event is available a report, which contains information about:

- date;
- airport;
- type of aircraft;
- phase of flight;
- nature of flight;
- n° of fatalities/ n° on board;
- aircraft damage; and
- dynamics.

The database used for present study includes only those hazards to aircraft associated with airport operations (e.g., landing, take-off, taxi and parking). Using such criteria, 1041 accidents and serious incidents were selected to compose the database which are derived from the information that formed the basis of this work. The figure 2 shows a screenshot of the database and the Table 1 summarizes the number of events for year and phase of flight.



| Date | Location | Phase | Event | Dinamic | Potential cause | Fatalities/ occupants | Aircraft | Flight Nature | Aircraft damage |
|---|---|---|---|---|---|---|---|---|---|
| 02 JAN 2010 | Kinshasa-N'Djili Airport (FIH) | landing | Landing veer off | The airplane reportedly landed in very heavy rain and substantial standing water on runway 06 and slid off the side of the runway. | Heavy rain | 0/2 | Boeing 727 | Cargo | T |
| 06 JAN 2010 | Kearney Regional Airport, NE (EAR) | take - off | Take-off overrun | The aircraft suffered a loss of engine power on take-off and crashed in a wet flood plain and overturned. | Engine failure | 0/6 | Cessna 208B | Non scheduled passenger | S |
| 08 Jan 2010 | Vail-Eagle County Airport, CO (EGE) | landing | Landing overrun | Takeoff was aborted. The airplane proceeded past the departure end of the runway and past the overrun area, 400 feet, into deep snow. | Outbrake of pneumatic | 0/7 | Dassault Falcon 20 | Executive | S |
| 13 JAN 2010 | Moba Airport (BDV) | landing | Landing veer off | The aircraft undercarriage collapsed the airplane careered off the Moba runway | Unknown | 0/22 | de Havilland Canada DHC 8-102 | Non scheduled passenger | S |
| 24 JAN 2010 | Mashhad Airport (MHD) | landing | Overshoot | During this descent the airplane's pitch appeared to increase until the airplane entered a right bank and struck the grass area west of the runway in a nose down, right wing low attitude. | Inadequate crew competence | 0/170 | Tupolev 154M | Scheduled passenger | T |

Figure 2 – Screenshot of database

Table 1 – Number of events for phase of flight and years

| | Parking | Taxi | Take-off | Landing | Total |
|---|---|---|---|---|---|
| 2000 | 12 | 9 | 29 | 47 | 97 |
| 2001 | 13 | 6 | 12 | 44 | 75 |
| 2002 | 13 | 5 | 21 | 49 | 88 |
| 2003 | 15 | 10 | 21 | 56 | 102 |
| 2004 | 6 | 5 | 31 | 47 | 89 |
| 2005 | 16 | 3 | 17 | 63 | 99 |
| 2006 | 17 | 4 | 19 | 64 | 104 |
| 2007 | 14 | 5 | 31 | 66 | 116 |
| 2008 | 9 | 11 | 21 | 53 | 94 |
| 2009 | 9 | 6 | 12 | 65 | 92 |
| 2010 | 7 | 3 | 18 | 57 | 85 |
| Total | 131 | 67 | 232 | 611 | 1041 |

Analysis the information contained in the database has gone back to the aircraft accident likely, associated with airport operations. This event are classified into seven scenarios:

- Landing veer-off;
- Landing overrun;
- Landing overshoot;
- Take-off veer-off;
- Take-off overrun;
- Ground collision with other aircraft in landing; and
- Ground collision with other aircraft in take-off.

Each of these scenarios is defined as follows [4]:

➢ The overrun incident is a "longitudinal deviation" in which the longitudinal deviation is described by the longitudinal distance travelled beyond the accelerate/stop distance available (for take-off events), and beyond the landing distance available (for landing events).

➢ The overshoot incident is a "longitudinal deviation" in which the "longitudinal deviation" is described by the longitudinal distance the aircraft undershoots the intended runway threshold. A touchdown off the runway surface:
  - An undershoot/overshoot of the runway occurs in close proximity to the runway and also includes offside touchdowns and any occurrence where the landing gear touches off the runway surface.
  - Off-airport emergency landings are excluded from this category.
  - To be used for occurrences during the landing phase.

➢ The veer-off incident is a "lateral deviation" in which the lateral deviation is the lateral distance to the extended runway centerline.

➢ The Ground collision with other aircrafts includes ground collisions resulting from events categorized under Runway Incursion (RI) or Ground Handling (RAMP).

For each category of hazard we have considered all accidents and serious incidents belonging to it, the number of fatalities and the occupants, and the aircraft damage (Table 2).

Table 2 – Number of events for phase of flight and years

| | N° | Fatalities/occupants | Aircraft damage | | |
|---|---|---|---|---|---|
| | | | T | S | M |
| Landing veer-off | 147 | 124/5379 | 35 | 106 | 6 |
| Landing overrun | 120 | 208/5368 | 33 | 76 | 11 |
| Landing overshoot | 43 | 15/1127 | 12 | 31 | 0 |
| Landing collision | 1 | 2/3 | 1 | 0 | 0 |
| Take-off veer-off | 40 | 176/ 715 | 14 | 25 | 1 |
| Take-off overrun | 40 | 98/987 | 12 | 28 | 0 |
| Take off collision | 5 | 125/214 | 4 | 1 | 0 |

# RISK SEVERITY ASSESSMENT

The risk severity assessment is that process by which determine the severity of the hazard in terms of its potential impact on the people, equipment, or mission. Severity assessment should be based upon the worst possible outcome that can reasonably be expected. Severity categories are defined to provide a qualitative measure of the worst credible mishap resulting from personnel error, environmental conditions; design inadequacies; procedural deficiencies; or system, subsystem, or component failure or malfunction [5].

In order to determine the severity of each hazard identified in this work it has been used a qualitative measure based on data about fatalities, and aircraft damages for the events of the database.

It was considered useful also to assess the severity depending on the class of aircraft, for that reason the accident were grouped by type of aircraft.

## AIRCRAFT CLASSIFICATION

The accidents were analysed according to the different classes of aircraft operations represented in the: general aviation (GA), corporate aircraft (CA), Commuter aircraft (Com A) and transport aircraft (TA) - to address these different operational perspectives. The aircraft operation classes represented in this study are defined as:

- General aviation aircraft (GA): typically these aircraft can have one (single engine) or two engines (twin engine). Their maximum gross weight usually is always below 14.000 lb.
- Corporate aircraft (CA): typically these aircraft can have one or two turboprop driven or jet engines (sometimes three). Maximum gross mass in up to 90.000 lb.
- Commuter aircraft (COM A): usually twin engine aircraft with a few exceptions such as the De Havilland DHC-/ which has four engines. Their maximum gross mass is below 70.000 lb.
- Transport aircraft (TA):
  - Short-range (S-R): their maximum gross mass usually is below 150.000 lb.
  - Medium-range (M-R): these are transport aircraft employed to fly routes of less than 3.000 nm (typical). Their maximum gross mass usually is below 350.000 lb.
  - Long-range (L-R): these are transport aircraft employed to fly routes of more than 3.000 nm (typical). Their maximum gross mass usually is above 350.000 lb.

Table 3 shows the distribution of accidents as a function of the class of aircraft

The severity of the possible consequences of an unsafe event or condition, taking as reference the worst foreseeable situation, was assessed, using the FAA’s Accident severity classification (2000) (Table 4).

Table 3 – Accident for class of aircraft

| | GA | | | CA | | | Com A | | |
|---|---|---|---|---|---|---|---|---|---|
| | N° | Fatalities/ occupants | Aircraft damage | N° | Fatalities/ occupants | Aircraft damage | N° | Fatalities/ occupants | Aircraft damage |
| Landing veer-off | 8 | 0/37 | 3T 5S | 44 | 8/507 | 10T 34S | 40 | 8/1173 | 7T 31S 2M |
| Landing overrun | 14 | 0/90 | 4T 10S | 35 | 25/169 | 8T 22S 5M | 24 | 0/903 | 7T 14S 3M |
| Overshoot | 8 | 0/32 | 3T 5S | 14 | 2/171 | 3T 11S | 5 | 0/47 | 1T 4S |
| Landing collision | 1 | 2/3 | 1T | 0 | 0 | 0 | 0 | 0 | 0 |
| Take-off veer-off | 5 | 1/23 | 2T 3S | 15 | 9/84 | 5T 10S | 9 | 3/167 | 3T 5S 1M |
| Take-off overrun | 7 | 12/47 | 2T 5S | 9 | 16/55 | 3T 6S | 9 | 5/220 | 2T 7S |
| Take-off collision | 1 | 4/4 | 1T | 1 | 3/3 | 1T | 0 | 0 | 0 |

Table 3 – continued -– Accident for class of aircraft

| | S-R | | | M-R | | | L-R | | |
|---|---|---|---|---|---|---|---|---|---|
| | N° | Fatalities/ occupants | Aircraft damage | N° | Fatalities/ occupants | Aircraft damage | N° | Fatalities/ occupants | Aircraft damage |
| Landing veer-off | 35 | 90/2442 | 7T 25S 3M | 11 | 0/493 | 4T 7S | 9 | 18/727 | 4T 4S 1M |
| Landing overrun | 28 | 55/2501 | 8T 19S 1M | 16 | 128/1034 | 4T 10S 2M | 3 | 0/671 | 3S |
| Overshoot | 9 | 12/294 | 3T 6S | 7 | 1/583 | 2T 5S | 0 | 0 | 0 |
| Landing collision | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Take-off veer-off | 7 | 162/405 | 2T 5S | 3 | 1/32 | 2T 1S | 1 | 0/4 | 1S |
| Take-off overrun | 7 | 49/424 | 2T 5S | 6 | 3/229 | 2T 4S | 2 | 7/12 | 1T 1S |
| Take-off collision | 0 | 0 | 0 | 3 | 118/207 | 2T 1S | 0 | 0 | 0 |

Table 4 – FAA Severity of consequence criteria [6]

| | |
|---|---|
| **Catastrophic** | Results in multiple fatalities. |
| **Hazardous** | Reduces the capability of the system or the operator ability to cope with adverse conditions to the extent that there would be:<br>(1) Large reduction in safety margin or functional capability<br>(2) Crew physical distress/excessive workload such that operators cannot be relied upon to perform required tasks accurately or completely<br>(3) Serious or fatal injury to small number of persons (other than flight crew) |
| **Major** | Reduces the capability of the system or the operators to cope with adverse operating condition to the extent that there would be –<br>(1) Significant reduction in safety margin or functional capability<br>(2) Significant increase in operator workload<br>(3) Conditions impairing operator efficiency or creating significant discomfort<br>(4) Physical distress to occupants of aircraft (except operator) including injuries<br>Major occupational illness and/or major environmental damage, and/or major property damage. |
| **Minor** | Does not significantly reduce system safety. Actions required by operators are well within their capabilities. Including –<br>(1) Slight reduction in safety margin or functional capabilities<br>(2) Slight increase in workload such as routine flight plan changes<br>(3) Some physical discomfort to occupants or aircraft (except operators)<br>Minor occupational illness and/or minor environmental damage, and/or minor property damage |
| **No Safety Effect** | Has no effect on safety |

Each event of database was classified using the classification FAA depending on the number of fatalities and damage to the aircraft [6]. Figure 3 shows for each type of event and class of aircraft the number of events distinct by severity, the ground collision in landing and in take-off are not represented because of the number of events is not statistically significant.

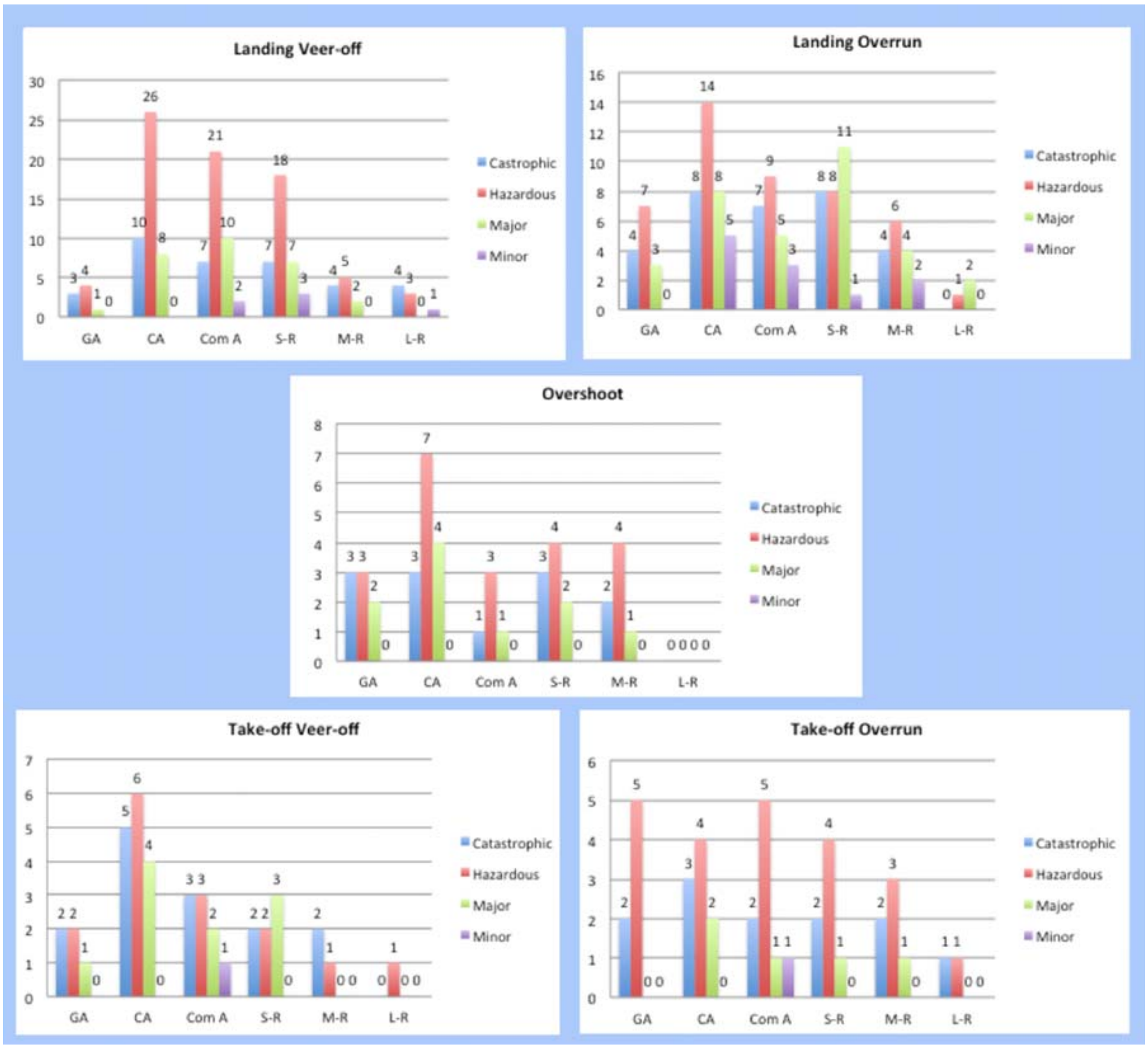



Figure 3 – Numbers of events for class of severity

Table 5 gives the percentage of accidents depending on the severity attributed to each class of aircraft.

Table 5 – Percentage of accident for class of severity

| | Landing veer-off | | | | Landing overrun | | | | Overshoot | | | | Landing collision | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | %C | %H | %MJ | %MN | %C | %H | %MJ | %MN | %C | %H | %MJ | %MN | %C | %H | %MJ | %MN |
| GA | 37,5 | 50,0 | 12,5 | 0,0 | 28,6 | 50,0 | 21,4 | 0,0 | 37,5 | 37,5 | 25,0 | 0,0 | 100 | 0 | 0 | 0 |
| CA | 22,7 | 59,1 | 18,2 | 0,0 | 22,9 | 40,0 | 22,9 | 14,3 | 21,4 | 50,0 | 28,6 | 0,0 | - | - | - | - |
| Com A | 17,5 | 52,5 | 25,0 | 5,0 | 29,2 | 37,5 | 20,8 | 12,5 | 20,0 | 60,0 | 20,0 | 0,0 | - | - | - | - |
| S-R | 20,0 | 51,4 | 20,0 | 8,6 | 28,6 | 28,6 | 39,3 | 3,6 | 33,3 | 44,4 | 22,2 | 0,0 | - | - | - | - |
| M-R | 36,4 | 45,5 | 18,2 | 0,0 | 25,0 | 37,5 | 25,0 | 12,5 | 28,6 | 57,1 | 14,3 | 0,0 | - | - | - | - |
| L-R | 50,0 | 37,5 | 0,0 | 12,5 | 0,0 | 33,3 | 66,7 | 0,0 | - | - | - | - | - | - | - | - |

Table 5 – continued - Percentage of accident for class of severity

| | Take-off veer-off | | | | Take-off overrun | | | | Take off collision | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | %C | %H | %MJ | %MN | %C | %H | %MJ | %MN | %C | %H | %MJ | %MN |
| GA | 40,0 | 40,0 | 20,0 | 0,0 | 28,6 | 71,4 | 0,0 | 0,0 | 100 | 0 | 0 | 0 |
| CA | 33,3 | 40,0 | 26,7 | 0,0 | 33,3 | 44,4 | 22,2 | 0,0 | 100 | 0 | 0 | 0 |
| Com A | 33,3 | 33,3 | 22,2 | 11,1 | 22,2 | 55,6 | 11,1 | 0,0 | - | - | - | - |
| S-R | 28,6 | 28,6 | 42,9 | 0,0 | 28,6 | 57,1 | 14,3 | 0,0 | - | - | - | - |
| M-R | 66,7 | 33,3 | 0,0 | 0,0 | 33,3 | 50,0 | 16,7 | 0,0 | 66,6 | 33,3 | 0 | 0 |
| L-R | 0,0 | 100,0 | 0,0 | 0,0 | 50,0 | 50,0 | 0,0 | 0,0 | - | - | - | - |

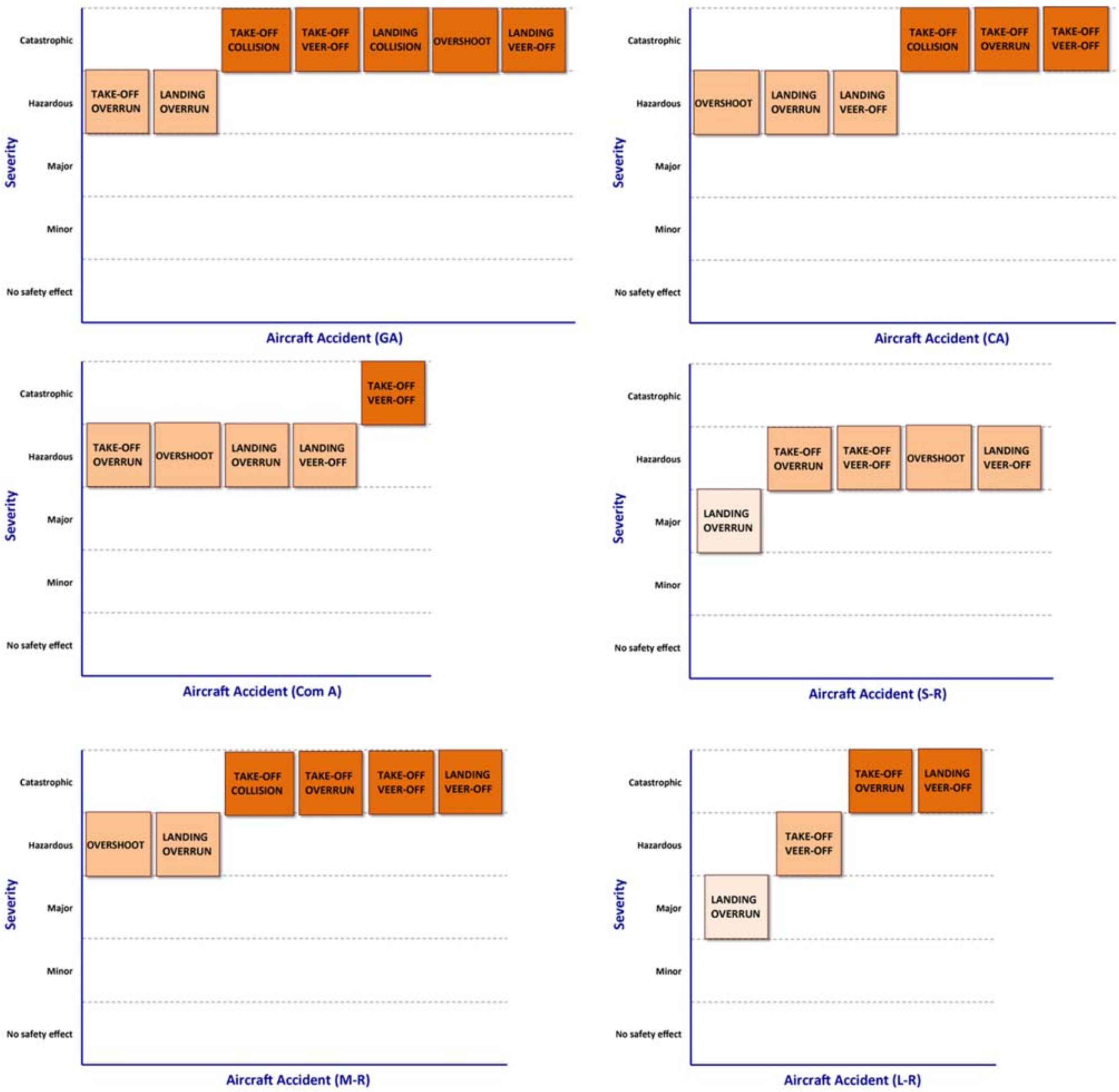



Figure 4 – Accident severity for class of aircraft

Analysis of the data contained in Table 5 we obtained the graphs of Figure 4, which show the assessment the potential severity of types of accidents analysed for each class of aircraft considered.

Each event was assigned to the class with higher percentage of occurrence, in the case of percentage of occurrence equal to two distinct classes are assigned to the event the class is more serious.

## CONCLUSIONS

With this work the authors intend to provide a practical tool for estimating the severity of aircraft accidents useful for the broader process of risk assessment.

Element original of this study is to analyse the consequences of historical events as a function of the class of aircraft involved.

The database developed, which is the basis of the methodology proposed in this paper, will serve to define the parameters needed to estimate the probability of aircraft accidents (second step of the risk assessment process) that the authors propose to define the development of research.

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